

PROCEEDINGS

THE 2ND ASEAN UNIVERSITY SYMPOSIUM FOR SUSTAINABLE FOOD SYSTEM

*“Advancing Sustainable Food Systems in Asean
Region for a Resilient and Inclusive Future”*

*Faculty of Economics and Management,
Bogor, May 5 - 6th 2025*



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*“Advancing Sustainable Food Systems in ASEAN Region for
A Resilient and Inclusive Future”*

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Proceedings of the 2nd ASEAN University Symposium on Sustainable Food System

“Advancing Sustainable Food Systems in ASEAN Region for a Resilient and Inclusive Future”

May 5-6, 2025

Faculty of Economics and Management, IPB University, Bogor, Indonesia

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Preface

It is with great pleasure that we present the Proceedings of the 2nd ASEAN University Symposium on Sustainable Food Systems, held on May 5–6, 2025, at the Faculty of Economics and Management, IPB University, Bogor, Indonesia.

This symposium gathered scholars, researchers, students, and practitioners from across the ASEAN region and beyond to share ideas, research findings, and insights on the urgent challenges and transformative innovations within our food systems. With the theme of “*Advancing Sustainable Food Systems in ASEAN Region for a Resilient and Inclusive Future*”, the event offered a vibrant platform for interdisciplinary exchange across key areas including sustainable agricultural practices, digital innovation in food systems, food and nutrition security, climate resilience, community development, gender and youth inclusion, and sustainable consumption.

This proceeding compile selected full papers that have undergone a rigorous peer-review process. We are deeply grateful to our team of dedicated reviewers, many of whom are esteemed professors, for their valuable time, constructive feedback, and commitment to enhancing the quality of each submission.

We also extend our sincere appreciation to all the presenters, moderators, and participants who contributed to making this symposium a success. We are especially proud of the lively discussions and collaborative spirit that filled the sessions, both online and onsite, and we hope this proceeding will serve as a lasting resource and inspiration for future research and actions in the pursuit of sustainable food systems in the ASEAN region and beyond.

We acknowledge that organizing such an event would not have been possible without the hard work of the organizing committee, volunteers, and partners. May the knowledge shared here foster further collaboration, learning, and impactful solutions to our shared food system challenges.

Bogor, July 2025
On behalf of the Organizing Committee,

Dr. Lukytawati Anggraeni, S.P., M.Si.
Chairperson
The 2nd ASEAN University Symposium on Sustainable Food Systems 2025

Acknowledgements

The Organizing Committee of the 2nd ASEAN University Symposium on Sustainable Food Systems 2025 would like to extend its heartfelt gratitude to all individuals and institutions whose support, contributions, and dedication made this event and the publication of this proceeding possible.

We express our deepest appreciation to the Faculty of Economics and Management, IPB University, for hosting the symposium and for the continuous support throughout the planning and implementation stages. Our sincere thanks also go to our collaborating universities and partners across ASEAN:

- i. Can Tho University (CTU), Vietnam
- ii. Chiangmai University (CMU), Thailand
- iii. Kasetsart University (KU), Thailand
- iv. Mahidol University (MU), Thailand
- v. National University of Laos (NUOL), Laos PDR
- vi. Royal University of Phnom Penh (RUPP), Cambodia
- vii. Universiti Islam Sultan Sharif Ali (UNISSA), Brunei Darussalam
- viii. University of Philippines, Los Banos (UPLB), Philippines
- ix. Universiti Putra Malaysia (UPM) & Universiti Putra Malaysia (Bintulu Campus)
- x. Vietnam National University of Agriculture (VNUA), Vietnam
- xi. Yezin Agricultural University (YAU), Myanmar

who have helped bring diverse perspectives and meaningful dialogues to the symposium.

We are especially grateful to our distinguished keynote speakers, plenary speakers, and session moderators who shared their insights and expertise, enriching the discussions on sustainable food systems.

- i. Prof. Brian Yulianto (Minister of Higher Education, Science, and Technology, Republic of Indonesia)
- ii. Prof. Dr. Ir. Nunung Nuryartono, M.Si (Deputy for Coordination of Social Welfare Improvement, Coordinating Ministry for Community Empowerment, Republic of Indonesia)
- iii. Datuk Amer Bukvić (Director and Resident Representative of Islamic Development Bank (IsDB) Regional Hub Indonesia)
- iv. Prof. Bayu Krisnamurthi (Professor at Faculty of Economics and Management, IPB University)
- v. Prof. Bustanul Arifin (Professor in Agricultural Economics, UNILA & Chair of Asian Society Agricultural Economist)
- vi. Prof. Christopher Bennett (Professor at Faculty of Land and Food Systems, University of British Columbia)
- vii. Dr. Yose Rizal Damuri (Director of CSIS)

We also acknowledge with great respect the reviewers, many of whom are respected scholars and professors, for their thoughtful, timely, and constructive reviews which ensured the quality and academic rigor of the papers selected for this proceeding.

To all presenters and participants, we thank you for your active engagement, for sharing your research and experiences, and for contributing to the success of this symposium.

Special thanks are also due to the organizing committee, student volunteers, and technical teams, whose tireless efforts and behind-the-scenes work made the smooth running of the event possible, both online and onsite.

Lastly, we thank all those who we may not have mentioned by name, but whose support and encouragement have been invaluable in bringing this event and publication to fruition.

May this proceeding serve as a platform for continued dialogue, collaboration, and progress toward building more sustainable, resilient, and inclusive food systems in the ASEAN region and beyond.

Bogor, July 2025
On behalf of the Organizing Committee,

Dr. Lukytawati Anggraeni, S.P., M.Si.
Chairperson
The 2nd ASEAN University Symposium on Sustainable Food Systems 2025

Editorial Note

It is with great pleasure that we present the *Proceedings of the 2nd ASEAN University Symposium on Sustainable Food System (AUSSFS) 2025*, held on 5–6 May 2025 at the Faculty of Economics and Management, IPB University, Bogor, Indonesia.

This symposium continues our collective effort to strengthen academic and institutional collaboration among ASEAN universities toward advancing the sustainability, inclusivity, and resilience of our regional food systems. With the theme “*Advancing Sustainable Food Systems in ASEAN Region for a Resilient and Inclusive Future*”, this year’s symposium brought together researchers, practitioners, and policymakers to exchange insights, share best practices, and explore innovative solutions for the transformation of food systems in the region.

The proceeding compiles selected papers presented during the symposium, covering diverse but interconnected topics such as sustainable agricultural practices, food and nutrition security, natural resource management, agribusiness digitalization, social inclusion, and Islamic social finance. Each paper has undergone a review process by our academic reviewers to ensure quality, clarity, and relevance.

We extend our heartfelt gratitude to all authors and reviewers for their invaluable contributions, and to the organizing committee and supporting institutions for their dedication and commitment in making this event a success. Our appreciation also goes to the keynote and plenary speakers for their inspiring insights that enriched the discussions throughout the symposium.

We hope this proceeding will serve not only as a scholarly record of the symposium but also as a meaningful reference for ongoing research, policy formulation, and collaborative action toward achieving sustainable food systems across ASEAN.

On behalf of the Editorial Team,

Chief Editor

Proceedings of the 2nd ASEAN University Symposium on Sustainable Food System 2025
Faculty of Economics and Management, IPB University

Prof. Dr. Orachos Napisintuwong
Kasetsart University (KU) – Thailand

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A Systematic Literature Review of Good Agricultural Practices for Rice

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Abstract

In 2013, the Philippine Food Safety Act was enacted. In the same year, the Department of Agriculture (DA) released the implementing rules and regulations on the certification of Philippine Good Agricultural Practices (PhilGAP) for crops. Rice farmers are encouraged to undergo PhilGAP certification to help them establish a strong market linkage with institutional buyers who demand PhilGAP-certified products. However, only few rice farmers sought certification, although an uptick in number was observed in 2024. This study reviewed literatures related to Good Agricultural Practices (GAP) for rice to gather global evidence on GAP's effects and how it was perceived or accepted by rice stakeholders. The rich information gathered could aid in identifying and designing research that could help direct GAP implementation in the Philippines. This paper used a systematic literature review using PRISMA checklist. Literatures were searched from Scopus, Web of Science, and ScienceDirect. A total of 93 materials passed the screening based on a set of criteria (i.e., research area, document type, language used). The list was reduced to 20 after checking for eligibility (i.e., rice and GAP-focused, assessment/adoption study, accessibility of full text). Many studies used descriptive, costs and returns, and regression analyses, reporting better yield, income, and input use efficiency for GAP-certified farms. GAP foster sustainable rice production but some of its aspects perceived as difficult to attain. Participation factors included sociodemographic, land-, labor-, and extension-related variables, financial resources, and market demand. Research on net benefits of PhilGAP for rice, marketing study on PhilGAP-certified rice, and policy analysis may be explored.

Keywords: food safety act, PRISMA checklist, PICOC framework

JEL code: Q13, Q18

SDG classification: SDG 3

Introduction

Increased occurrence of foodborne illnesses in developed countries brought unsafe food in the 1990s. Food safety for consumers was the driving force for the creation of the guidelines on Good Agricultural Practices (GAP) initiated in the United States in 1997 (Hopper and Rogers, 2024). It is a set of recommendations that promote economic, environmental, and social sustainability of “on-farm production and post-production processes resulting in safe and quality food and non-food agricultural products” (Food and Agriculture Organization, 2007). It became a standard regulatory guideline to ensure the safety and quality of produce traded in the international markets (Banzon, et al., 2013).

This has prompted the implementation of GAP among ASEAN nations; they need to comply to the standards set forth by other trading partners, hence, the birth of ASEANGAP. This was based on the GAP of individual ASEAN member estate (Banzon, et al., 2013). In 2013, the Food Safety Act was enacted that became the legal basis of the Philippine GAP (Food Safety Act of 2013, R.A. No. 0611). The Department of Agriculture then released the rules and regulations on the certification of PhilGAP for fruits and vegetables (Department of Agriculture, 2018).

Rice farmers are encouraged to undergo PhilGAP Certification to help them promote their product in the market. This will also help establish a strong market linkage with institutional buyers who normally demand PhilGAP-certified products. Being GAP-certified means that growers adopt food safety practices in their farms. Additionally, this will make safe and quality rice available to consumers. However, only few rice farmers sought for the certification and it is only in 2024 that an uptrend was observed.

This study gathered and reviewed literatures related to Good Agricultural Practices (GAP) for rice to synthesize global evidences on GAP's effects and how it was perceived or accepted by rice stakeholders. The rich information gathered could partly aid in identifying and designing researches that could help direct GAP implementation in the Philippines. This study hopes to contribute to the body of knowledge that is deficient on GAP-related researches.

Methodology

This paper used the Systematic Literature Review (SLR) to consolidate information from selected relevant materials and address the review question. SLR is a methodical way of gathering and processing information from literatures to provide a synthesized answer to a research question. It also identifies aspects of a topic where only little or still no evidence is available. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Page et al., 2020) served as a guide in doing the SLR.

The following core stages of conducting SLR were adopted from Mohring, et al. (2024): (a) formulation of the research question (b) identification of relevant literatures (c) assessment of the selected documents based on a set of inclusion and exclusion criteria, and finally (d) synthesis of extracted information from the included literatures.

The methods used in the review were summarized in a protocol presented in Table 1. It consists of the review questions, the search databases, the inclusion and exclusion criteria used in filtering the literatures, the search syntax used for each database, and the extracted data and information from the full text.

Table 1. The review protocol used

Items	What were done/used
<i>Review questions</i>	Are rice producers and consumers better-off if GAP is implemented/adopted? (b) How has rice stakeholders perceived or accepted GAP?
<i>Search databases</i>	Scopus, Web of Science, and Science Direct
<i>Inclusion/exclusion criteria</i>	
Inclusion	Research area: Agriculture and Biological Sciences, Social Sciences, Business, Management and Accounting, Economics, Econometrics, and Finance, Decision Sciences; Mathematical Methods in Social Sciences
	Research articles, review articles, early access articles
	Publication written in English
Exclusion	Full text inaccessible
	Not GAP-focused; not directly related to GAP for rice
	Not an assessment material
<i>Search Syntax</i>	
Scopus	TITLE-ABS-KEY ("Good Agricultural Practices" AND rice) AND (LIMIT-TO (LANGUAGE , "English"))
Web of Science	TS=("Good Agricultural Practices" AND rice)
Science Direct	Title, abstract, keywords: "Good Agricultural Practices" and rice
<i>Data extracted</i>	First author and year of publication, title, objectives, covered site/population, research design, and impact indicators and its measurement

The research question was formulated using the PICOC framework. PICOC stands for P-population/problem, I-intervention/object of interest, C-Comparison, O-outcomes, and C-Context (Petticrew and Roberts, 2006). Table 2 presents the PICOC components considered in this review. The research question was then drawn based on this PICOC.

Three comprehensive databases were considered in the search strategy: Scopus, Web of Science, and ScienceDirect. These were chosen because they have extensive collection of reliable materials for science-based researches. The terms "Good Agricultural Practices" and "rice" were searched in the title, abstracts, and keywords of the documents. The search syntaxes used are presented in Table 1. Initially, the search results yielded 201 English-written documents. Later, the list was trimmed down to 150 after removing duplicate entries. These were then screened based on the inclusion and exclusion criteria as stated in the review protocol (Table 1).

Table 2. The PICOC framework used.

Components	Items
P-population/problem	Rice stakeholders (especially, producers and consumers)
I-Intervention/object of interest	GAP implementation/adoption
C-Comparison/alternative to intervention	Non-GAP practices
O-Outcomes	Safe rice supply
C-Context	Rice farming

The following subject area were considered: Agriculture and Biological Sciences, Social Sciences, Business, Management and Accounting, Economics, Econometrics, and Finance, Decision Sciences, and Mathematical Methods in Social Sciences. Research, review, and early access articles were the type of documents that were considered.

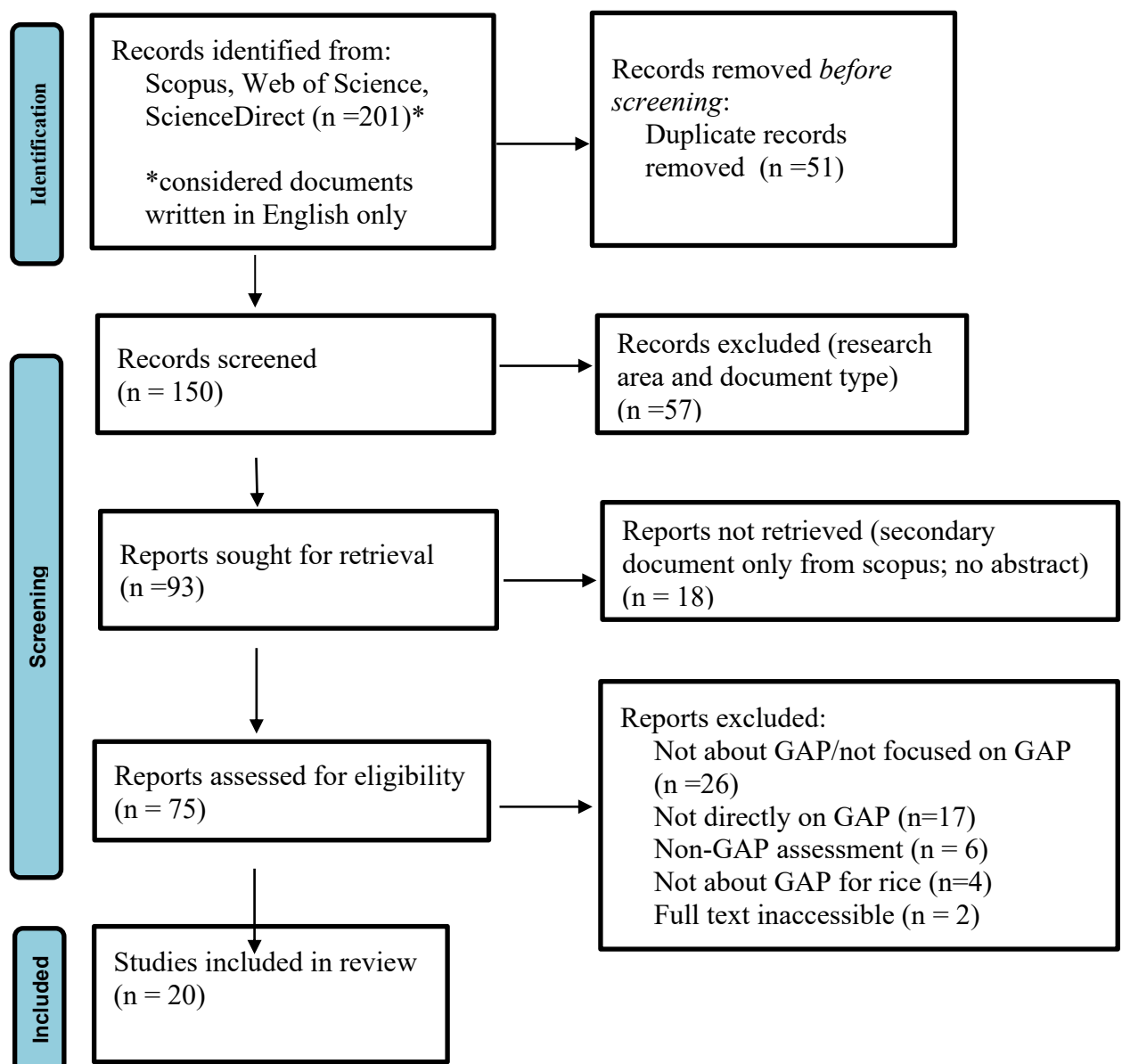


Figure 1. The PRISMA flow diagram showing the selection process for full-text review

On one hand, literatures that are (a) not directly related to GAP for rice or not even focused on GAP (b) not an assessment study (c) have inaccessible full text were excluded from the list. In some literatures the phrase “good agricultural practices” was used to refer to farming activities in itself and do not pertain to the certification system, which is the focus of this paper. Meanwhile, some also mentioned GAP in its document but was just part of the introduction or the recommendation, hence, were non-GAP focused. After considering all the inclusion and exclusion criteria, the process resulted in a total of 20 studies for full-text review, as summarized in Figure 1.

Finally, the extracted information from the literatures were: (a) author and year of publication (b) title (c) objectives (d) research site or population (e) research methods/analysis (d) key findings (e) recommendation. Synthesis involves studying the extracted information and discerning pattern making general observation or conclusion about it. This review hopes to synthesize the results of the studies to learn from the experiences of other nations in adopting GAP for rice.

Results and Discussion

There are only few literatures that tackled GAP for rice. GAP was originally created for vegetables and fruits (Hopper and Rogers, 2024), but was later applied to crops. The distribution of literatures related to GAP for rice, as found from the databases, are presented in Figure 2. This still includes documents that were non-assessment study and those with inaccessible full text.

The chart shows that most literatures covered sites in Thailand, Vietnam, India, and Ghana. The first three nations are net rice exports. Trading a commodity internationally requires passing a certain product standard, such as GAP standards. On one hand, foodborne diseases had been an issue in Ghana (World Health Organization – Africa, 2023; Botha et al., 2023) that triggered researches that revolves around food safety, which is one of the pillars of GAP.

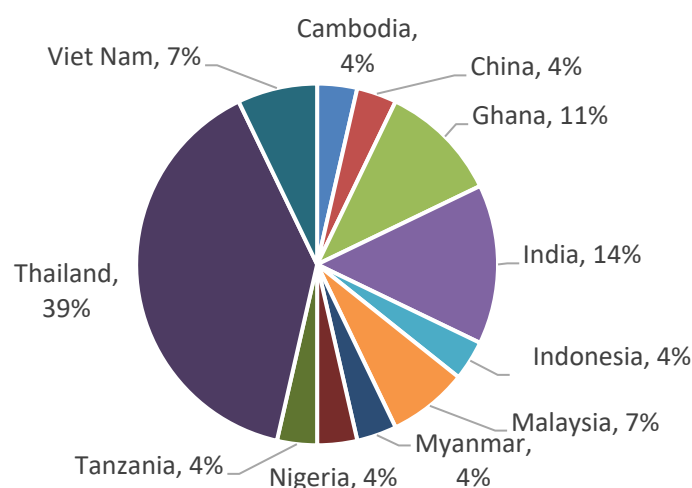


Figure 2. Distribution of the included literatures by study site

Effects/outcomes of gap adoption

Table 3 summarizes the themes and sub-themes of the final set of literatures. Majority of them discussed mainly on the production effects of GAP. Moreover, almost all of them were studies on farmers, and only few about consumers.

Table 3. Summary of themes and sub-themes of the included literatures

Theme	Subtheme	Frequency	Percentage
Production-related effects	Effects on yield, costs, income, input use	7	35%
	Sustainability of rice production and/or practices	2	10%
	GAP effects on the adoption of resource-saving technologies	2	10%
	Technical efficiency of farmers	1	5%
Knowledge, attitudes, and perceptions	Awareness and preparedness of farmers for GAP	1	5%
	Perception of consumers on GAP	1	5%
	Perception of farmers on GAP and its determinants	1	5%
	Level of understanding and attitude towards GAP	1	5%
Adoption of GAP	Factors affecting implementation/adoption/disadoption	2	10%
	Willingness to adopt	1	5%
	Comparison of performance of farmer-group and individual farmers under GAP	1	5%

Many literatures reported that GAP adoption resulted in higher yield and profit, and better input use efficiency than the conventional or organic farming (Suwanmanepong, et al., 2024; Senthilkumar, 2022; Ayamba, et al., 2023; Tann, et al., 2012). These benefits were attributed to better water use, weed management, chemical application, higher plant height, increased tiller number, and heavier grain weight. Additionally, adoption of GAP could lead to judicious use of chemicals (Khoja et al., 2012), proper disposal of wastes and proper storage of chemicals, thus, avoids contamination of harmful chemicals on the crop. Farmers' technical efficiency also improved (Suwanmanepong, et al., 2024; Taraka, et al., 2012) under GAP. This means that farmers became more effective in producing more with a given set of resources.

Since rice is a staple food of many nations, its sustainable production has brought a lot of attention to its people. Sustainable rice farming involves maintaining the ability of the soil to produce quality harvest through preservation of soil health (Greenland, 1997). Preservation of natural resources, such as water, is also important in sustainable rice farming. GAP adoption promotes the use of resource-saving technologies such as the Alternate Wetting and Drying (Suwanmanepong et al., 2023), which could help sustain rice farming. One of the pillars of GAP is environmental management. Under GAP, farmers are encouraged to align their practices with environment preservation. Rice farming in Yogyakarta, Indonesia was found to be moderately sustainable under the GAP program (Pratama, et al., 2024). The contrary, however, was observed in Ubon Ratchathani province in Thailand, wherein rice farming under GAP obtained insufficient score to qualify as sustainable. Nevertheless, GAP-managed rice farming still obtained higher sustainability score than the conventional farming (Rattanacharnoen, et al., 2022).

Adopting GAP doesn't come without a cost. Sattaka et al. (2020) reported that production cost under GAP was higher than that in organic and traditional farming in Sakon Nakhon Province in Thailand. This was mainly driven by labor and soil preparation cost. Some farmers also had difficulty in attaining selected GAP components (Senthilkumar et al., 2018; Hassim, et al., 2013). Oo et al. (2020) relayed that their respondents perceived some GAP components as difficult to attain. This perception was affected by gender, education, farmland size, access to credit, income from crop production, contact with extension agents, agricultural information, and training on GAP.

Factors of adoption

GAP adoption ranged from low to average level. In Nigeria, farmers' eagerness to adopt GAP was mid-range (Kehinde, et al., 2023). Meanwhile, GAP adoption among Basmati producers in India was still low (Pandit, 2017). Farmers in some sites in Malaysia performed well in following the GAP components (Hassim et al., 2013). Adoption of resilient farming practices, wherein GAP is a part of, was affected by age, education, gender of the household head, membership to farmer-groups or cooperatives, household size, land acquisition through inheritance and purchase, newly deforested land, mechanical cleaning and bush burning (Kahinde, et al., 2023; Fakhong, et al., 2017). Farmers can also be encouraged to adopt GAP by establishing field demonstrations in their own field.

Disadoption, however, also happened among farmers. Some of the reasons were household labor and land ownership constraints, and unmaterialized perceived market opportunities for GAP produced rice (Srisopaporn et al., 2015). Despite disadoption, farmers still practice his/her learnings obtained from the GAP program.

GAP-certified farmer-groups were found to receive better support, had better opinion than individual farmers. Nevertheless, the latter expressed greater satisfaction in the acquired knowledge and skill on rice production more than the farmer-groups (Kwang-Ngoen et al., 2018).

Consumers', on one hand, patronage of GAP-certified rice can be affected positively by their perception about the importance of consuming safe and quality rice (My, et al., 2017). Pandit, et al. (2017) enumerated the perceived benefits of consumers from Karnal and Kurukshetra Districts of Haryana State in India. These are quality grains, traceability mechanism, increased awareness of consuming safe and quality rice, and increased stakeholders' confidence in the market.

Conclusions and Recommendations

The GAP sets standards in producing safe food and quality harvest for consumption, environmental management, and worker health and safety. Evidences from the literatures confirmed that farmers and consumers benefitted from GAP. For farmers, benefit was mainly on better yield, hence, raised income. For consumers it was on the access to safe food. Demand depends on the perceived importance of consuming safe food.

In the Philippines, the Food Safety Act of 2013 enforced the implementation of PhilGAP for crops. Even if this policy was put in place, only few farmers attempted to undergo PhilGAP certification, not until 2024. Since the certification has just started to intensify, no extensive scientific research has been done yet on PhilGAP for rice.

The following may be explored by future:

What is the net benefit of adopting GAP? Will the society (especially the farmers) really benefit from participating in the certification considering the costs involved in its implementation? This study should focus on estimating and comparing the benefits and costs of rice PhilGAP adoption or implementation. This can be accomplished using Cost-Benefit Analysis.

Can PhilGAP-certified rice be marketed at a premium price? Will the consumers be willing to pay higher than the other types of white rice in the market? This can be a reference of farmers or farmer-groups in selling their PhilGAP-certified farms. Consumers' willingness-to-pay and Principal Components Analysis can be explored.

What policy issues need to be addressed to better facilitate PhilGAP certification for rice? This should try to identify and assess the policy issues surrounding PhilGAP certification. It should identify key constraints that may hinder participation of rice farmers in PhilGAP certification. After problem identification, the study will identify and examine policy options that may solve the identified problem. Data will be gathered through Focus Group Discussion (FGDs) and Key Informant (KI) interviews.

References

- Ayamba, B.E., Buri, M.M., Sekyi-Annan, E., Devkota, K., Dossou-Yovo, E.R., Ulzen, O.O., Adjei, E.O., Musah, M., Biney, N. (2023). Increasing lowland rice yields of smallholder farmers through the adoption of good agricultural practices in the forest agro-ecological zone of Ghana. *Plant Production Science*, 26 (4), 335-349.
- Banzon, A.T., Mojica, L.E., and Cielo, A.A. 2013. Good Agricultural Practices (GAP) in the Philippines: Status, Issues, and Policy Strategies. Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).
- Botha, N.N., Ansah, E.W., Segbedzi, C.E., Darkwa, S. 2023. Public health concerns for food contamination in Ghana: A scoping review. *PLoS ONE* 18(8): e0288685. <https://doi.org/10.1371/journal.pone.0288685>
- Department of Agriculture (2018). Administrative Circular No. 01, s.2018. https://www.da.gov.ph/wp-content/uploads/2018/03/ac01_s2018.pdf
- Food Safety Act, Republic Act No. 10611, (2013).
- Fakkhong, S., Suwanmaneepong, S. (2017). The implementation of Good Agricultural Practice among rice farmers in eastern region of Bangkok, Thailand. *International Journal of Agricultural Technology*, 13 (7.3), 2509-2522.
- Food and Agriculture Organization. 2007. Report of the FAO Expert Consultation on Good Agricultural Practices Approach. <https://www.fao.org/4/ag852e/ag852e00.pdf>
- Hassim, M.D., Aungsuratana, A. O., Champrame, S., Poramacom, N., Rojanaridpiched, C. (2013). Assessing Malaysian farmers' capability, acceptability, and practicality toward a rice Good Agricultural Practices model. *Kasetsart Journal of Social Science*, 34 (3), 562-572.
- Hopper, B. and Rogers, E. 2024. *A historical perspective on Good Agricultural Practices (GAPs)*. NC State Extension. <https://ncfreshproducesafety.ces.ncsu.edu/ncfreshproducesafety-gaps-history/>

- Kehinde, M.O., Shittu, A.M., Oriade, O.A., Edewor, S.E. (2023). Land tenure, land use antecedents, and willingness to embrace resilient farming practices among smallholders in Nigeria. *Frontiers in Sustainable Food Systems*, 7, 1-12.
- Khoa, D.B., Ngan, H.T., Huy, N.B., Nhung, N.T., Liem, N.V. (2015). Development of Good Agricultural Practices (GAPs) models for tea, rice and vegetables in Vietnam. *FFTC E-Journal*. <https://ap.ffmpeg.org/article/991>
- Kwang-Ngoen, P., Limnirankul, B., Sirisunyaluck, R. (2018). Comparison of factors affecting on KDML 105 rice production according to GAP standard of individual and group farmers in Mahasarakham Province. *International Journal of Agricultural Technology*, 14 (1), 1-13.
- Mohring, N., Muller, A., and Schaub, S. 2025. Farmers' adoption of organic agriculture-a systematic global organic agriculture. *European Review of Agricultural Economics* Vol 51 (4) (2025) pp. 1012–1044 doi:<https://doi.org/10.1093/erae/jbae025>
- My, N.H.D., Rutsaert P., Van Loo, E.J., Verbeke, W. (2017). Consumers' familiarity with and attitudes towards food quality certifications for rice and vegetables in Vietnam. *Food Control*, 82, 74-82.
- Nodin, M.N., Mustafa, Z., Hussain, S.I. (2021). A conceptual framework of Malaysian rice postharvest losses management best practices adoption. *Journal of Quality Measurement and Analysis*, 17 (2), 41-49.
- Oo, S.P., Usami, K. (2020). Farmers' perception of good agricultural practices in rice production in Myanmar: A case study of Myaungmya District, Ayeyarwady Region. *Agriculture (Switzerland)*, 10 (7), 1-20.
- Page M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., and Moher, D. 2020. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021 Mar 29;372:n71. doi: 10.1136/bmj.n71. PMID: 33782057; PMCID: PMC8005924.
- Pandit U., Nain, M.S., Singh, R., Kumar, S., Chahal, V.P. (2017). Adoption of Good Agricultural Practices (GAPs) in Basmati (Scented) rice: A study of prospects and retrospect. *Indian Journal of Agricultural Sciences*, 87 (1), 36-41.
- Petticrew, M. and Roberts, H. 2006. *Systematic Reviews in the Social Sciences: A practical guide*. Blackwell Publishing Ltd.
- Pratama, I.A., Suryantini, A., Perwitasari, H. (2024). Sustainability of the Different Rice Cultivation Practices in Yogyakarta, Indonesia. *Caraka Tani: Journal of Sustainable Agriculture*, 39 (2), 321-342.
- Rattanacharoen, N., Caldwell, J.S., Ryuichi, Y. (2022). Assessment of the sustainability of rice cultivation practice of farmers in three certified programs compared with conventional farmers in ubon ratchathani province, thailand. *Journal of the International Society for Southeast Asian Agricultural Sciences*, 28 (2), 1-16.
- Sattaka, P., Muengpak, S., Xuan, H.P., Mueangkhrot, T. (2020). Comparison of glutinous rice production systems for sustainable development in Sakon Nakhon Province. *Journal of the International Society for Southeast Asian Agricultural Sciences*, 26 (1), 54-62.
- Senthilkumar, K., Tesha, B.J., Mghase, J., Rodenburg, J. (2018). Increasing paddy yields and improving farm management: results from participatory experiments with good

- agricultural practices (GAP) in Tanzania. *Paddy and Water Environment*, 16 (4), 749-766.
- Senthilkumar, K. (2022). Closing rice yield gaps in Africa requires integration of good agricultural practices. *Field Crops Research*, 285. <https://doi.org/10.1016/j.fcr.2022.108591>
- Srisopaporn, S., Jourdain, D., Perret, S.R., Shivakoti, G. (2015). Adoption and continued participation in a public Good Agricultural Practices program: The case of rice farmers in the Central Plains of Thailand. *Technological Forecasting and Social Change*, 96 (2015), 242-253.
- Suwanmaneepong, S., Kultawanich, K., Khurnpoon, L., Sabaijai, P.E., Cavite, H.J., Llonas, C., Lepcha, N., Kerdsriserm, C. (2023). Alternate wetting and drying as water-saving technology: an adoption intention in the perspective of Good Agricultural Practices (GAP) suburban rice farmers in Thailand. *Water (Switzerland)*, 15 (3), 1-13.
- Suwanmaneepong, S., Kultawanich, K., Khurnpoon, L., Sabaijai, P.E., Kerdsriserm, C., Cavite, H.J.M. (2024). Production performance and adoption opinion toward wet and dry farming of GAP and Non-GAP farmers in Suburban Bangkok, Thailand. *Agricultural Research*, 13 (1), 169-181.
- Tann, H., Makhonpas, C., Utthajadee, A., and Soyong, K. (2012). Effect of Good Agricultural Practice and organic methods on rice cultivation under the system of rice intensification in Cambodia. *Journal of Agricultural Technology*, 8 (1), 289-303.
- Food and Agriculture Organization. 2007. Report of the FAO Expert Consultation on Good Agricultural Practices Approach
- World Health Organization – Africa. 2023. Promoting food safety in Ghana through community engagement. WHO. <https://www.afro.who.int/photo-story/promoting-food-safety-ghana-through-community-engagement>

Resource Utilization and Sustainability Practices in The Pili Nut Value Chain in The Bicol Region, Philippines

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Abstract

Pili nut is a flagship agricultural commodity that can be found in the Bicol region, Philippines. Recent developments on food safety assessment revealed that the consumption of pili nuts does not raise food safety concerns based on its composition and history of consumption. This is an opportunity for the product to reach the export market particularly the European Union. However, the growth of the pili nut industry is beset by diminishing productivity at the farm level and inefficiencies in post-harvest processing. Guided by the Circular Economy (CE) perspective and using the Life Cycle Assessment (LCA) framework, this study augmented the mainstream value chain analysis by an empirical assessment of resource utilization and disposal along the different nodes of the value chain. There were 120 pili farmers and 110 processors from four provinces in the Bicol region that participated in the study to provide a baseline information about the potential impacts of mechanization in post-harvest processing. Their sustainability practices were assessed using the Circularity and Maturity Firm-Level Assessment tool (CM-FLAT) based on Circular Value Chain (cVC) and Porter's Value Chain (PVC) categories. Results reveal that unsustainable practices can be traced in the disposal of pili pulp and wastewater during primary processing. Low level maturity performance was also observed along inbound and inbound logistics. These findings suggest potential improvement in sustainability practices through resource recovery and value addition. Finally, the information about the environmental footprints can be useful for ecolabeling and prospective life cycle assessment for technology adoption.

Keywords: circular economy, life cycle assessment, environmental footprints

JEL code: O13, Q00, Q01, Q56

SDG classification: SDG 12, SDG 15

Introduction

The global pursuit of sustainability is beset by the challenge of ensuring efficient production systems while protecting the planet's finite resources and biodiversity to satisfy the needs of the present generation without compromising the needs of future generations. Intergenerational equity in the intertemporal allocation of resources requires not only the use of the best available technology to achieve optimal levels of efficiency and profitability of production systems. It should ensure that natural and man-made resources are also available to be used by future generations during the time when they will need them. Thus, sustainable adoption of technology requires sufficient availability of raw materials in the production continuum that maximizes the social welfare of the stakeholders. This is more relevant in the agricultural sector which is dependent on natural resources for production.

In the Philippines, *Canarium ovatum*, Engl. or pili is known as the "Tree of Hope". It is a dioecious tree species belonging to the Burseraceae family. According to the Pili Industry Situationer (2020), there were 2,281 hectares (ha) planted with pili in the country in 2016, and more than half of this area can be found in Sorsogon province (1,370 ha) followed by Albay (345 ha), and Camarines Sur (112 ha). In 2019, the country produced 7,158 metric tons (MT) of pili kernels from 158,221 bearing trees (PSA, 2021). At present the estimated yield of pili in the Bicol region averages 44 kg/tree with a growth rate of 0.6 kg/tree/year (PSA, 2021). The volume of production in 2021 was recorded at 3,056.49 MT in Sorsogon and 1,533.03 MT in Albay. The province of Northern Samar is also catching up through the years with a volume of production of 771.50 MT in 2021. According to the Department of Agriculture Regional Field Unit V (DA RFU 5, 2023), there were 8,952 backyard pili farms and 1,404 orchard pili farms in the Bicol Region in 2023.

The recent development on pili export market happened on February 8, 2023, when the EU issued Commission Implementing Regulation 2023/267 which authorized placing on of dried nuts of *Canarium ovatum* Engl. on the EU market as a traditional food from a third country and amended the Implementing Regulation 2017/267. Domenico de Lucia Spa, an Italian company involved in canning of fruits, vegetables, and fruit and vegetable juices demonstrated that dried nuts of *Canarium ovatum* Engl. have a history of safe food use in the Philippines. The EU authority then concluded that its consumption does not raise safety concerns based on available data on its composition and history of its consumption. The Implementing Regulation requires the labeling of the foodstuffs containing dried nuts of *Canarium ovatum* Engl. that it may cause allergic reactions to consumers with known allergies to cashews and walnuts. It was reported that the cause of diminishing productivity of pili trees in the Bicol region is the aging of pili stands, particularly in the wild. However, this observation is not supported by empirical data about the productivity of pili trees at different age. In response to the market potential of pili oil, national government agencies, particularly the Department of Agriculture and local government units are establishing pili plantations in available lands to increase the number of trees that can produce the needed raw materials.

The opportunities for international market led to the initiatives to boost production of pili fruits and mechanize processing to meet the global demands. However, something is missing in the analysis of potential benefits and costs of these initiatives. Oftentimes, the environmental criterion is not given emphasis in decision making. Life Cycle Assessment (LCA) incorporates the environmental, economic, and social dimensions in the assessment of the impacts of technological progress. Stillitano et al. (2021) documented the standard approaches in doing LCC, such as the economic model derived from SWOLF, the

approach proposed by Hunkeler et al. (2008) and Swarr et al. (2011), the value-added approach, and the unit-cost method approach. In a broader context, Stillitano et al. (2021) recognize the need for life cycle methodologies to adopt some key elements to ensure that the results fit perfectly with circularity measurements.

One of the valuable natural resources that necessitate efficient use is land. Environmental objectives in sustainable use of land include the preservation, and when possible, improvement in the quality of agricultural land to ensure future biological production capacity while preserving the landscape value and biological diversity. While land is considered as an important production resource, it is also essential in providing other ecosystem services such as absorbing anthropogenic emissions and preserving valuable biotopes (Mattsson *et al.*, 2000). However, the common midpoint categories of the land use component in life cycle impact assessment only considers the use of nonrenewable primary energy and extraction of minerals (Jolliet *et al.*, 2015). The nonrenewable primary energy dissipated is based on the surplus energy required to extract future resources as well as the overall nonrenewable primary energy content of fossil fuels. Since the minerals do not disappear but only distributed into the economy and the environment (where it can be reused), mineral use is aggregated with energy use based on the additional mining energy consumed in the future due to lower ore grades. Ecoinvent and IMPACT 2002+ were the most common methodologies for estimating these impacts. Current impact assessment methods for natural resource depletion in LCA tends to be fragmented in the absence of a unified approach to take account the different components in a comprehensive, scientifically robust, but parsimonious manner (Klinglmair *et al.*, 2014). Among the issues in the current resource depletion models include the consideration of natural renewal rates for biotic resources, recycling of non-renewable resources such as metals, and the influence of socio-economic factors on the level of criticality and supply safety or threat of disruption of raw material flows. This is particularly needed at the midpoint level to provide an immediate picture of biophysical depletion.

Thus, this research aims to evaluate the resource utilization and sustainability practices in the pili nut value chain to serve as baseline information for the potential impacts of mechanization at the industry level. This technical and economic information can be used by technology developers in re-designing machines for pili nut processing that will ensure financial feasibility and economic viability to the processors while promoting circular economy and reducing environmental impacts.

Methodology

The conceptual framework of this study is presented in Figure 1. Following the Theory of Change (TOC) for impact evaluation and Life Cycle Assessment frameworks, the system boundary of analysis is the pili kernel processing. This system requires inputs from the natural environment to produce pili kernels which include pili fruits, materials, water, energy, land, and labor. These inputs undergo the process of producing pili nut kernels through pre-processing, depulping, cracking, and an optional testa removal. In practice, these processes are manually done. Aside from pili kernels, the system boundary waste materials, waste water, and heat. Land is mentioned here because this is necessary to produce pili trees that bear the fruits used for pili nut processing. It should be recognized that each processor may adopt sustainability practices in pili nut processing which can be called circularity practices especially when the seemingly wastes generated by the system are re-cycled in the processing. These are the loops that can be observed in the framework.

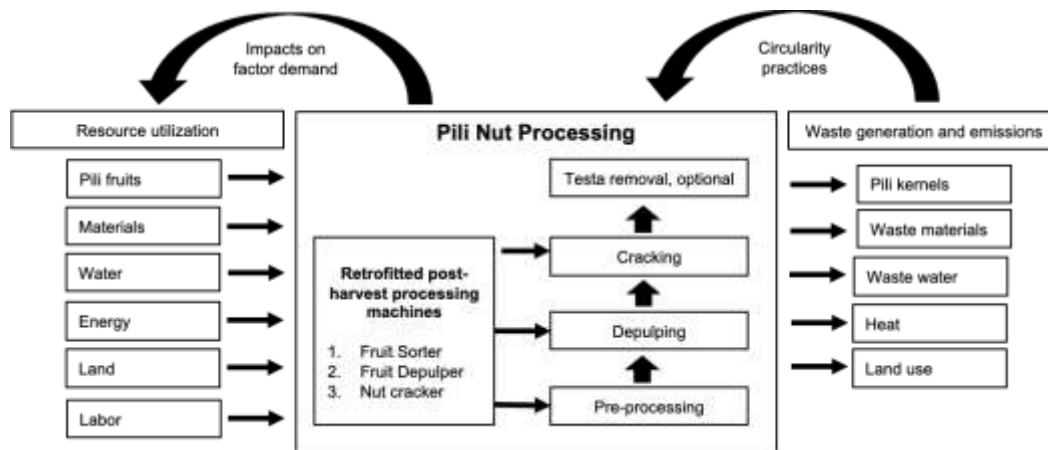


Figure 1. Conceptual framework

The LCIA methodology that was used in this study is ReCiPe 2016. This methodology integrates the ‘problem-oriented approach’ of CML-IA and the ‘damage-oriented approach’ of Eco-indicator 99. CML-IA measures the midpoint level impacts with relatively low uncertainty in the estimates but obtains complex impact category estimates. At the same time, Eco-indicator 99 only shows the three impact categories with relatively higher uncertainty. ReCiPe uses midpoint characterization factors multiplied by damage factors to obtain the endpoint characterization values. Figure 2 shows the relationship between the life cycle inventory, midpoint impact categories, damage pathway, and endpoint area of protection.

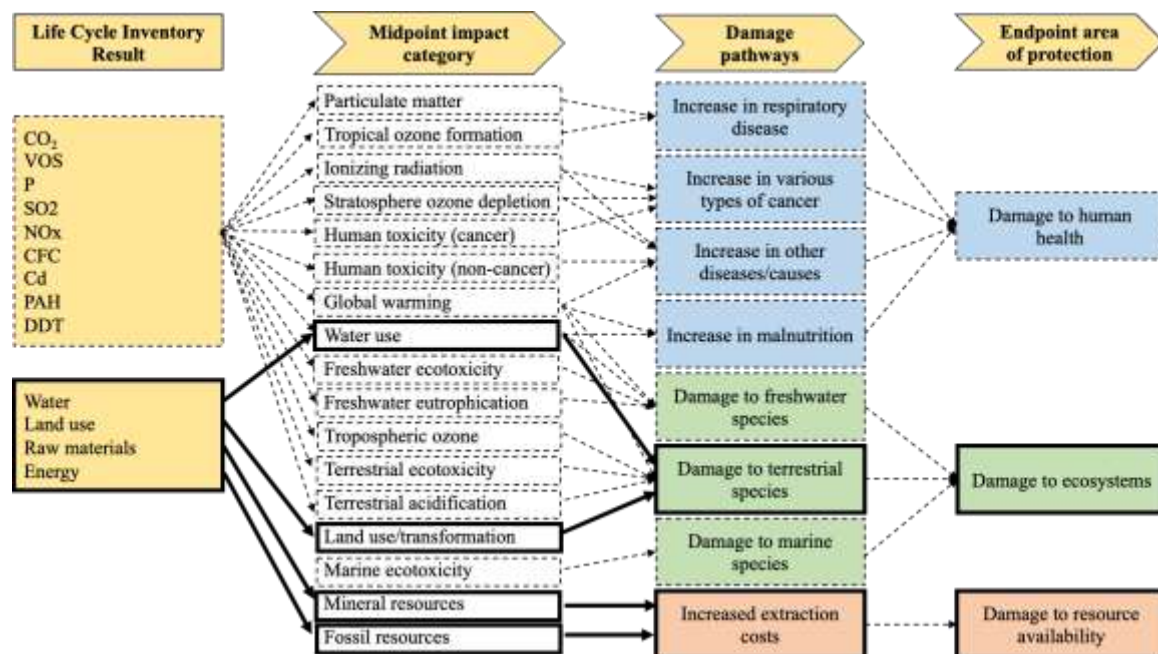


Figure 2. Relationship between inventory, midpoint categories (damage pathways) and endpoint impact categories in an LCA (modified from: Huijbregts *et al.* (2017) and SimaPro Database Manual (2022))

For this research, life cycle inventory was focused on the damage to the terrestrial ecosystem and damage to resource availability endpoint areas of protection. To determine the aggregate damage scores, the life cycle inventory on water, land use, raw materials, and energy were estimated. The ReCiPe 2016 midpoint impact categories that

were measured include water use (water consumption potential in m³ water consumed), land use/transformation (agricultural land occupation potential in m² x year annual crop land), mineral resources (surplus ore potential in kg Cu equivalent), and fossil resources (fossil fuel potential in kg oil equivalent).

Description of the study site. The locale of the study is Bicol region in the southern part of Luzon Island, Philippines. This is the major pili nut producer in the Philippines.

Sources of data. The study participants are composed of three groups of respondents, namely, 15 technology developers, 110 pili nut processors, and 120 pili farmers. Pili farmers and primary processors are primarily located in the province of Sorsogon, while secondary processors are located in the provinces of Albay, Camarines Sur, and Camarines Norte.

Analysis of resource utilization. Environmental Life Cycle Assessment (E-LCA) was used in estimating and internalizing the environmental burden of production systems using the Ecoinvent database particularly ReCiPe .1.03 midpoint (I) and endpoint (I) categories. According to ISO 14040, LCA is composed of the following stages:

1. Goal and scope, that identifies the purpose, system boundaries, and functional units.
2. Life cycle inventory (LCI) which collects whole inputs (materials and energy) as well as outputs (air, soil, and water emissions).
3. Life cycle impact assessment (LCIA), which calculates the environmental consequences of the results of LCI.
4. Interpretation of results.

Analysis of circularity practices. Circularity and Maturity Firm-Level Assessment tool (CM-FLAT) based on Circular Value Chain (cVC) and Porter's Value Chain (PVC) categories. The documented practices, includes firm infrastructure (e.g., business model, and cooperation and industrial symbiosis), service (e.g., post-sales services), inbound and outbound logistics (e.g., reverse logistics, direct logistics), operations (e.g., resource recovery, waste management, resource consumption), and technology development (e.g., ecodesign).

Results and Discussion

This section is composed of three parts. It starts with the quantification of natural resources used in a typical value chain of pili nuts that applies life cycle inventory methodology. This is followed by the description of sustainability practices based on Circularity and Maturity Firm-Level Assessment tool (CM-FLAT). Finally, results of life cycle impact assessment of alternative pili nut processing technologies based on selected ReCiPe v.1.03 midpoint (I) and endpoint (I) categories are shown.

Resource utilization

The functional unit used for this analysis is one kilogram of pili kernel. Pili kernel processing typically involves de-pulping of fruits using either hot water treatment, retting, or fermentation, and nut cracking to obtain the kernels. Confectionary makers perform testa removal prior to processing pili kernels into different delicacies. Among these processes, retting takes longer time in de-pulping compared to hot water treatment and fermentation because processors let pili pulp soften by soaking in large containers before removing the pulp from the nuts. They use this process so that they will not damage the kernels when exposed to heat using the hot water treatment method. Processors can de-

pulp 151.00 ± 64.26 kg of fruits using retting, followed by 123.33 ± 111.53 using hot water treatment (See Table 1). There is only one processor that uses fermentation because of the limited water supply in their area.

Table 1. Volume of material requirements per processing technology in pili kernel processing.

Process	Processing Technologies	Duration (man-days)	Estimates (kg)	One kernels ¹	kg
De-pulping	Hot water treatment	2.09 ± 0.79	123.33	+	15.00 ± 0.00
	Retting	3.40 ± 2.58	151.00 + 64.26		15.00 ± 0.00
	Fermentation	2.00 ± 0.00	350 ± 0.00		15.00 ± 0.00
	Mechanized ²	1.00 ± 0.00	417.20 to 742.24		15.00 ± 0.00
Nut cracking	Manual	0.72 ± 0.28	255.68 to 328.58	±	5.00 ± 0.00
	Mechanized ²	1.00 ± 0.00	592.99 to 835.20		5.00 ± 0.00
Testa removal	Manual	0.48 ± 0.54	49.68 ± 121.77		1.00 ± 0.00

¹ Adjusted by weight

² Adjusted based on machine efficiency

The volume of materials used by each processing technology is presented as the average per processor in a year. These quantities vary within a year due to the seasonality of fruit production and processing for kernels throughout the Bicol region. Figure 3 shows the trend in the volume of fruits, nuts, and kernels processed by an average processor from January to December 2023. Procurement of pili fruits begins in March and this peaks in August with the highest volume processed with a mean of 4,325kg.

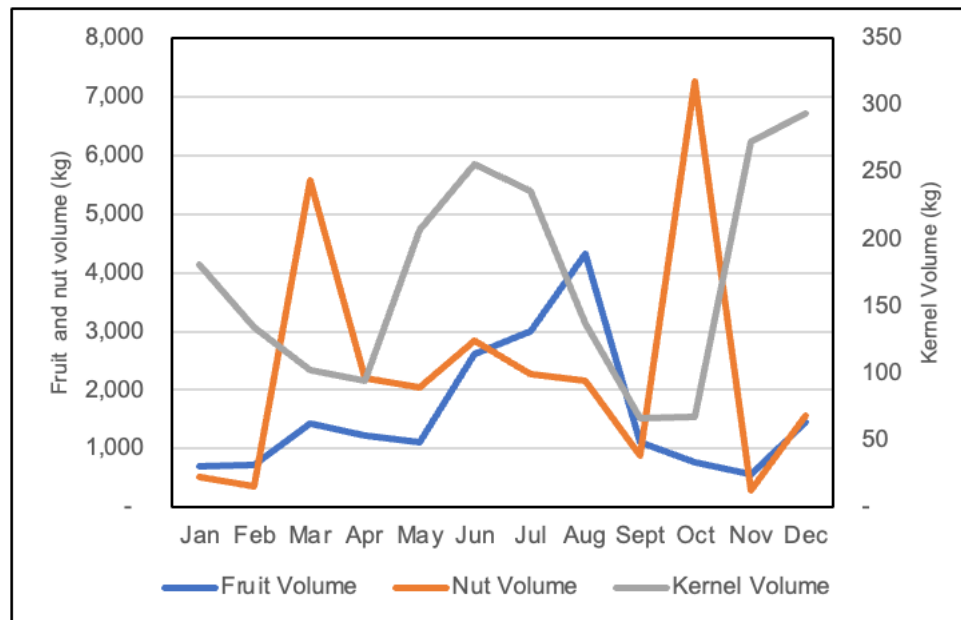


Figure 3. Trend in the volume of pili fruits, nuts, and kernels processed by processors.

There are two peaks in the volume of nuts procured in a year, first during March which has the highest volume with a mean of 5,573 kg followed by October, with a mean of 7,270 kg. These months coincide with summer vacation and Christmas season when there is high demand for pili-based products by tourists. Farmers and processors also take advantage of these periods to dry pili nuts under the sun in preparation for storage

and in anticipation of the months when there is a relatively high demand for pili-based products. The uptrend in the volume of pili kernels procured begins in May and peaks in June with a mean of 207 kg pili kernels. The second uptrend begins in October and peaks in December with a mean of 293 kg pili kernels processor.

Water is a critical resource for de-pulping because this is needed to soften the pulp either through hot water treatment, retting, or fermentation. Among these methods, retting requires more water with mean 206 liters per day, followed by fermentation with 50 liters per day, and hot water treatment with 19 liters per day (See Table 2). This translates to 20.82 ± 3.52 liters per kg kernels using retting, 4.98 ± 4.15 liters using hot water treatment, and 2.14 ± 0.00 liters using fermentation.

Table 2. Volume of water requirement per processing technology in pili kernel processing.

Process	Processing Technologies	Duration (man-days)	Estimates (l)	One kg kernels (l)
De-pulping	Hot water treatment	2.09 ± 0.79	19.00 ± 8.26	4.98 ± 4.15
	Retting	3.40 ± 2.58	206.00 ± 87.77	20.82 ± 3.52
	Fermentation	2.00 ± 0.00	50.00 ± 0.00	2.14 ± 0.00
	Mechanized	NA	NA	NA
Nut cracking	Manual	NA	NA	NA
	Mechanized	NA	NA	NA
Testa removal	Manual	NA	NA	NA

Retting requires more time for processing because it takes an average of 3.40 man-days compared to other de-pulping methods. Workers have to wait for several days for the pulp to soften. Unlike in hot water treatment, lesser water is required to soften the pulp at high temperature through blanching. Fermentation requires lower volume of water because the pulp is softened though internal heat generated inside the bags.

In manual processing, only hot water treatment requires energy to boil the water used in de-pulping. Processors either use wood or LPG to boil water. On average, processors use 2.86 ± 3.00 kg wood per day while boiling using LPG requires 28.00 ± 4.00 minutes (See Table 3). It is difficult to compare the energy requirement at this point, and we will reserve its discussion in the section about resource utilization estimation using life cycle assessment.

Mechanical processing of pili kernels requires electricity for the de-pulper and nut cracker. Based on the energy requirement of the electric motors of each machine, the depulper requires 0.0329 kWh of energy to process one kg kernels while the nutcracker requires 0.0755 kWh of energy. This information will be useful in the succeeding sections for the comparison of associated costs of producing one functional unit of pili kernel.

Table 3. Amount of fuel and energy per processing technology in pili kernel processing.

Process	Processing Technologies	Estimates	One kg kernels
De-pupling	Hot water treatment	Wood: 2.86 ± 3.00 kg LPG: 28.00 ± 4.00 min	1.18 ± 1.98 kg 20.25 ± 22.42 min
	Retting	0.00 ± 0.00	0.00 ± 0.00
	Fermentation	0.00 ± 0.00	0.00 ± 0.00
	Mechanized	NA	Electricity: 0.0329 kWh
Nut cracking	Manual	NA	NA
	Mechanized	NA	Electricity: 0.0755 kWh
Testa removal		NA	NA

In summary, to produce one kg pili kernels, an average of 15 kg pili fruits is needed which can produce 5 kg pili nuts. Producing 15 kg of pili fruits requires 0.30 ± 0.79 labor for harvesting in 0.048 hectares of pili plantation. Labor, water, wood, and LPG requirements depend on the de-pulping method used by the processors. Hot water treatment requires 0.17 ± 0.32 man-days, while retting requires 0.04 ± 0.02 man-days, and fermentation requires 0.09 ± 0.00 man-days for every batch of pili fruits processed. To produce one kg kernel, 0.12 ± 0.20 man-days of labor for nut cracking is required.

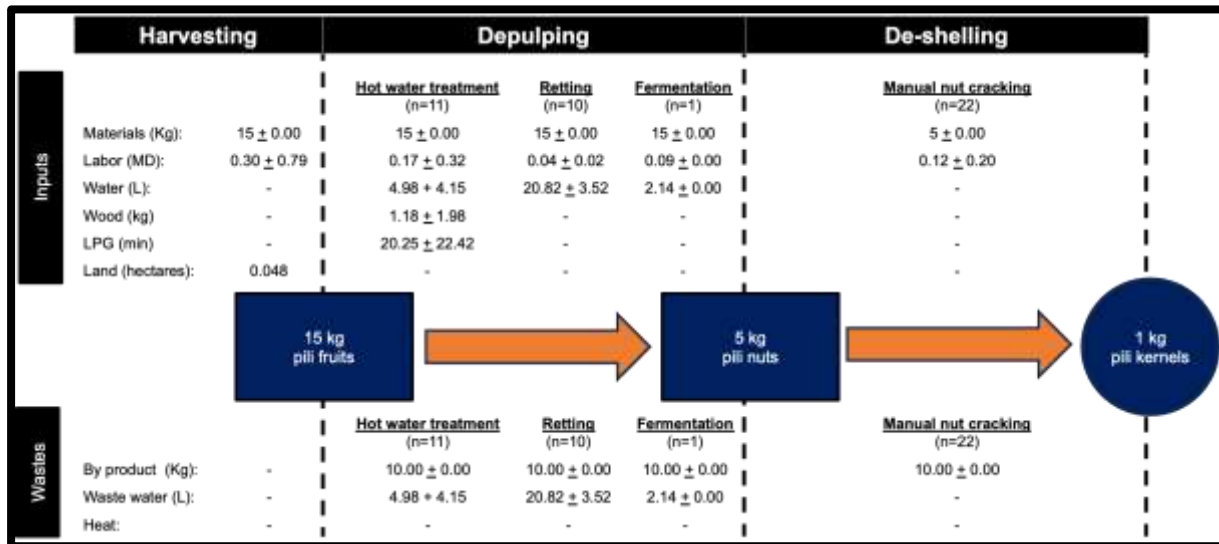


Figure 4. Summary of inputs and wastes in producing one kg of pili kernels.

Water consumption varies depending on the de-pulping method, hot water treatment requires 4.98 ± 4.15 , retting requires 20.82 ± 3.52 , and fermentation requires 2.14 ± 0.00 . Among the depulping methods, only hot water treatment requires energy from 1.18 ± 1.98 kg wood or 20.25 ± 22.42 minutes boiling using LPG.

Sustainability practices

Pili plantations do not require significant farm inputs. Farmers only produce pili pulp and wastewater as by-products and wastewater of pili nuts using hot water treatment. Processors also produce pili pulp and wastewater as by-products of de-pulping using hot water treatment, retting, or fermentation. Finally, nut cracking produces shells as by-products.

Table 4. Sustainability practices in pili nut processing according to Porter's Value Chain (PVC) and Circular Value Chain (cVC) categories.

Porter's Value Chain (PVC) Categories	Circular Value Chain (cVC) Categories	Sustainability Practices
Firm infrastructure	Business model Cooperation and industrial symbiosis	Limited number of firms practicing industrial symbiosis with other businesses.
Services	Post-sales services	Broken pili kernels (as reported by retailers) are replaced in the next delivery.
Inbound and outbound logistics	Reverse logistics Direct logistics	None
Operations	Resource recovery (Recycle, energy recovery, disposal)	Use of pili pulp for fertilizer or feed for livestock and poultry Use of pili shells as fuel for cooking.

Technology development	Waste management Resource consumption	
	Ecodesign	None

At the farmer's level, pili pulp and wastewater are left in the farm, which according to the farmers, are used as organic fertilizer for the trees by letting these decompose above ground. This is also practiced by the processors in their pili processing facilities. Pili pulps are buried in the ground while wastewaters are thrown away in waterways or on the ground.

The common use of pili shells is an alternative to firewood used in cooking by the household or for boiling water for de-pulping using the hot water treatment method. There was one processor that sold pili shells to a coconut oil processor in the Province of Albay while two processors sold pili shells to local bakeries as fuelwood for their oven. Pili shells are typically sold at USD 0.10 per kilogram and the buyers picked up these by-products from the processors.

Life Cycle Impact Assessment of Alternative Pili Nut Processing Technologies

Among the four alternative de-pulping methods, retting generates the least midpoint and endpoint environmental impacts and this is followed by the use of mechanical de-pulper. For every one kg pili kernels, retting generates 1.53×10^{-03} kg oil-eq of fossil fuel potential, 8.87×10^{-05} m² * crop-eq agricultural land occupation, 6.98×10^{-05} kg Cu-eq surplus ore potential, and 3.05×10^{-05} m³ water consumption potential (See Table 5). The estimated endpoint impacts were: 7.87×10^{-13} species-year, 2.96×10^{-04} USD (2013) scarcity rent for non-renewable energy resources, and 1.11×10^{-05} USD (2013) scarcity rent for material resources.

In the case of using mechanical pili de-pulper, for every one kg pili kernels, it generates 1.18×10^{-02} kg oil-eq of fossil fuel potential, 6.65×10^{-04} m² * crop-eq agricultural land occupation, 8.30×10^{-03} kg Cu-eq surplus ore potential, and 2.09×10^{-05} m³ water consumption potential. The estimated endpoint impacts were: 5.90×10^{-12} species-year, 1.57×10^{-03} USD (2013) scarcity rent for non-renewable energy resources, and 1.32×10^{-03} USD (2013) scarcity rent for material resources. Hot water treatment using either LPG or charcoal have relatively high midpoint and endpoint environmental impacts because of the amount of water and fuels used to soften the pulp for processing.

Table 5. Midpoint and endpoint environmental impacts of alternative technologies in producing one kg of pili kernels.

Producing one kg of pin kernels:									
Environmental Impacts ¹	Unit		De-pulping				Retting	Nut cracking	
			Pili pulper	De-	Hot Water Treatment			Pili Nut Cracker	
Midpoint Impact Categories									
Energy Resources: Non-renewable, Fossil Fuel Potential (FFP)	kg oil-eq		1.18E-02		9.97E-01	9.87E-02	1.53E-03		1.80E-02
Land Use: Agricultural Land Occupation (LOP)	m2*a crop-eq		6.65E-04		1.76E-03	2.31E+00	8.87E-05		6.90E-04
Material Resources: Metals/Minerals	kg Cu-eq		8.30E-03		2.94E-02	9.22E-03	6.98E-05		9.74E-04

(Surplus Potential)	Ore						
Water Use: Consumption Potential	Water	m3	2.09E-04	8.07E-04	2.44E-02	3.05E-05	1.66E-04

Endpoint Impact Categories

Ecosystem Land Use	Quality:	species-year	5.90E-12	1.56E-11	2.05E-08	7.87E-13	6.12E-12
Natural (Energy):	Resource	USD 2013	1.57E-03	3.57E-01	3.09E-02	2.96E-04	1.50E-03
Natural (Material):	Resources	USD 2013	1.32E-03	4.68E-03	1.47E-03	1.11E-05	1.55E-04
Metals/minerals							

¹ Based on ReCiPe 2016 v.1.03 midpoint (I) and endpoint (I) categories

The environmental impacts of manual nut cracking cannot be estimated in the absence of environmental impacts associated with labor. However, it is interesting to note the midpoint and endpoint environmental impacts of using the mechanical nutcracker as basis for comparison with alternative technologies and as basis for economic analysis in the next section. For every one kg pili kernels produced, mechanical nutcracker generates 1.80×10^{-02} kg oil-eq of fossil fuel potential, 6.90×10^{-04} m² * crop-eq agricultural land occupation, 9.74×10^{-04} kg Cu-eq surplus ore potential, and 1.66×10^{-04} m³ water consumption potential. The estimated endpoint impacts were: 6.12×10^{-12} species-year, 1.50×10^{-03} USD (2013) scarcity rent for non-renewable energy resources, and 1.55×10^{-04} USD (2013) scarcity rent for material resources.

Conclusions and Recommendations

Pili processing is done manually from sorting, de-pulping, nutcracking, and testa removal. Although there are machines available for processing in research institutions, these are not widely used by the players in the pili industry. Sustainability practices are minimal. Most of the respondents that pulp and wastewater are thrown away in their farms or processing areas. Some use this as fertilizer in pili plantations by letting these decompose above ground. Pili shells are used as fuel for cooking and are sometimes sold to oil processors or bakeries as fuel for their oven.

Manual processing of pili, particularly hot water treatment in de-pulping produces the highest environmental impacts because of the volume of water needed and the use of fuels for heating water. Mechanization in pili kernel processing can decrease these environmental impacts because it utilizes electricity and the other midpoint and endpoint environmental impact parameters are relatively lower compared to manual processing. Compared to manual processing, mechanical processing of pili using the de-pulper and nut cacker have lower midpoint and endpoint environmental impacts. When scarcity rent of natural resource use (e.g., energy and minerals) was incorporated in economic analysis, adopting the machineries were found to be economically viable in alternative scenarios. However, economic viability lowers when the current efficiencies of the machines are considered. Results also confirm the initial findings that adopting the nutcracker only is more economically viable than adopting both de-pulper and nutcracker.

This study introduced prospective life cycle assessment as an alternative approach to determine the financial feasibility and economic viability of technology adoption by incorporating scarcity rent and using the functional unit of the commodity of interest as

the unit of analysis for scalability. The result of financial and economic analysis can guide the technology developers in determining the machine efficiency needed to make the adoption of the machineries financially feasible and economically viable. They can perform simulation in the sensitivity analysis to test possible financial and economic outcomes of changing machine design. Results can also be utilized in estimating the value of the technology given the future net benefits that can be derived by the processors from using the technology. Finally, since the values were presented based on the functional unit, the processors can have an idea how much material inputs will be needed to produce their target volume of kernels.

Acknowledgement

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References

- Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F. *et al.* ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. *Int J Life Cycle Assess* **22**, 138–147 (2017). <https://doi.org/10.1007/s11367-016-1246-y>
- Hunkeler, D., Lichtenwort, K., & Rebitzer, G. (2008). *Environmental Life Cycle Costing* (1st ed.). CRC Press. <https://doi.org/10.1201/9781420054736>
- Joliet, O., Saade-Sbeih, M., Shaked, S., Joliet, A., & Crettaz, P. (2015). *Environmental Life Cycle Assessment* (1st ed.). CRC Press. <https://doi.org/10.1201/b19138>
- Klinglmair, M., Sala, S., & Brandão, M. (2013). *Assessing resource depletion in LCA: a review of methods and methodological issues. The International Journal of Life Cycle Assessment*, *19*(3), 580–592. doi:10.1007/s11367-013-0650-9
- Mattsson, B., Cederberg, C., & Blix, L. (2000). *Agricultural land use in life cycle assessment (LCA): case studies of three vegetable oil crops. Journal of Cleaner Production*, *8*(4), 283–292. doi:10.1016/S0959-6526(00)00027-5
- Pré Sustainability. (2022). *SimaPro database manual: Methods library*. Pré Sustainability. <https://simapro.com>
- Sacco, P., Vinante, C., Borgianni, Y., & Orzes, G. (2020). Circular Economy at the Firm Level: A New Tool for Assessing Maturity and Circularity. *Sustainability*, *13*(9), 5288. <https://doi.org/10.3390/su13095288>
- Stillitano, T., Spada, E., Iofrida, N., Falcone, G., and De Luca, A.I. (2021). Sustainable Agri-Food Processes and Circular Economy Pathways in a Life Cycle Perspective: State of the Art of Applicative Research. *Sustainability* **2021**, *13*(5), 2472; <https://doi.org/10.3390/su13052472>.
- Swarr, T.E., Hunkeler, D., Klöpffer, W. *et al.* Environmental life-cycle costing: a code of practice. *Int J Life Cycle Assess* **16**, 389–391 (2011). <https://doi.org/10.1007/s11367-011-0287-5>

Organic Paddy Farmers' Profile and Continuance Intention Determinants: A Preliminary Work in Central Java, Indonesia

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Abstract

Since 2002, many organic farming programs have been introduced in Indonesia, showing the government's serious commitment to achieve the *Indonesia EMAS* target, which aims for 25% of smallholder farmers to practice regenerative farming in 2045. The third-party organic certification scheme is currently the only government-recognized mechanism for organic practices. However, no evaluation or follow-up programs have been implemented to evaluate the post-adoption stage of organic farming, particularly in paddy cultivation. While continuance intention is a common concept used in marketing, limited research has applied this model to agriculture. This preliminary study aims to identify the organic paddy profile in Central Java and determine the key factors influencing their continuance intention toward organic paddy farming. Farmers' characteristics are considerably important in questionnaire development. A total of 25 organic-certified paddy farmers participated in this study. The results indicate that, on average, organic farmers are 54 years old, with 60% having completed senior high school. Organic paddy farmers occupied 3,988 m² fields with an average productivity of 4.19 tons per hectare. Several factors influencing continuance intention were adapted from existing models and tested for reliability, including market factors (0.83), organizational support (0.92), subjective norms (0.77), perceived benefits (0.78), perceived enjoyment (0.90), satisfaction (0.81), environmental concern (0.88), marker variable (0.91), and continuance intention (0.81). The reliability analysis confirms that these factors are sufficiently robust to be included in the continuation intention model of organic paddy farming.

Keywords: determinants, organic paddy, post-adoption, profiling

JEL code: Q10, Q12, C83

SDG classification: SDG 2, SDG 15

Introduction

Decision-making is a continuous process in innovation adoption. In the first stage, people need knowledge of an innovation and decide whether to implement or reject the innovation. However, the process does not stop in the stage but is followed by the confirmation. In general, in the innovation-decisions process, the stage includes (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. In the confirmation stage as the post-adoption situation, the individual will decide to continue or discontinue an innovation (Rogers, 1995). The concept of continuance intention was first spelled by (Bhattacharjee, 2001a) around technology with the satisfaction as the central point with the model of Expectation Confirmation Model (ECM). The context was getting broader in various scope such as electric vehicle (Cruz-Jesus et al., 2023); mobile apps for e-commerce (Chong, 2013); online learning (Guo, 2016), video streaming (X. Jia et al., 2023) and internet of things (Wang et al., 2023). Although continuance intention is widely used in technology and marketing, limited research in agriculture scope use the model of continuance intention as proposed by (Bhattacharjee, 2001).

ECM was adopted in (Gai et al., 2021) to explore the continuance intention to crop residue retention and several model such as Technology Acceptance Model (TAM) was applied in continuance intention of organic coconut sugar (Restianto et al., 2021). Furthermore, the unified theory of acceptance and use of technology (UTAUT) was deployed in (F. Jia et al., 2023) to explain the continuance intention of cooperative members on new agricultural technology. Several research in agriculture work in the area of continuance intention nuanced and used regression (Karipidis & Tselempis, 2014) or descriptive analysis (Chia et al., 2024). However, the use of model or theory of acceptance model to be applied in post-adoption model is criticized (Bhattacharjee, 2001). Research on continuance intention with the appropriate model in agriculture is needed since the innovation adoption process is dynamic.

This research is essential since the government of Indonesia has implemented number of programs in organic farming, including Go Organic program from 2002 until 2010 (Jahroh, 2010); 1,000 Organic Village (Ministry of Agriculture, 2023), Genta Organik in 2023 (Ministry of Agriculture), and followed by the UPLAND program in 2021-2024 to boost and accelerate organic farming +2,000 hectares of organic paddy farming in Magelang, Central Java, Indonesia (Ministry of Agriculture, 2023). In Indonesia's long-term development program namely Indonesia EMAS 2045 it is targeted that 25% of smallholder farmers in Indonesia should practice regenerative farming (Indonesian Chamber of Commerce and Industry, 2023). The term regenerative farming may not the same as organic farming; however, the regenerative principles are embedded in organic practices principles. Regenerative farming follows the rule not to disturb the soil, keeping the soil surface covered, keeping living roots in the soil, growing diverse crops, and bringing animals back to the land.

Nevertheless, the difference between organic farming and regenerative farming is that "organic" is subject to a clear legal framework in most regions of the world, whereas "regenerative" is not (Giller et al., 2021). Although the government of Indonesia has so many programs in organic or regenerative farming, the organic farmers still face the difficulties and challenges in organic practices (Sujiyanto et al., 2022). In 2018, organic paddy farmers switch back to convention due to technical and market issue (Yadi Heryadi et al., 2018). This preliminary study aims to identify the organic paddy profile in Central Java and determine the key factors influencing their continued intention to grow organic paddy. Furthermore, a pretesting of a questionnaire is important to know whether the

question is understandable for all respondents' classes. When the questionnaire is unreliable, they are not valid (Roopa & Rani, 2012). Exploring the farmers profile will find the key demographic characteristics, help the questionnaire development, and adjustment if needed.

In the knowledge domain, the research will contribute to the continuance intention model in agriculture scope. It will reveal the factors predicted to have significance in organic agriculture. This research is preliminary work and will be continued with more profound research. Recommendations for stakeholders will have a valuable impact on this research in maintaining organic farming practices in Indonesia. However, regarding data quality, questionnaire development in continuance intention should consider farmers' characteristics or profile. Hence, this preliminary work will capture farmers' profile and reliability testing for proposed constructs to provide the actual data collection. This paper will start with an introduction, methodology, result-discussion, conclusion and acknowledgment.

Methodology

The method used in this study is a survey involving 25 organic paddy farmers in Magelang, Central Java, Indonesia. All participants were 3rd organic certification. A structural questionnaire was deployed to obtain the respondents' answers in January 2025. Several questions were administered to learn the farmers' profiles and test the reliability of the questionnaire. The data collected were analysed with Ms. Excel for descriptive analysis and SPSS to test reliability.

Results and Discussion

Organic paddy farmers characteristics

Indonesia faces the farmers' demographic challenges including farmers' age and education. Based on (Hasanah et al., 2023) in 2022, the crops farmers are dominated by those who only completed elementary school (92%). Furthermore, in farmers age case, the older farmers in Indonesia (60 years and over) escalate from 7.61% in 1971 to 21.2% in 2020 (Ngadi et al., 2023). Table 1 shows the demographic characteristics of organic paddy farming, including age, family members, and education. The average age is 53.4, and the average family size is 4. High-school alumnae dominate the organic farmers.

Table 1. Organic paddy farmers' demographic profile

Components	Unit	Min	Max	Average
Age	years	40	68	53.4
Family members	person(s)	1	5	4
Education		Primary school	Graduate	High school

Source: Primary data analysis (2025)

For education, organic paddy farmers have a higher level of education than farmers in general, with the number of elder farmers about 20%. Education and age issues are crucial in organic farming since they can limit organic farmers' access to information. Related to family members, other people in the household may help the farmers to upgrade their farming knowledge in organic paddy (Syafrial et al., 2024).

In Indonesia, we have 3 schemes of organic certification including self-declaration, Participatory Guarantee System (PGS), and 3rd party scheme (Wangsit et al., 2020). However, only 3rd party scheme is recognized by the government of Indonesia with the legalities of Organic Indonesia logo (Fritz et al., 2021). Regarding cost, 3rd party certification is relatively more expensive than self-declaration and PGS. Both certification schemes should be renewed every 3 years. In Magelang's case, the regional government is currently highly concerned about organic farming, and the farmers do not need to pay for the recertification process alone. In 2021-2024, the UPLAND project was introduced to increase the organic paddy farm area by as many as 2,000 hectares, making Magelang the largest organic paddy area in Indonesia. UPLAND project ended in 2024, and the continuity of organic paddy farming after the project needed to be evaluated.

Table 2. Recertification Status

Recertification Status	Number (people)	Percentage (%)
Ever	23	92
Never	2	8
Total	25	100

Source: Primary data analysis (2025)

Discussing about land occupation, as many as 38% farmers in Indonesia are categorized as smallholders' farmers (Statistics Indonesia, 2023) meaning that organic paddy farmers are categorized as smallholders. In Indonesia, smallholder farmers are those who occupy less than 5,000 m². In the last three harvesting seasons, pest attacks came from the mice causing low productivity. However, the situation is also faced by non-organic paddy farmers in general. Average farmer experience in farming is about 20 years, and 8 years in organic paddy farming, meaning that farmers have been familiar enough with agriculture practices specifically for paddy cultivation. The farm area is certified by 3rd party scheme. Most farmers have ever been recertified (92%), meaning that the farmers have been practicing organic farming for more than 3 years. The regional government funds organic farming certification.

Organic paddy farmers occupied 3,988 m² in average with the lowest land occupation is 500 m². The maximum productivity in the 3 latest harvesting period is 4.2 ton/ha. Most of organic paddy farmers have been being practising organic farming for 8 years with the average of farming experiences is 19.72 years. Farmers' experience in certification process constructs a knowledge background in practicing organic farming. Additionally, farmers have sufficient experience in practicing paddy farming for years. However, production experiences may affect their response to the questions proposed (Figure 1).

Table 3. Organic paddy farmers' socio-economic characteristics

Components	Unit	Min	Max	Average
Land occupation	meter square	500	5,000	3,988
Productivity	tons/ha	2.0	6.7	4.2
Organic paddy farming experience	years	2	13	8.52
Paddy farming experience	years	4	46	19.72

Source: Primary data analysis (2025)

In constructing questionnaires, the knowledge of farmers' characteristics is important. A questionnaire reliability and validity closely relate to respondents' background (i.e age, education, and experiences) due to their understanding to respond to the question. To highlight, profiling is not a mere activity in questionnaire development.

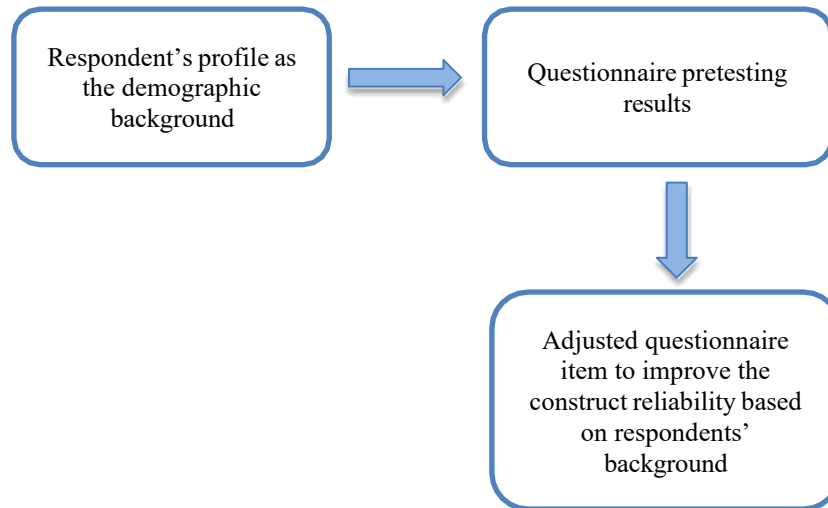


Figure 1. Respondent's profiling role in questionnaire development and adjustment
Source: Author's work (2025)

Proposed Construct for Continuance Intention

We proposed constructs to be reliability-tested with SPSS. Modification for items in each construct has been done by deletion some items and show the reliability using Cronbach's Alpha. Proposed constructs are captured in Table 4.

Table 4. Reliability test of proposed constructs

Constructs	Initial Indicators (items)	Initial Alpha	Cronbach's Revised Indicators (items)	Revised Cronbach's Alpha
Market Factors	7	0.83	7	0.83
Organizational Supports	7	0.92	7	0.92
Subjective Norms	6	-0.31	3	0.77
Perceived Benefits	7	0.78	7	0.78
Perceived Enjoyment	6	0.9	7	0.90
Satisfaction	7	0.77	6	0.81
Environmental Concern	7	0.88	7	0.88
Continuance Intention	10	0.72	9	0.81
Marker Variables	4	0.91	4	0.91

In this preliminary work, we proposed market factors, organizational support, subjective norms, perceived benefits, enjoyment, satisfaction, environmental concern, marker variables as the independent variable and continuance intention as the dependent variable. Market factors were the main reason why farmers converted to organic farming, according to the meta-analysis research covering 53 references (Karipidis & Karypidou, 2021). Demand decreasing leads the organic farmers leaving organic certification in apple commodities (Brady et al., 2023). In Indonesia's case, market factors should be important to include since agriculture is the main occupation for farmers in the majority. Organizational support was initially stated as facilitating condition (Venkatesh et al., 2012). Joining farmer's groups in Indonesia is mandatory to access government subsidies

or to certify organic farming areas. The high cost of organic certification needs a zoning area of organic which is managed under a farmers' group (Irham et al., 2024). The existence of farmers group forms social norms. Social norms play a significant role with the extension officers' facilities (Mardianah et al., 2021). Perceived benefit term is proposed to reflect a series of usefulness including technical or conceptual productivity (Bhattacharjee & Barfar, 2011). Farming benefit could be family income, improvement of living standard, and increasing farming productivity (Matekele et al., 2024).

Furthermore, we introduced satisfaction as the core of continuance intention as the utilitarian value (Gai et al., 2021; Li et al., 2022). Perceived enjoyment is predicted to give a significant effect toward continuance intention of organic farming since organic farmers are found to have a better mental health situation (David et al., 2024). Finally, environmental concern is predicted to give a good insight into the continuance intention model since organic farming in Indonesia comes from the farmers' social movement and responsibility toward environment (Yana et al., 2023). We also proposed for marker variables to detect the common method bias in the model specifically in Structural Equation Modelling analysis (Simmering et al., 2015). Common method bias appears when the dependent and independent variable is measured by the same response method. Common method bias can impact the result significantly by deflating or inflating the relationship between variables and affect the reliability and validity (Kock et al., 2021). Marker variables are adopted from Attitude Toward the Color Blue (Miller & Simmering, 2023). It is quite tricky to find a set of marker variables in social research since the variables should have no relationship with the research context.

Cronbach's Alpha is an indicator to measure the internal consistency of a set item in a construct (Raharjanti et al., 2022). Internal consistency means a degree to express the ability of items to produce of a similar score in measurement. Three measures of internal consistency are considered, namely Kuder-Richardson Formula 20 (KR20), Cronbach's α , and person separation reliability. KR20 and Cronbach's Alpha is widely used and adopted to evaluate the cognitive and personality aspects (Anselmi et al., 2019). Cronbach's Alpha lies down between 0-1 in terms of how well the items in a construct measure the same concept. The higher correlation among items in a construct will lead to the higher Cronbach's Alpha (Tavakol & Dennick, 2011). A general acceptance of the reliability test is 0.6-0.7 in Alpha Cronbach's and will be better when it can be more than 0.8. However, a score of more than 0.95 is not good and indicates the redundancy level (Ursachi et al., 2015); (Raharjanti et al., 2022). Cronbach's Alpha decreases due to behavioral factors, such as fake-good or random responses, such as respondents' boredom. However, random responses are not easy to detect (Anselmi et al., 2019). In this case, adjustment to existing questionnaires is needed to improve reliability and gain the desirable data qualification.

In this preliminary work, Cronbach's Alpha is distributed from 0.77-0.92, meaning that the item is consistent in measuring the farmers' response. Cronbach's Alpha of 0.6 is accepted in exploratory research, and in advanced research, between 0.7-0.9 is satisfactory. However, technically, the ρ_c is more appropriate to measure composite reliability (Hair et al., 2017). Additionally, Alpha Cronbach's range in 0.45-0.60 is acceptable (Zalma et al., 2015). Based on the Table 4, the final Cronbach's Alpha in preliminary study is acceptable with some adjustment by deletion several items. However, to increase the Cronbach's Alpha is not simply deleting the item but improving the question item to clarify the same measurement of a concept (Tavakol & Dennick, 2011). Subjective Norm has a negative Cronbach's Alpha in the origin items due to item composition. Statistically, there are negative correlations among the items. To solve the problem, the researchers should prove the negative correlation and improve those

negatively correlated items. In further analysis, reliability testing is substantial for regression and structural equation modelling analysis to check the measurement model. However, preliminary work is not a single method to measure the questionnaire quality. Face validity and content validity is the suggested technic to gain the qualified questionnaire (Roopa & Rani, 2012). In addition, the length of questionnaire causes the respondent's burden implying that shorter questionnaire is preferable (Rolstad et al., 2011; Yusoff et al., 2021).

Conclusion

Based on the result, it can be concluded that the X Generation dominates organic paddy farming, with most farmers finishing their education in Senior High School. Old farmers will face several challenges in the next research process, which the researcher should anticipate. The questionnaire should be constructed regarding farmers' capacity and capability as simply as possible to maintain internal reliability. The factors predicted to significantly affect continuance intention include market factors, organizational support, subjective norms, perceived benefits, enjoyment, satisfaction, and environmental concern. Using marker variables is essential to validate the proposed model, specifically when the research will use Structural Equation Modelling. Reliability testing showed that Cronbach's Alpha ranges from 0.77-0.92 and is categorized as acceptable and high. In the future research avenue, the mentioned variable should be examined due to the specific characteristics of agriculture topics. In addition, adjusting questionnaires based on respondents' profile is predicted to be plausible to capture the desirable data.

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References

- Anselmi, P., Colledani, D., & Robusto, E. (2019). A Comparison of Classical and Modern Measures of Internal Consistency. *Frontiers in Psychology*, 10. <https://doi.org/10.3389/fpsyg.2019.02714>
- Bhattacharjee, A. (2001a). An empirical analysis of the antecedents of electronic commerce service continuance. *Decision Support Systems*, 32(2), 201–214. [https://doi.org/10.1016/S0167-9236\(01\)00111-7](https://doi.org/10.1016/S0167-9236(01)00111-7)
- Bhattacharjee, A. (2001b). Understanding information systems continuance: An expectation-confirmation model. *MIS Quarterly*. <https://www.jstor.org/stable/3250921>
- Bhattacharjee, A., & Barfar, A. (2011). Information Technology Continuance Research: Current State and Future Directions*. In *Asia Pacific Journal of Information Systems* (Vol. 21, Issue 2).
- Brady, M. P., Granatstein, D., & Kirby, E. (2023). Survival and growth of organic farms over the long-run. *Journal of the Agricultural and Applied Economics Association*, 2(2), 248–262. <https://doi.org/10.1002/jaa2.53>
- Chia, E. L., Chirwa, P. W., & Nsubuga, F. W. (2024). An Analysis of the Behavioural Persistence of Tree-growing Farmers in the Sudano-Sahelian Region of Cameroon. *Small-Scale Forestry*. <https://doi.org/10.1007/s11842-024-09566-2>

- Chong, A. Y. L. (2013). Understanding mobile commerce continuance intentions: an empirical analysis of Chinese consumers. *Journal of Computer Information Systems*. <https://doi.org/10.1080/08874417.2013.11645647>
- Cruz-Jesus, F., Figueira-Alves, H., Tam, C., Pinto, D. C., Oliveira, T., & Venkatesh, V. (2023). Pragmatic and idealistic reasons: What drives electric vehicle drivers' satisfaction and continuance intention? *Transportation Research Part A: Policy and Practice*, 170. <https://doi.org/10.1016/j.tra.2023.103626>
- David, L., Streith, M., Michaud, A., & Dambrun, M. (2024). Organic and Conventional Farmers' Mental Health: A Preliminary Study on the Role of Social Psychological Mediators. *Sustainability (Switzerland)*, 16(5). <https://doi.org/10.3390/su16051926>
- Fritz, M., Grimm, M., Keilbart, P., Laksmana, D. D., Luck, N., Padmanabhan, M., Subandi, N., & Tamtomo, K. (2021). Turning indonesia organic: Insights from transdisciplinary research on the challenges of a societal transformation. *Sustainability (Switzerland)*, 13(23). <https://doi.org/10.3390/su132313011>
- Gai, H., Yan, T., Zhang, A., Batchelor, W. D., & Tian, Y. (2021). Exploring factors influencing farmers' continuance intention to crop residue retention: Evidence from rural China. *International Journal of Environmental Research and Public Health*, 18(14). <https://doi.org/10.3390/ijerph18147412>
- Giller, K. E., Hijbeek, R., Andersson, J. A., & Sumberg, J. (2021). Regenerative Agriculture: An agronomic perspective. *Outlook on Agriculture*, 50(1), 13–25. <https://doi.org/10.1177/0030727021998063>
- Guo, Z. (2016). Promoting online learners' continuance intention: An integrated flow framework. *Information and Management*, 53(2), 279–295. <https://doi.org/10.1016/j.im.2015.10.010>
- Hair, J. F. ., Hult, G. T. M. ., Ringle, C. M. ., & Sarstedt, Marko. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage.
- Hasanah, L., Gultom, R., Wiratno, O., Sulistyowati, H., Abdurachman, A. A., Uliyah, Surasa, J., Indah, K., Martono, H., Yukarina, S., & Heruwaty. (2023). *Statistik Ketenagakerjaan Sektor Pertanian*.
- Irham, I., Nurhayati, A., Widada, A. W., Subejo, S., Devi, L. Y., Simarmata, R., Anantasari, E., Rosidah, A., & Anggraini, A. I. (2024). Farmer's willingness to accept the sustainable zoning-based organic farming development plan: A lesson from Sleman District, Indonesia. *Open Agriculture*, 9(1). <https://doi.org/10.1515/opag-2022-0253>
- Jahroh, S. (2010). Organic Farming Development in Indonesia: Lessons Learned From Organic Farming in West Java and North Sumatra. *Innovation and Sustainable Development in Agriculture and Food*. <https://hal.science/hal-00521832>
- Jia, F., Zhang, R., & Li, J. (2023). *The impact of continuous use intention of cooperative members on new agricultural technologies*.
- Jia, X., Pang, Y., Huang, B., & Hou, F. (2023). Understanding consumers' continuance intention to watch streams: A value-based continuance intention model. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1073301>
- Karipidis, P., & Karypidou, S. (2021). Factors that impact farmers' organic conversion decisions. In *Sustainability (Switzerland)* (Vol. 13, Issue 9). MDPI AG. <https://doi.org/10.3390/su13094715>

- Karipidis, P., & Tselempis, D. (2014). Farmers' intention to maintain quality certification. *EuroMed Journal of Business*, 9(1), 93–110. <https://doi.org/10.1108/EMJB-04-2013-0015>
- Kock, F., Berbekova, A., & Assaf, A. G. (2021). Understanding and managing the threat of common method bias: Detection, prevention and control. *Tourism Management*, 86. <https://doi.org/10.1016/j.tourman.2021.104330>
- Li, J., Jiang, R., & Tang, X. (2022). Assessing psychological factors on farmers' intention to apply organic manure: an application of extended theory of planned behavior. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-022-02829-y>
- Mardianah, Fuady, I., & Armien Syifaa Sutarjo, M. (2021). Factors affecting the intention of organic agricultural behavior in Tidore City. *E3S Web of Conferences*, 306. <https://doi.org/10.1051/e3sconf/202130602013>
- Matekele, C. K., Rutatola, P. P., & Imori, M. M. (2024). Determinants of farmers' intentions to seek Agricultural Value Chain Financing in Tanzania. *Cogent Business and Management*, 11(1). <https://doi.org/10.1080/23311975.2024.2312964>
- Miller, B. K., & Simmering, M. J. (2023). Attitude Toward the Color Blue: An Ideal Marker Variable. *Organizational Research Methods*, 26(3), 409–440. <https://doi.org/10.1177/10944281221075361>
- Ministry of Agriculture, Republic of Indonesia. <https://balaimedan.ditjenbun.pertanian.go.id/kunci-sukses-program-pertanian-organik-fokus-responsif-dan-kolaboratif/>. Accessed in March, 11, 2024.
- Ministry of Agriculture, Republic of Indonesia. <https://bppsdp.pertanian.go.id/blog/post/gentaorganik>. Accessed in March, 11, 2024.
- Ministry of Agriculture, Republic of Indonesia. <https://upland.psp.pertanian.go.id>. Accessed in March, 11, 2024.
- Ngadi, N., Zaelany, A. A., Latifa, A., Harfina, D., Asiati, D., Setiawan, B., Ibnu, F., Triyono, T., & Rajagukguk, Z. (2023). Challenge of Agriculture Development in Indonesia: Rural Youth Mobility and Aging Workers in Agriculture Sector. *Sustainability (Switzerland)*, 15(2). <https://doi.org/10.3390/su15020922>
- Raharjanti, N. W., Wiguna, T., Purwadianto, A., Soemantri, D., Indriatmi, W., Poerwandari, E. K., Mahajudin, M. S., Nugrahadi, N. R., Roekman, A. E., Saroso,
- O. J. D. A., Ramadianto, A. S., & Levania, M. K. (2022). Translation, validity and reliability of decision style scale in forensic psychiatric setting in Indonesia. *Heliyon*, 8(7). <https://doi.org/10.1016/j.heliyon.2022.e09810>
- Restianto, Y. E., Suliyanto, Dinanti, A., & Naufalin, L. R. (2021). Enhancing organic continuance intentions of organic coconut sugar technology. *Quality - Access to Success*, 22(184), 138–147. <https://doi.org/10.47750/QAS/22.184.18>
- Rogers, E. M. . (1995). *Diffusion of innovations*. Free Press.
- Rolstad, S., Adler, J., & Rydén, A. (2011). Response burden and questionnaire length: Is shorter better? A review and meta-analysis. *Value in Health*, 14(8), 1101–1108. <https://doi.org/10.1016/j.jval.2011.06.003>
- Roopa, S., & Rani, M. (2012). Questionnaire Designing for a Survey. *The Journal of Indian Orthodontic Society*, 46, 273–277. <https://doi.org/10.5005/jp-journals-10021-1104>

- Simmering, M. J., Fuller, C. M., Richardson, H. A., Ocal, Y., & Atinc, G. M. (2015). Marker Variable Choice, Reporting, and Interpretation in the Detection of Common Statistics Indonesia. <https://sensus.bps.go.id/topik/tabular/st2023/215/0/0>. Accessed in March, 11, 2024.
- Method Variance: A Review and Demonstration. *Organizational Research Methods*, 18(3), 473–511. <https://doi.org/10.1177/1094428114560023>
- Sujianto, Gunawan, E., Saptana, Syahyuti, Darwis, V., Ashari, Syukur, M., Ariningsih, E., Saliem, H. P., Mardianto, S., & Marhendro. (2022). Farmers' perception, awareness, and constraints of organic rice farming in Indonesia. *Open Agriculture*, 7(1), 284 – 299. <https://doi.org/10.1515/opag-2022-0090>
- Syafrial, S., Rahman, M. S., Retnoningsih, D., & Toiba, H. (2024). Exploring the Impact of Participation in Agricultural Social Media Groups on Technical Efficiency: A case Study From Organic RiceFarmers in Indonesia. *Journal of Sustainability Science and Management*, 19(9), 121–131. <https://doi.org/10.46754/jssm.2024.09.008>
- Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. In *International journal of medical education* (Vol. 2, pp. 53–55). <https://doi.org/10.5116/ijme.4dfb.8dfd>
- Ursachi, G., Horodnic, I. A., & Zait, A. (2015). How Reliable are Measurement Scales? External Factors with Indirect Influence on Reliability Estimators. *Procedia Economics and Finance*, 20, 679–686. [https://doi.org/10.1016/s2212-5671\(15\)00123-9](https://doi.org/10.1016/s2212-5671(15)00123-9)
- Venkatesh, V., Thong, J. Y. L., Xu, X., & Walton, S. M. (2012). Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology Quarterly Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology1. In *Source: MIS Quarterly* (Vol. 36, Issue 1).
- Wang, M. X., Kim, K. S., & Kim, J. K. (2023). Investigating the Determinants of IoT Device Continuance Intentions: An Empirical Study of Smart Speakers Through the Lens of Expectation-Confirmation Theory. *SAGE Open*, 13(3). <https://doi.org/10.1177/21582440231197067>
- Wangsit, S., Suprayogi, W., Bayu, P. G. P., Wahab, A., Wardhani, E. W., Eka, N. R., & Alkausar, S. (2020). Panduan Pamor Indonesia (2021). *Aliansi Organias Indonesia*.
- Indonesian Chamber of Commerce and Industry. (2023). White-paper-Indonesia-Emas-2045. In *Indonesian Chamber of Commerce and Industry*. Indonesian Chamber of Commerce and Industry.
- Yadi Heryadi, D., Noor, T. I., Deliana, Y., & Hamdani, J. S. (2018). Why Organic Rice Farmers Switch Back To Conventional Farming ? In *Journal of Economics and Sustainable Development* www.iiste.org ISSN (Vol. 9, Issue 8). Online. www.iiste.org
- Yana, H., Hidayat, K., Sukesu, K., & Yuliati, Y. (2023). *Reduction of Farmer's Attitudes and Value in the Implementation of Organic Agricultural Programs in Indonesia*. www.intechopen.com
- Yusoff, M. S. B., Arifin, W. N., & Hadie, S. N. H. (2021). ABC of questionnaire development and validation for survey research. In *Education in Medicine Journal* (Vol. 13, Issue 1, pp. 97–108). Penerbit Universiti Sains Malaysia. <https://doi.org/10.21315/EIMJ2021.13.1.10>

Zalma, A. R., Safiah, M. Y., Ajau, D., & Khairil Anuar, M. I. (2015). Reliability and validity of television food advertising questionnaire in Malaysia. *Health Promotion International*, 30(3), 523–530. <https://doi.org/10.1093/heapro/dat072>

Fish Farmers' Intention to Adopt Non-Invasive In-Situ Surfaced Enhanced Raman Spectroscopy (NI-SERS) in Peninsular Malaysia

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Abstract

The adoption of advanced technologies in aquaculture is crucial for enhancing production efficiency and meeting national targets set by the National Agro-Food Policy 2.0. The production of aquaculture was targeted to account for 40% of the total fisheries production by 2030, according to NAP2. However, aquaculture production in Malaysia remains below the expected levels, and fish farmers' willingness to adopt new technologies remains uncertain. This study investigates the factors influencing fish farmers' intention to adopt Non-Invasive In-Situ Surface-Enhanced Raman Spectroscopy (NI-SERS) technology in Peninsular Malaysia. NI-SERS is the new technology that is introduced to help the fish farmer identifying the good quality fingerlings from the hatcheries. A total of 348 fish farmers participated in this study. Unified Theory of Acceptance and Use of Technology (UTAUT) was used to construct the questionnaire and the data was analysed by Partial Least Square Structural Equation Modelling (PLS-SEM). The findings reveal that performance expectancy, social influence, and facilitating conditions significantly impact the intention to adopt NI-SERS technology. These results highlight the importance of ensuring farmers perceive the technology as beneficial, receive adequate support from their social environment, and have access to necessary resources for adoption. The study provides valuable insights for industry stakeholders, and researchers in promoting the adoption of innovative aquaculture technologies to enhance fish farming productivity in Malaysia.

Keywords: aquaculture technology, PLS-SEM, UTAUT, farmer

JEL code: Q10, Q13, Q16

SDG classification: SDG 2

Introduction

In Malaysia, fish production plays a crucial role in meeting the nutritional needs of its citizens. However, despite efforts to increase aquaculture production, the country still heavily relies on marine capture fisheries, which poses sustainability concerns. Aquaculture has been recognized as one of the important activities to ensure food security since the Seventh Malaysia Plan as well as to eradicate poverty (1996-2000) (FAO, 2022). The Ministry of Agriculture and Food Industry (MAFI) aims to address this issue by targeting a 40% aquaculture contribution to Malaysia's total fish production as outlined in the National Agriculture Policy 2, 2021-2030 (NAP2). However, despite these efforts, the aquaculture sector still falls short of its targets. In 2021, aquaculture production stood at 23.80% of the total fish production, with a self-sufficiency ratio (SSR) of only 93%, indicating difficulties in meeting the country's fish demand (DOF, 2020).

The decline in fish fry production within Malaysia's private sector has been an ongoing issue attributed to several key challenges. Local hatcheries have been struggling to produce high-quality fry in sufficient quantities to meet the needs of fish farmers (DOF, 2020). The significant drop in local fry production thereby jeopardises the sustainability of the domestic aquaculture industry (DOF, 2022). Currently, broodstock selection, crucial for producing high-quality fry, relies on individual breeding and genetic selection methods, which have limitations such as inbreeding depression and complexity. Therefore, a new technology called Non-Invasive In-Situ Surface Enhanced Raman Spectroscopy (NI-SERS) is proposed to address these challenges and meet farmers' needs.

Non-invasive in-situ Surface-Enhanced Raman Spectroscopy (NI-SERS) is a new technology that emerges as a potential tool for broodstock selection. NI-SERS aids in identifying high-quality broodstock before breeding, reducing fry mortality rates. By improving broodstock selection and reducing mortality rates, NI-SERS contributes to achieving Malaysia's self-sufficiency target in fish production. It also enhances fish farmers' profitability by minimizing losses due to fish mortality. However, farmers are often reluctant to adopt new technology (Kumar et al., 2018), which causes suboptimal productivity (Ntshangase et al., 2018).

The Unified Theory of Acceptance and Technology (UTAUT) provides a comprehensive framework for understanding farmers' intention to adopt technology. While UTAUT has been extensively used to study technology adoption (Tinh et al., 2019, Hernandez & Hernandez, 2020, Smidt & Jokonya, 2022, Wang et al., 2023), limited research exists on its application in the aquaculture sector. Therefore, this study explores fish farmers' intention to adopt NI-SERS in Peninsular Malaysia, addressing the gaps in understanding technology adoption in the aquaculture industry. Thus, this study is important in identifying the factors that influence fish farmers' intention to adopt NI-SERS. Later, this study can provide valuable insights for industry stakeholders, and researchers in promoting the adoption of innovative aquaculture technologies to enhance fish farming productivity in Malaysia.

Methodology

The theory that was used in this is the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al., (2003). UTAUT is one of the prominent models in the technology acceptance and adoption field and has been used in various study that relates to the acceptance of new technology (Faridi, Kavoosi-Kalashami, & Bilali, 2020; Kalavani, Kazerani, & Shekofteh, 2018). One significant advantage of UTAUT is that it provides an all-encompassing and integrative paradigm that reconciles the shortcomings

and limits of eight theories and models. As a result, despite its youth, UTAUT is gaining traction among technology adoption models. UTAUT have four main variables which are performance expectancy, effort expectancy, social influence and facilitating condition. These variables is then moderated by gender, age, voluntariness, and experience. However, in this study, the moderator is not measured as the researcher focusing on the main variables in the theory. The conceptual framework for this study is shown in Figure 1 below.

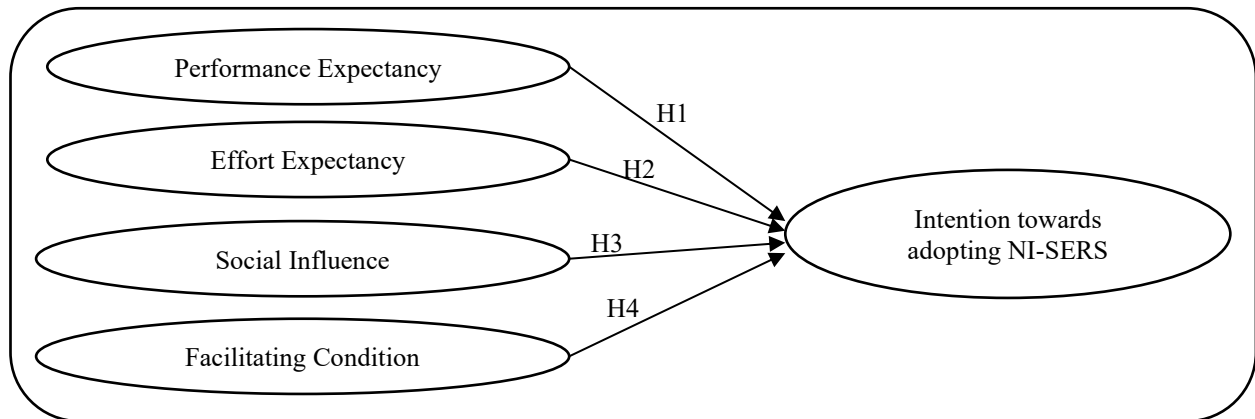


Figure 1. Conceptual Framework

Hypothesis testing

Performance expectancy refers to a person's point of view on whether the technology will have a performance for him or her (Venkatesh et al. 2003). Rose et al. (2016) emphasize that performance expectancy is important for the farmers to have intention to adopt the decision support tools in their farm. performance expectancy is described as perceived benefits and usefulness that the fish farmers tend to receive once they adopt the NI-SERS technology.

H1: Performance expectancy is positively influence fish farmers' intention to adopt NI-SERS.

Effort expectancy refers to the user's perception of how difficult or easy it is for him or her to use the new technology or measures (Venkatesh et al., 2003). In this study, effort expectancy refers to the thought the fish farmer has toward the NI-SERS and to what extent he/she thinks it is easy to learn or use. Effort expectancy had become the most important factor in analysing the behavioural intention of farmers in water and soil conservation measures (Faridi, Kavoosi-Kalashami, & Bilali, 2020).

H2: Effort expectancy is positively influence fish farmers' intention to adopt NI-SERS.

Social influence, also known as subjective norms, refers to the extent to which an individual's behavior is shaped by the opinions and expectations of others who are significant in their lives (Venkatesh et al., 2003). Michels, Bonke, and Musshoff (2020) found that interactions with colleagues had a notable effect on the adoption of crop protection applications among farmers. In this study, social influence refers to the impact of significant people in the farmers' lives that can encourage them towards the NI-SERS technology.

H3: Social influence is positively influence fish farmers' intention to adopt NI-SERS.

Venkatesh et al. (2003) define Facilitating Conditions (FC) as the extent to which individuals perceive that the existing technical infrastructure adequately supports their

ability to use a particular technology. In the original UTAUT framework, facilitating conditions were seen as a direct predictor of actual technology use rather than a determinant of behavioral intention. However, since this study focuses on potential users who have not yet engaged with NI-SERS technology in their farms, the traditional UTAUT model needs some adaptation. This approach is consistent with findings from prior research (Gupta et al., 2019; Jewer, 2018; Suki & Suki, 2017), which identified FC as a direct driver of behavioral intention, particularly in scenarios where individuals have limited experience with a technology.

H4: Facilitating conditions positively influence fish farmers' intention to adopt NI-SERS.

Sampling, sample size and data collection

This study was conducted in four states, all located in four different regions in Peninsular Malaysia. Peninsular Malaysia was selected compared to Sabah and Sarawak because the aquaculture activities, especially the fish production, are mainly focussed in Peninsular Malaysia with a total 5705 fish farmers. About 348 fish farmers became the respondents for this study. Multistage stratified random sampling techniques were utilized to select the samples. States in each region with the highest number of fish farmers registered with the Department of Fisheries Malaysia is selected. The states that are selected as the targeted area are Perak (Northern region), Pahang (East coast region), Selangor (Central Region) and Negeri Sembilan (Southern Region). Respondents were then randomly selected. Data collection was conducted from February 2023 to July 2023 with the help of three enumerators and officer from Department of Fisheries.

The questionnaire is prepared in Bahasa Malaysia, and the content is adapted from existing literature from the theoretical framework. There were three sections of the questionnaire. Section A is about the farm profiles, while Section B is related to the sociodemographic profiles of the respondents. Section C is related to the factors that affect the intention to adopt Ni-SERS using UTAUT variables. For section C, a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) is used to measure respondents' agreement with each statement. The data were manually inputted into IBM SPSS statistics 2.1 for further processing and analysis. The Partial Least Square (PLS) technique with Smart-PLS 4.0 software was employed to estimate the model and identify the factors that influence technology adoption intention among fish farmers.

Results and Discussion

Sociodemographic characteristics of respondents and farm characteristics

Most respondents in the study are males (87.4%), Malay (89.7%), aged 57 years old and above (29.9%). A majority of them have completed secondary school (59.8%), while a significant number hold a tertiary school (27.9%). More than half of the farmers report monthly incomes of RM1500 or lower (43.7%) from fish farming. Additionally, farmers in the survey report have an average of 10.92 years of farming experience, with most of them (33.0%) have farming experience between 1 to 5 years of farming experience. Lastly, the majority manages farms from 1.0 acres and below in size (75.3%). It is said that most of the respondents are operating on a small scale.

Measurement model evaluation

For good convergent validity, AVE values should exceed 0.50, indicating that at least 50% of the variance in the indicators is explained by the construct (Hair et al., 2017). All constructs demonstrated Average Variance Extracted (AVE) values above 0.50 across each data group. For internal consistency to be deemed acceptable, composite reliability

values must be greater than 0.7 (Hair, Ringle, & Sarstedt, 2011). In this study, composite reliability values ranged from 0.858 to 0.964, exceeding the minimum requirement and confirming the reliability of the measurement model.

Discriminant validity was evaluated using the heterotrait-monotrait ratio (HTMT), which is an essential metric for determining whether constructs are empirically distinct. If HTMT values surpass the 0.85 threshold (Kline, 2011), it may signal issues with discriminant validity. As shown in Table 1, all constructs had HTMT values below the threshold of 0.85, as assessed by the PLS Algorithm. These results verify that the measurement model meets the criteria for discriminant validity, confirming that all constructs are distinct and comply with the established standards.

Table 1. Discriminant validity

	1	2	3	4	5
1. Effort Expectancy					
2. Facilitating Condition	0.654				
3. Intention	0.480	0.628			
4. Performance Expectancy	0.523	0.588	0.762		
5. Social Influence	0.453	0.581	0.650	0.688	

The structural model evaluation and testing of hypothesis

The significance of the model's pathways was analyzed using the bootstrapping method. For this evaluation, a one-tailed test at a 0.05 significance level was applied, utilizing 5,000 subsamples. Critical t-values for significance at 1% ($\alpha = 0.01$) and 5% ($\alpha = 0.05$) in a one-tailed test were identified as 2.33 and 1.645, respectively, as per Ramayah et al. (2018). Table 2 shows the path coefficient assessment. The R^2 value of 0.596 for intention signifies that the model displays moderate predictive power (Hair et al., 2017). The analysis shows that performance expectancy, facilitating conditions, and social influence collectively explain 59.6% of the variance in behavioral intention, demonstrating substantial predictive accuracy.

Based on the table, it shows that performance expectancy ($\beta=0.484$, $t\text{-value}=10.264$, $p<0.001$) had become the most influencing factor for farmers to have the intention to adopt the NI-SERS. This indicates that farmers who perceive NI-SERS technology as beneficial and can enhance their productivity in the farm is more willing to adopt the NI-SERS in the future. These findings are similar to the other research, such as research by Rübcke von Veltheim et al. (2020) on the uptake of autonomous field robots in agriculture, Molina-Maturano et al. (2021) on agricultural app usage and Ulhaq et al. (2022) on ICT adoption in shrimp farming.

Besides that, social influence also becomes a significant factor in this study ($\beta=0.188$, $t\text{-value}=3.760$, $p<0.001$). This finding shows the importance of peer recommendation and validation while in this study context is other fish farmers in shaping their decisions to have intention in adopting NI-SERS. Other studies also give the same result on the importance of social influence, such as the study by Rübcke von Veltheim(2020) on autonomous field robots. Ulhaq et al. (2022) on ICT solutions and Feisthauer, Hartmann, and Börner (2024) on spot spraying.

Last but not least, facilitating condition ($\beta=0.202$, $t\text{-value}=4.486$, $p<0.001$) shows the positive significant relationship towards the intention to adopt NI-SERS. Farmers who perceive that they will have suitable resources and support systems are more motivated to have the intention to adopt innovations. Also, farmers feel confident to use the

technology within their ability as they know there will an organization or person that they can seek if having difficulties in using the technology. This aligns with the conclusions of Kang et al. (2020), and Molina-Maturano et al. (2021) who found that facilitating conditions play a significant role in adopting agricultural apps and smart farming technologies.

However, effort expectancy shows no significant relationship towards the intention to adopt. This is contradicted by the study by Obiero et al. (2019), Rübcke von Veltheim et al. (2020), and Salifu, Aheto, and Vondolia (2024) revealed that the ease of using the technology becomes a predictor towards the intention to adopt. In addition, the non-significant impact of effort expectancy on intention relates to the farmers prioritizing the benefits and the outcome of using the technology over the effort required to learn it. Whether the technology is easy or not to use, if it can increase their farm production and income, they are willing to adopt it in the future.

Table 2. Path coefficient assessment

Hypothesis	Path	Path Coefficient (β)	Std. Error	t-value	p-value	Result	R ²
H1	PE → INT	0.484	0.047	10.264	0.000	Significant	0.596
H2	EE → INT	0.024	0.050	0.486	0.314	Not Significant	
H3	SI → INT	0.188	0.050	3.760	0.000	Significant	
H4	FC → INT	0.202	0.045	4.486	0.000	Significant	

*Note: PE=Performance Expectancy, EE=Effort Expectancy, SI=Social Influence, FC=Facilitating Condition, INT=Intention

Conclusion

The implementation of advanced technologies such as NI-SERS within Malaysia's aquaculture sector is regarded as a strategic initiative to support the national objective of achieving a 40% contribution to total fish production by the year 2030. The findings indicate that farmers who perceive substantial benefits towards NI-SERS will have the intention to adopt the technology in the future. Furthermore, the likelihood of intention to adopt is also positively influenced by social encouragement and the perception that adequate support will be available from relevant individuals or institutions. Thus, hypothesis 1, hypothesis 3 and hypothesis 4 are accepted. Technology developers and marketers should emphasize strategic and effective communication with farmers to gain deeper insights into their needs and preferences. Such an approach ensures that the promotion of emerging technologies is more targeted and aligns closely with the practical demands and expectations of end-users. As NI-SERS technology is still in the development stage, it is recommended that future research measure the adoption of the technology in the future once the technology is applied in the farm and including the moderator from the original UTAUT can enhance the result for NI-SERS technology adoption.

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References

- Department of Fisheries Malaysia. (2020). *Annual Fisheries Statistics (2019)*. Retrieved at <https://www.dof.gov.my/en/resources/fisheries-statistics-i/>
- Department of Fisheries Malaysia. (2022). *Fisheries Research Division (2021)*. Retrieved at <https://www.dof.gov.my/korporat/bahagian-unit/bahagian-penyelidikan-perikanan>
- FAO 2022. Malaysia. Text by Mazuki Hashim. Fisheries and Aquaculture Division [online]. Rome. [Cited Friday, May 27th 2022]. <https://www.fao.org/fishery/en/countrysector/my/en>
- Faridi, A. A., Kavoosi-Kalashami, M., & El Bilali, H. (2020). Attitude components affecting adoption of soil and water conservation measures by paddy farmers in Rasht County, Northern Iran. *Land use policy*, 99, 104885.
- Feisthauer, P., Hartmann, M., & Börner, J. (2024). Behavioral factors driving farmers' intentions to adopt spot spraying for sustainable weed control. *Journal of Environmental Management*, 353, 120218
- Gupta, K. P., Manrai, R., & Goel, U. (2019). Factors influencing adoption of payments banks by Indian customers: extending UTAUT with perceived credibility. *Journal of Asia Business Studies*. 13, 173–195.
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice*, 19(2), 139–152.
- Hair, J., Hollingsworth, C. L., Randolph, A. B., & Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial management & data systems*.
- Hernandez, R. M., & Hernandez, A. A. (2020). *Acceptance Analysis of Mobile Application for Nile Tilapia Classification using Unified Theory of Acceptance and use of Technology*. 2020 16th IEEE International Colloquium on Signal Processing & Its Applications (CSPA). doi:10.1109/cspa48992.2020.906872
- Jewer, J. (2018). Patients' intention to use online postings of ED wait times: A modified UTAUT model. *International journal of medical informatics*, 112, 34-39.
- Kalavani, A., Kazerani, M., & Shekofteh, M. (2018). Acceptance of evidence based medicine (EBM) databases by Iranian medical residents using unified theory of acceptance and use of technology (UTAUT). *Health Policy and Technology*, 7(3), 287-292.
- Kang, D. B., Chang, K. J., Lee, Y. K., & Jeong, M. U. (2020). A Study on the Effects of Changes in Smart Farm Introduction Conditions on Willingness to Accept Agriculture-Application of Extended UTAUT Model. *Korean Journal of Organic Agriculture*, 28(2), 119-138
- Kline, R. B. (2011). *Principles and Practice of Structural Equation Modeling*. 3rd edition.
- Kumar, G., Engle, C., & Tucker, C. (2018). Factors driving aquaculture technology adoption. *Journal of the world aquaculture society*, 49(3), 447-476.
- Michels, M., Bonke, V., & Musshoff, O. (2020). Understanding the adoption of smartphone apps in crop protection. *Precision Agriculture*, 21(6), 1209-1226.
- Molina-Maturano, J., Verhulst, N., Tur-Cardona, J., Güereña, D. T., Gardeazábal-Monsalve, A., Govaerts, B., & Speelman, S. (2021). Understanding smallholder farmers' intention to adopt agricultural apps: the role of mastery approach and innovation hubs in Mexico. *Agronomy*, 11(2), 194.

- Ntshangase, N., L., Muroyiwa, B., Sibanda, M. (2018). Farmers' Perceptions and Factors Influencing the Adoption of No-Till Conservation Agriculture by Small-Scale Farmers in Zashuke, KwaZulu-Natal Province. *Sustainability*, 10 (2), pp. 1-16.
- Obiero, K. O., Waidbacher, H., Nyawanda, B. O., Munguti, J. M., Manyala, J. O., & Kaunda-Arara, B. (2019). Predicting uptake of aquaculture technologies among smallholder fish farmers in Kenya. *Aquaculture International*, 27, 1689-1707.
- Rose, D. C., Sutherland, W. J., Parker, C., Lobley, M., Winter, M., Morris, C., ... Dicks, L. V. (2016). *Decision support tools for agriculture: Towards effective design and delivery*. *Agricultural Systems*, 149, 165–174
- Rübcke von Veltheim, F., Claussen, F., & Heise, H. (2020). Autonomous Field Robots in Agriculture: A Qualitative Analysis of User Acceptance According to Different Agricultural Machinery Companies.
- Salifu, I., Aheto, D. W., & Vondolia, G. K. (2024). Unraveling the Drivers of the Adoption of Improved Fish Smoking Technology Among Small-Scale Fisheries: A Case Study of the Ahotor oven in Ghana. *Food and Humanity*, 100266.
- Smidt, H. J., & Jokonya, O. (2022). Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa. *Information Technology for Development*, 28(3), 558-584.
- Suki, N. M., & Suki, N. M. (2017). Determining students' behavioural intention to use animation and storytelling applying the UTAUT model: The moderating roles of gender and experience level. *The International Journal of Management Education*, 15(3), 528-538.
- Tinh, L., Hung, P. T. M., Dzung, D. G., & Trinh, V. H. D. (2019). Determinants of farmers' intention of applying new technology in production: The case of vietgap standard adoption in Vietnam. *Asian Journal of Agriculture and Rural Development*, 9(2), 164-178.
- Ulhaq, I., Pham, N. T. A., Le, V., Pham, H. C., & Le, T. C. (2022). Factors influencing intention to adopt ICT among intensive shrimp farmers. *Aquaculture*, 547, 737407
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.
- Wang, J., Zhang, S., & Zhang, L. (2023). Intelligent hog farming adoption choices using the unified theory of acceptance and use of technology model: Perspectives from China's new agricultural managers. *Agriculture*, 13(11), 2067.

Strategic Analysis for Sustainable Chrysanthemum Production: A Case Study in Cianjur Regency, West Java

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Abstract

Indonesia possesses rich biodiversity, including a diverse range of ornamental plants. West Java Province, particularly Cianjur Regency, is a major center for chrysanthemum production. This study examines the business environment of the Sekar Gunung Gede Farmers Group in Cianjur Regency, West Java, specializing in chrysanthemum production. The research aims to analyze the company's profile, pinpoint business challenges and potential, and formulate effective business expansion strategies. Employing a mixed-methods approach, including descriptive analysis, SWOT analysis, and the Analytic Hierarchy Process (AHP), the study identifies key areas for improvement. The findings reveal that marketing, production, human resources, and financial aspects are the primary challenges faced by the business. SWOT and AHP analyses generate various business development strategies, with top priorities being greenhouse expansion (score: 0.31), production improvement (0.26), digital marketing (0.17), customer service enhancement (0.17), and value addition (0.08). Based on the analysis, the primary recommendation is to prioritize infrastructure expansion through the construction of new greenhouses. This strategy is expected to improve productivity and enhance the business's competitiveness.

Keywords: chrysanthemum, sustainable production, swot analysis, AHP, business development

JEL code: Q13, M21

SDG classification: SDG8, SDG 9, SDG 12

Introduction

Indonesia is a country with exceptionally high biodiversity, particularly in flora, which includes all types of plants on Earth, such as ornamental plants. West Java is one of the largest producers of ornamental plants in Indonesia, especially chrysanthemum flowers. Farmers choose to cultivate chrysanthemums due to increasing market demand, higher profitability compared to other ornamental crops, and a relatively short harvest period. Chrysanthemums also offer the advantage of adjustable harvest timing, allowing farmers to meet high demand during national and religious holidays, such as Independence Day, wedding seasons, and other celebrations (Hayati et al., 2018). This makes chrysanthemum cultivation a sustainable economic activity. Additionally, chrysanthemums are photoperiod-sensitive plants, meaning their growth and flowering phases depend on light availability, enabling year-round cultivation with controlled daylight exposure (Mufarrikha et al., 2014).

The growing demand for cut flowers, including chrysanthemums, has made them a promising agricultural commodity. The Sekar Gunung Gede Farmers' Group (KTSGG) in Cugenang District, Cianjur Regency, is a collective of farmers cultivating cut flowers, foliage plants, vegetables, and rice. Chrysanthemums are the group's primary commodity, particularly for its leader, Mr. Lasmo. Besides chrysanthemums, the group also grows pikok flowers and foliage plants such as philodendron, ruscus, and Song of India.

West Java is the third-largest producer of chrysanthemum flowers in Indonesia, with production reaching 100.22 million stems in 2021 and increasing to 145.24 million stems in 2022. Cianjur Regency is the largest chrysanthemum production hub in West Java. However, intense local competition has led KTSGG to expand its market beyond Cianjur, targeting regions like Yogyakarta, where prices are higher. According to data of Sekar Gunung Gede Farmers' Group, there is a supply-demand imbalance in chrysanthemum production. Monthly demand for cut chrysanthemums reaches 5,520 bundles, while supply is only 3,680 bundles, primarily due to land limitations.

The Analytical Hierarchy Process (AHP) method can serve as a tool for more objective and systematic decision-making. This study aims to analyze the factors influencing farmers' decision-making using AHP and provide recommendations to enhance their agricultural strategies. It identifies key criteria and sub-criteria affecting the group's decisions while offering insights for stakeholders.

This research will benefit the Gunung Gede Farmers' Group, local government, and other agricultural stakeholders. For farmers, the findings can guide better decision-making. For policymakers and academics, the study contributes to data-driven policy formulation and decision-making methods in agriculture. While previous studies have applied AHP in agricultural decision-making, few focus on farmers' groups in Gunung Gede, Cianjur. This research fills at gap, offering new insights into localized AHP applications.

The study's main contribution is providing an AHP-based decision-making model for farmers' groups while enriching literature on agricultural decision-making methods. It also enhances understanding of factors influencing successful farming strategies in Indonesia. The paper's structure begins with an introduction (background, objectives, and

benefits), followed by a literature review (AHP concepts and agricultural applications). The methodology section explains the research approach, while results and discussion present key findings and implications. Finally, the conclusion and recommendations summarize outcomes and suggest actionable steps for stakeholders.

Methodology

Data collection

This research employed two types of data collection: primary and secondary data (Smith & Johnson, 2020). Primary data were obtained from the results of an industrial internship at the Sekar Gunung Gede Farmer Group. Data were collected through interviews with the farmer group leader and workers, the distribution of questionnaires to respondents (Anderson, 2019), and direct observation of the conditions and activities in the field involved in business operations (Taylor et al., 2021). Secondary data were obtained from external sources, such as data from the Agricultural Extension Center (Balai Penyuluhan Pertanian - BPP), books (Davis, 2018; Thompson, 2020), and scientific literature from the internet related to agricultural business and farm management.

Analysis Methods

This research used three main analysis methods: descriptive analysis, SWOT analysis (Thompson, 2020), and the Analytical Hierarchy Process (AHP) (Saaty, 2008).

Descriptive analysis

Descriptive analysis was used to describe the conditions of the chrysanthemum farming business at the Sekar Gunung Gede Farmer Group based on the collected data. According to Sugiyono (2019), this method aims to describe data as it is without making generalizations to a wider population (Sugiyono, 2019).

SWOT analysis

SWOT analysis was used to evaluate the internal and external factors influencing the business of the Sekar Gunung Gede Farmer Group. The results of the SWOT analysis will be used to formulate business development strategies (Thompson, 2020).

Analytical Hierarchy Process (AHP)

AHP was used to determine the priority factors in making strategic business development decisions for the Sekar Gunung Gede Farmer Group (Miller & White, 2021). AHP works by comparing existing factors pairwise and assigning weights based on their level of importance (Saaty, 2008; Wilson & Brown, 2022). The main factors in the development of the chrysanthemum farming business will be ranked based on priority to assist the Sekar Gunung Gede Farmer Group in making the most effective strategic decisions.

Results and Discussion

Internal environment analysis

The Sekar Gunung Gede Farmer Group conducts its business activities by distributing cut flowers to various destinations, including flower shops such as Panah Merah in Yogyakarta, Cianjur Florist, and Patmarini Florist in Rawa Belong, West Jakarta. Additionally, cut flowers are also marketed to wedding organizers (WOs) in Cianjur and traditional flower markets, which then resell them to retailers and end consumers. This multi-channel distribution strategy allows the farmer group to reach diverse customer segments (Kotler & Armstrong, 2018). The marketing system within this farmer group involves implementing a direct promotion strategy through face-to-face interaction to reach potential customers more effectively, fostering personal relationships and trust, which can be particularly important in agricultural markets (Kotler & Keller, 2016). Furthermore, the utilization of Google My Business assists customers in accessing information about the products and services offered, enhancing online visibility and facilitating customer engagement in the digital age (Stokes, 2020).

Sekar Gunung Gede Farmer Group focuses on the cultivation process of cut flowers without having derivative or processed products. This specialization can lead to efficiency in production but may also limit diversification opportunities (Porter, 1985). The sales system is conducted on a B2B (business-to-business) basis according to customer demand, indicating a reactive production approach. The average production reaching 500 bunches of cut chrysanthemums per week suggests a moderate scale of operation. However, approximately 10% of the total cut flower production is not marketable, highlighting potential inefficiencies in the cultivation or post-harvest handling processes that could impact profitability (Titus et al., 2021). The cultivation process starts from land preparation to post-harvest, encompassing various stages such as mother plant production, seedling planting, fertilization, watering, lighting, cutting propagation, and intensive care to ensure the quality of the flowers produced. These detailed stages reflect the labor-intensive nature of floriculture (van der Ploeg, 2020).

Sekar Gunung Gede Farmer Group employs 9 workers who are responsible for the operational production of chrysanthemums. The size of the workforce is a key factor influencing production capacity and labor costs (Drucker, 1999). The wage payment system being carried out once a week in cash directly to the employees indicates a traditional approach to labor management. Meanwhile, in the financial aspect, the company's funding sources come from two main sources: internal and external. Internal funding is obtained from the sales of cut flowers, highlighting the reliance on operational revenue for sustainability. External funding comes from government assistance through the agricultural department, such as fertilizers, cultivators, and pesticides. Government support plays a crucial role in agricultural development, providing resources that can alleviate financial constraints and improve productivity (World Bank, 2019). The combination of these various internal factors, including distribution channels, production focus, workforce management, and funding sources, plays an important role in supporting the sustainability of the Sekar Gunung Gede Farmer Group's business in the cut flower industry. The identification of strengths and weaknesses of the farmer group's internal factors can be seen in Table 1.

Table 1. Matrix IFE (Internal Factor Evaluation)

Strength	Weakness
The chrysanthemums marketed are grade A. Certified seed production. Having regular customers. There is coaching for extension workers. There are online and social media platforms such as Google My Business and WhatsApp. There is an operational vehicle for product delivery. Various types of chrysanthemums follow market trends.	There is no marketing team. Chrysanthemum flower production cannot meet market demand. There are no promotional activities through social media other than WhatsApp. There are no derivative products. As a result, we are left with BS chrysanthemums (leftover goods) whose selling value has dropped by 50%, leading to a significant revenue loss. It's clear that implementing digital farming is a necessary change that we must consider for our future growth and success. Modernizing our financial records, moving from manual to digital, is crucial in our journey toward efficiency and growth.

External environment analysis

The external environment analysis of the Sekar Gunung Gede Farmer Group indicates that the ornamental plant industry has significant potential for development in Indonesia, especially with the government's support in accelerating floriculture export permits. Government policies promoting exports can significantly boost the growth of agricultural sectors (OECD, 2023). West Java, as one of the centers for chrysanthemum production, receives special attention through the Ornamental Plant Research Institute (Balai Penelitian Tanaman Hias - Balithi), which provides guidance to farmers.

Agricultural research and extension services play a vital role in enhancing the productivity and competitiveness of farmers. However, economic factors such as the impact of the COVID-19 pandemic and inflation due to the Russia-Ukraine war affect the availability of fertilizers and production costs. Global economic shocks can have cascading effects on agricultural input markets, leading to price volatility and supply chain disruptions (FAO, 2022). On the other hand, socio-cultural changes provide opportunities for the cut flower business, particularly due to the high demand from various traditional and religious events. Cultural traditions and social gatherings often drive the demand for specific agricultural products, including flowers (Hofstede, 2001). To increase production efficiency, technologies such as smart greenhouses and drip irrigation are beginning to be implemented to conserve resources and maintain flower quality. The adoption of advanced agricultural technologies is crucial for improving resource efficiency and sustainability in farming (Tilman et al., 2011).

In the industrial environment, the demand for chrysanthemums is higher than the supply, indicating a potential market gap and opportunity for expansion (Porter, 1980). However, challenges such as harvest delays and changing consumer taste trends increasingly complicate order fulfillment. Fluctuations in consumer preferences and operational

inefficiencies can pose significant challenges for agricultural businesses (Shepherd, 2013). The Sekar Gunung Gede Farmer Group faces competition from several other farmer groups in the surrounding area. Competitive rivalry within the agricultural sector can influence pricing and market share (Osterwalder & Pigneur, 2010). In addition, the presence of agricultural shops that provide fertilizers and pesticides is an important factor in maintaining production continuity, ensuring access to essential inputs for farming operations (Olson, 2007). Potential customers for ornamental flower farmers come from florists and wedding organizers in Jakarta and its surroundings, who require a large supply of high-quality flowers. These downstream industries represent significant market opportunities for flower producers (Gereffi et al., 2005). Although this industry has promising opportunities, barriers for new entrants are quite high, mainly due to limited investment and the technical knowledge required in ornamental plant cultivation. High entry barriers can protect existing players but may also hinder innovation and market dynamism. The identification of opportunities and threats from the farmer group's external factors can be seen in Table 2.

Table 2. Matrix EFE (External Factor Evaluation)

Opportunities	Threats
1. Assistance from the Ministry of Agriculture has been provided to build a greenhouse. 2. High market demand for chrysanthemums. 3. Increasingly sophisticated technology. 4. Information facilities are increasingly advanced. 5. Supportive geographical environment. 6. Regulation of the Minister of Agriculture No. 15/Permentan/HR.060/5/2017 concerning importing and exporting Horticultural Seeds. 7. Chrysanthemums are included in Balithi's priority commodity category for research.	1. The threat of HPT. 2. The threat of natural disasters. 3. The presence of competitors for chrysanthemums. 4. Consumer tastes tend to change. 5. Bad weather can disrupt the growth of chrysanthemums. 6. The inflation rate can affect fertilizer prices, causing uncertain fertilizer availability.

Alternative business development strategies

Alternative strategies were derived after identifying factors from the external and internal environments of the Sekar Gunung Gede Farmer Group. The SWOT analysis provides a framework for generating these strategies by matching internal strengths and weaknesses with external opportunities and threats.

A SO (Strength - Opportunity) business development strategy that can be implemented includes programs such as planning for the construction of new greenhouses. Greenhouses are very useful for protecting chrysanthemum plants from unfavorable environmental conditions such as sunlight, temperature, humidity, and others, thereby

enhancing yield and quality (Dorais, 2007). Investing in controlled environment agriculture like greenhouses aligns internal strengths (e.g., existing cultivation knowledge) with external opportunities (e.g., government support for floriculture and high demand).

A WO (Weakness - Opportunity) strategy involves increasing chrysanthemum flower production to meet consumer demand. Production is the process of transforming inputs into outputs and increasing it often requires addressing internal weaknesses (e.g., limited production capacity) to capitalize on external opportunities (e.g., unmet market demand) (Stevenson & Ozsomer, 2016). Programs that can be implemented to increase chrysanthemum flower production include analyzing factors that can increase production volume (e.g., optimizing planting density, nutrient management), utilizing technology in production activities (e.g., precision agriculture techniques, automated systems) (Gebbers & Adamchuk, 2010), and increasing revenue through the implementation of digital marketing. Digital marketing can help overcome weaknesses in market reach by leveraging online platforms to access broader customer bases and improve sales (Chaffey & Ellis-Chadwick, 2019).

Improving customer service is a ST (Strength – Threat) strategy development to create good relationships between sellers and buyers. Leveraging existing strengths (e.g., quality flowers) to mitigate external threats (e.g., increasing competition) through enhanced customer relationships can foster loyalty and provide a competitive edge (Morgan & Hunt, 1994; however, the relevance remains strong in contemporary marketing). Increasing the shelf life of chrysanthemums for a WT (Weakness – Threat) strategy can be done by drying the chrysanthemums through sun-drying, oven-drying, using silica powder, and so on, to add value to the product and address a weakness (perishability) in the face of external threats (e.g., market fluctuations, potential for unsold inventory) (Ali et al., 2018). Adding value through post-harvest processing can create new market opportunities and reduce losses. Table 3 shows alternative business development strategies for the farmer group.

Table 3 . Matrix SWOT

S-O Strategy	W-O Strategy
Addition of greenhouse	Increased production of chrysanthemums Increased income through the implementation of digital marketing
S-T Strategy	W-T Strategy
Improved customer service	Increased flower shelf life

Strategy prioritization

The prioritization of strategies in the business development of the Sekar Gunung Gede Farmer Group was carried out through a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, which generated various alternative strategies. The SWOT analysis is a widely used strategic planning tool that helps organizations identify internal and external factors relevant to their goals (Hill & Westbrook, 1997). These alternative strategies were then evaluated using the Analytical Hierarchy Process (AHP) method to determine the most optimal strategy based on three main criteria: profit, capital size, and risk. The AHP,

developed by Saaty (2008), is a structured technique for dealing with complex decisions by organizing and prioritizing factors, providing a framework for quantifying the relative importance of different criteria and alternatives. In the AHP process, profit reflects the positive impact obtained from the implemented strategy, capital size refers to the amount of investment required to execute the strategy, and risk describes the potential obstacles or challenges that may occur (Forman & Gass, 2001). The selected strategies are ranked based on the priority weights obtained by considering these three criteria. Based on the AHP calculations shown in Figure 1, the following results were obtained:

- a) The addition of a greenhouse obtained the highest score of 0.31, making it the top priority in the development strategy. This strategy is considered to provide significant benefits with increased production capacity, leading to higher potential profits, although it requires considerable capital investment (Joshi et al., 2015). The higher priority suggests that the perceived benefits in terms of profit outweigh the associated capital and risk compared to other strategies.
- b) Increasing production has a score of 0.26, indicating that efforts to improve yields are an important strategy for maintaining business sustainability and potentially increasing profitability (De Koeijer et al., 2015). While potentially less capital-intensive than building a new greenhouse, increasing production efficiently can directly impact the long-term viability of the farm.
- c) The implementation of digital marketing and improved customer service each obtained a score of 0.17, showing the importance of marketing strategies and service improvements to expand market reach and enhance customer loyalty, both of which contribute to profitability and reduce market-related risks (Bharadwaj et al., 2013; Kotler & Keller, 2016). These strategies often require moderate investment and carry manageable risks.
- d) Increasing the shelf life of flowers received the lowest score of 0.08, which means this strategy has a lower priority compared to other strategies. While reducing waste and potentially opening up new markets, the perceived benefits in terms of profit, considering the required investment and associated risks (e.g., technological feasibility, market acceptance of processed flowers), might be lower than other options in the short term (Ali et al., 2018).

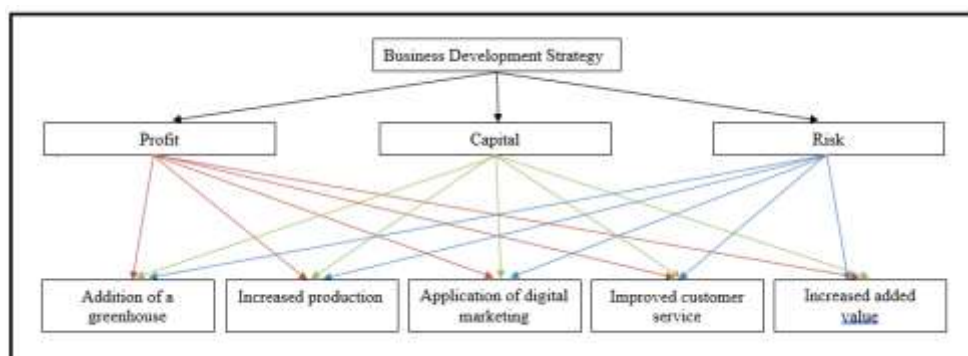


Figure 1. The Analytical Hierarchy Process (AHP) for chrysanthemum cultivation

These results indicate that the greenhouse addition strategy is the primary choice in the business development of the Sekar Gunung Gede Farmer Group. The expectation is that with the additional greenhouse, production can increase, the risk of losses due to weather

conditions can be minimized, and the continuously growing market demand can be met more optimally, ultimately leading to greater profitability and a stronger market position (van Ruijven et al., 2019).

Conclusion

This research aims to analyze the business development strategies of the Sekar Gunung Gede Farmer Group that influence the decision-making of the group, in order to develop their chrysanthemum cultivation business. The methods used include SWOT analysis and the Analytical Hierarchy Process (AHP). The imbalance between the supply and demand of chrysanthemums due to land limitations presents a challenge. This research seeks to provide recommendations for effective strategies to increase the production capacity and competitiveness of the farmer group.

Through the SWOT and AHP approaches, this study identifies various internal and external factors influencing the chrysanthemum business, and determines the priority of strategies based on three main criteria: profit, capital size, and risk. The analysis results indicate that the addition of a greenhouse is the main strategy with the highest score in the AHP, as it can increase production and reduce the risk of losses due to weather factors. Furthermore, the main recommendations of this research include increasing chrysanthemum production, implementing digital marketing, improving customer service, and increasing the shelf life of flowers to reduce waste and increase selling value. This research contributes to assisting the Sekar Gunung Gede Farmer Group in making more effective and data-driven decisions, as well as providing insights for stakeholders in the development of the agribusiness sector in Indonesia.

The formulation of alternative business development studies was carried out using the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis method and the AHP (Analytic Hierarchy Process) method. Based on the AHP calculations, the addition of a greenhouse scored 0.31; increased production 0.26; digital marketing 0.17; improved customer service 0.17; and increased added value 0.08. From these results, the main priority that can be undertaken by the Sekar Gunung Gede Farmer Group to develop its business is the addition of a greenhouse, which obtained the highest score of 0.31.

References

- Ali, A., Maqbool, M., Ramzan, M., Kwon, Y. S., & Shahzad, A. (2018). Postharvest handling and storage treatments to maintain the quality of cut flowers. *Journal of Postharvest Technology*, 6(1), 1-17.
- Anderson, L. (2019). Qualitative Research Methods in Agricultural Studies. *Journal of Farming Research*, 12(3), 45-62.
- Bharadwaj, S. G., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. *MIS Quarterly*, 37(2), 471-482.
- Chaffey, D., & Ellis-Chadwick, F. (2019). *Digital marketing: Strategy, implementation and practice* (7th ed.). Pearson Education.

- Davis, P. (2018). *Sustainable Farm Management Practices*. Agricultural Press.
- De Koeijer, T. J., Wossink, G. A. A., Struik, P. C., & экономика, A. (2015). The economics of yield gaps in food production: A review. *Agricultural Systems*, 136, 29-39.
- Dorais, M. (2007). Protected cultivation of high-value vegetables and ornamentals under cold climates. *Acta Horticulturae*, 761, 39-50.
- Drucker, P. F. (1999). *Management challenges for the 21st century*. HarperBusiness.
- Food and Agriculture Organization of the United Nations (FAO). (2022). The impact of the war in Ukraine on global food security and related matters under the mandate of the Food and Agriculture Organization of the United Nations. FAO.
- Forman, E. H., & Gass, S. I. (2001). The analytic hierarchy process—An exposition. *Operations Research*, 49(4), 469-486.
- Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and site-specific crop management. *Annual Review of Plant Biology*, 61, 255-271.
- Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy*, 12(1), 78-104.
- Hayati, N. Q., Nurmalingda, N., & Marwoto, B. (2018). Inovasi teknologi tanaman krisan yang dibutuhkan pelaku usaha [Innovative chrysanthemum cultivation technologies for agribusiness]. *Jurnal Hortikultura*, 28(1), 147-162.
- Hill, T., & Westbrook, R. (1997). SWOT analysis: It's more than just a list. *Long Range Planning*, 30(1), 46-52.
- Hofstede, G. (2001). *Culture's consequences: Comparing values, behaviors, institutions and organizations across nations* (2nd ed.). Sage Publications.
- Joshi, R., Adhikari, R., & Gautam, D. (2015). Economic analysis of greenhouse tomato production in Chitwan, Nepal. *Journal of Agricultural Economics and Development*, 4(1), 1-11.
- Kotler, P., & Armstrong, G. (2018). *Principles of marketing* (17th ed.). Pearson Education.
- Kotler, P., & Keller, K. L. (2016). *Marketing management* (15th ed.). Pearson Education.
- Miller, T., & White, S. (2021). Decision-Making Models for Smallholder Farmers. *Agribusiness Quarterly*, 8(2), 112-128.
- Mufarrikha, M., Herlina, N., & Widaryanto. (2014). Respon dua kultivar tanaman krisan (*Chrysanthemum morifolium*) pada berbagai lama penambahan cahaya buatan [Response of two chrysanthemum cultivars to varying artificial light exposure durations]. Universitas Brawijaya.
- OECD. (2023). *Agricultural policy monitoring and evaluation 2023: Addressing the challenges facing food systems*. OECD Publishing.
- Olson, M. (2007). *The logic of collective action: Public goods and the theory of groups*. Harvard University Press.
- Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: A handbook for visionaries, game changers, and challengers*. John Wiley & Sons.

- Porter, M. E. (1980). *Competitive strategy: Techniques for analyzing industries and competitors*. Free Press.
- Saaty, T.L. (2008). Decision Making with the Analytic Hierarchy Process. *International Journal of Services Sciences*, 1(1), 83-98.
- Shepherd, A. W. (2013). *Market information services: Theory and practice*. FAO Agricultural Services Bulletin No. 180.
- Smith, J., & Johnson, R. (2020). *Research Methods for Agricultural Development*. Springer.
- Stevenson, W. J., & Ozsomer, A. (2016). *Operations management (12th ed.)*. McGraw-Hill Education.
- Sugiyono. (2019). *Quantitative, Qualitative, and R&D Research Methods (2nd ed.)*. Alfabeta.
- Taylor, M., et al. (2021). Field Observation Techniques in Agricultural Research. *Farming Systems Journal*, 15(4), 201-215.
- Thompson, K. (2020). *Strategic Planning for Agricultural Businesses*. Rural Development Press.
- Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*, 108(50).
- Van Ruijven, B. J., Blok, K., & van Vuuren, D. P. (2019). Long-term global energy and climate scenarios: What are the driving factors and how do they compare?. *Energy Policy*, 132, 1059-1073.
- Wilson, E., & Brown, C. (2022). Analytical Approaches in Agricultural Research. *Journal of Agribusiness*, 10(1), 33-47.

Constraints and Opportunities for Agricultural Climate Resilience through Local Technical Agroclimatic Committee Approach

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Abstract

Each year hundreds of billions of dollars' worth of crops and livestock production are lost due to disaster events, and farmers are the front lines of loss and damage associated with climate change. With limited access to agroclimatic information undermines farmers' ability to make informed decisions, manage risks, and optimize their agricultural practices, ultimately affecting their productivity, income, and resilience to climate variability. Farmers need to know which crops are likely to do well and how to manage them on their farm at a specific moment in time. The conundrum has always been that farmers traditionally do not know, before they plant a given crop, the climatic or weather conditions that it will be subject to. Currently, climate science has advanced markedly over the past two decades, with international coordination and collaboration, and it is now possible to predict both short-term weather and longer-term climate patterns at specific sites with a certain degree of confidence. The local technical agroclimatic committee (LTAC) is based on the principle that relevant stakeholders involved in the development, translation, dissemination, and application of climate services work together to produce and distribute agroclimatic bulletins in both printed and digital formats for farmers. Although LTAC has been implemented in Cambodia since 2019, the country remains in the nascent stages of acceptance, both among farmers and within the LTAC members, who have only recently developed their capacity. Because of the need for an agroclimatic bulletin, the LTAC has numerous opportunities, including increased awareness of the importance of climate information in rice cultivation, basic digital literacy, LTAC members' ability to continue, increased stakeholder interest in the agroclimatic bulletin and LTAC services, and interest from the private sector to collaborate. Despite the opportunities, numerous constraints must be addressed, including the absence of precise ground-level climate data, insufficient interactive communication for advisory services, time limitations for the distribution of agroclimatic bulletins, time restrictions for co-creation based on human-centered design, and the exclusion of LTAC institutions from the official government policy agenda.

Keywords: LTAC, agricultural advisory services, constraints, opportunities, rice

JEL code: D19, O13, O18

SDG classification: SDG 1, SDG 2

Introduction

Each year hundreds of billions of dollars' worth of crops and livestock production is lost due to disaster events, and farmers are the front lines of loss and damage associated with climate change (FAO, 2023). The world's smallholder farmers produce around a third of the world's food (FAO, 2021). Despite of smallholder farmers often find themselves ensnared in a recurring cycle of low productivity, grappling with constraints related to agricultural product market issues, including challenges in accessing information services, technologies, and financial services (Fan & Rue, 2020; Meemken & Bellemare, 2020). With limited access to agroclimatic information undermines farmers' ability to make informed decisions, manage risks, and optimize their agricultural practices, ultimately affecting their productivity, income, and resilience to climate variability (Mapiye et al., 2021). Farmers need to know which crops are likely to do well and how to manage them on their farm at a specific moment in time. The conundrum has always been that farmers traditionally do not know, before they plant a given crop, the climatic or weather conditions that it will be subject to (Loboguerrero et al., 2018). Traditional agricultural advisory and extension services face limitations stemming from a limited of extension personnel, expertise, outdated climate information, inaccurate planting and harvesting dates, pest and disease management, irrigation management, and inadequate information storage (Mukherjee & Maity, 2015). Conventional agricultural advisory and extension have also not equally benefited female and male farmers due to differences in the control of production resources and participation in training programs (Kansiime et al., 2022).

Currently, climate science has advanced markedly over the past two decades, with international coordination and collaboration, and it is now possible to predict both short-term weather and longer-term climate patterns at specific sites with a certain degree of confidence (Stocker et al., 2013). With climate and weather analyses, crop models have improved to the point that a realistic prediction of crop performance under a range of climate conditions and management is possible (Timlin et al., 2024). It is now possible to combine weather and climate prognosis with crop models and farmers' knowledge so that farmers can evaluate cropping options considering likely weather and climatic conditions; therefore, CGIAR promoted a system of local technical agro-climatic committees (LTACs) for farmers to be informed about the expected climatic variations on their specific location. LTAC also open dialogues between farmers and stakeholder about seasonal climate forecast at multiple timescales, their effects on crops, mitigation strategies to reduce potential crop losses, and agronomic recommendations to farmers (CIAT). Since 2019, Cambodia had piloted the DeRISK project in regarding LTAC, which led by the International Institute of Rural Reconstruction (IIRR) with technical support from the Alliance of Biodiversity International and CIAT, working closely with the department of agricultural land resource management (DALRM) at Ministry of Agriculture, Forestry and Fisheries, RIMES, and PDAPP of Battambang and Kampong Speu provinces. DeRIKS project implemented LTAC for two years, during the rainy season of 2021 (June – November) and the rainy season of 2022 (June – November). The approach was centered around the co-development of agroclimatic advisory by the members of the LTAC committee for rice and cassava farmers in Battambang and Kampong Speu based on the seasonal climate forecast.

Nevertheless, both printed LTAC bulletin and digital dissemination are struggle with user engagement, resulting in the slow adoption of digital advisory services in recent years, according to the study of User Need Assessment and Giles et al. (2023). Furthermore, agroclimatic advisory have not been widely embraced by small farmers due to limited access and adoption of new techniques and technologies (Ayim et al., 2022). Infrastructure shortcomings, ICT knowledge gaps, **and especially financial constraints hinder adoption, leading to slow productivity growth**. There are many sources of financial viability for agroclimatic advisory services such as public funding, public-private partnership (PPP), international aid from development program, private sector investment, membership or services fees from farmer cooperative and association, loan, and bundle financing. Climate variability and extreme events are escalating, complicating farmers' ability to adjust and predict, resulting in losses and diminished output and income, while impacting broader value chains. Cambodia possesses a public climate information system; nevertheless, it solely offers daily weather forecasts. Long-term projections are either lacking or very vague to be useful for agricultural decision-making. CIAT, with the assistance of IIRR and in partnership with DOM/DALRM, commenced the LTAC methodology for delivering agricultural guidance informed by seasonal forecasts. The LTAC strategy is founded on the premise that pertinent stakeholders engaged in the creation, translation, distribution, and utilisation of climate services collaborate to create and distribute agroclimatic bulletins for farmers. This was executed for two years in Kampong Speu and Battambang under DERISK and subsequently piloted in Takeo and Prey Veng under AMD during the 2023 and 2024 seasons. This study aims to assess the experiences of key stakeholders and their perceptions of the constraints and opportunities for sustainable implementation.

This study aims to identify the financing options for investment in LTAC either printing or digital platform to enhance the agroclimatic information to increase productivity and avoid damage of the rice crop. This study focusses on rice. This study tries to address the following research questions.

- What is the relevance, utility, and effectiveness as perceived by various stakeholders?
- What advantages and disadvantages do various stakeholders perceive regarding the LTAC strategy, and what enhancements would they suggest?
- How would LTAC be improved to increase adoption?

Methodology

This study used qualitative approach to capture the complexity of stakeholders' perspectives, agroclimatic information users' experiences, users' preference of information sources, and detailed insights into the underlying motivation and subjective norms of accessing the agroclimatic advisory information. This research used the subsequent methods for data collection.

Literature and secondary data review

This study collected various secondary data from national budgeting policies, official reports issued by the government, agroclimatic services and extension service programs operating in Cambodia, consultancy reports, information found on web pages and official social media pages, as well as current agricultural applications. We synthesized the

information to compile a comprehensive list of all existing agroclimatic services and their tools for farmers' use. We focused on the LTAC approach and the climate service ecosystem with following points.

Key-informants interviewed

To gain insight into how the development agroclimatic advisory are being operated in Cambodia, several key informants at Battambang and Prey Veng were interviewed. The interviews involved various stakeholders at provincial level as follows. Provincial department of agriculture, forestry and fisheries and Provincial Department of Water Resources and Meteorology, representative of agricultural cooperatives, agricultural district officers, commune extension workers, and commune councils from.

This study selected the LTAC users for building for their experience on relevance and usefulness. We interviewed at least 4 to 6 farmers at Battambang and Prey Veng to capture the background story (a brief narrative context about persona's life and circumstances), demographic information, behaviour actions (interest, experience of using LTAC, what drives that persona to use the LTAC), motivation goals (objectives that persona wants to achieve, preferred channels that person want to communicate or engage), and pain points (challenges or frustrations).

Focus group discussion with LTAC members

Two focus group discussions were conducted to understand the complex systems of developing LTAC and agroclimatic advisory services in Cambodia. The focus group discussions aim to understand the complex interactions between climate risks, agricultural practices, and socio-economic factors, especially users' preference to use the agroclimatic advisory services. The focus group discussion was tried to understand the process of LTAC committees for providing the agro-climatic advisory to farmers in related to resources used, coordination, technical information, and approach for creating, validating, and scaling the services.

One FGD were done in Battambang, and another were in in Prey Veng. LTAC committees including PDAFF, PDoWRAM, agricultural district office, commune council, cooperatives and lead farmers to participate were invited to join discussion. Open-ended questions were used for discussion around the topics of: What are the problems of rice farmers in related to agro-climatic information and decision making in rice cultivation? What are the solutions from LTAC committees? How were bulletin tested for farmers' use? How to build farmers' trust in advisory services? Would LTAC approach be continued? How can you scale up the use of agro-climatic advisory services? What resources are needed to sustain the LTAC? And how could that be mobilized? The narrative was synthesised as the user's path from discovery, initial access, utilisation, modification, and feedback.

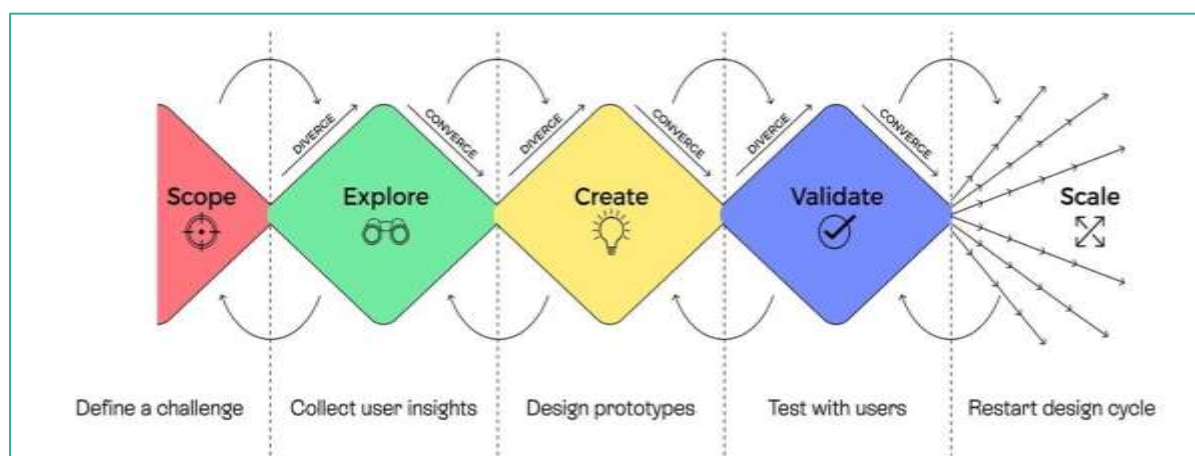


Figure 1. Human-centred designed framework

Focus group discussions with LTAC users/farmers

This focus group discussion tried to understand the underlying factors, users' preferences, and users' need that ensure the user-centred and adaptable. Two focus group discussions with LTAC users were conducted. One FGD was done in Battambang, and another at in Prey Veng. The participants were around 15 to 20 farmers per FGD. Two sub-groups (one group for male and another for female) were done in order to capture the perspective from both male and female. Open-ended questions were for discussion around the topics of behaviour actions (interest, experience of using LTAC, what drives to use the LTAC), motivation goals (objectives that users want to achieve, preferred channels that users want to communicate or engage), and good and bad experience of using agroclimatic bulletin and related services from LTA.

Group technical meetings with experts

Technical meeting with experts from relevant stakeholders were conducted with 23 experts from difference institutions including, MAFF-DALRM, MAFF-MDS, MAFF-DAPIC, MAFF-DRC, MAFF-DEAFF, Forestry administration, MAFF-GDA, IIRR, CambodHRRRA, ASPIRE-AT, Techo-Startup, Greenovator. The discussions were related to the topic of who should manage the LTAC? Who should participate in the co-creation of agroclimatic bulletins? Who should interpret the agroclimatic bulletin? What is the appropriate method for disseminating the agroclimatic bulletin? What are the barriers and risks associate with LTAC? What are opportunities associated with LTAC?

Consultative workshop with relevant stakeholders

Consultative workshop was conducted the national level. The workshop was collaborated between IIRR and Royal University of Phnom Penh with 46 participants from the national government, development partners/NGOs, academics, private sectors, and extension workers. The participants were from MAFF, PDAFF-Prey Veng, PDAFF-Kampong Spue, PDAFF-Battambang, PDAFF-Takeo, PDAFF-Kandal, PDAFF-Kampong Chhnang, PDAFF-Kampong Thom, Forestry Administration, Tonle Sap Application Operator, Royal University of Agriculture, CESAIN-RUA, CambodHRRRA, FNN, Fishery Administration, and Royal University of Phnom Penh.

Results and Discussion

General landscape of LTAC approach and climate services ecosystems in Cambodia

Agriculture is a risky undertaking, as farmers often encounter volatile markets, uneven yields, substantial political, social, or economic disruptions, and most severely, the impacts of climate change (Fan & Rue, 2020). Farmers frequently lack access to the knowledge and advice necessary for making the most appropriate choices and managing these risks (Thi Hoa Sen et al., 2024). Concerning the key consideration of climate, farmers frequently possess limited access to meteorological and climatic data (Giles et al., 2024). When they do, they frequently struggle with how to interpret information and utilise data to enhance on-farm decision-making (Whitton & Carmichael, 2024).

To enable farmers access to climate projection information and advice on good agricultural practices under various climate events and stages of production cycles, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), led by the Alliance Bioversity & CIAT, developed Local Technical Agroclimatic Committees (LTACs) (Alliance Bioversity & CIAT). LTAC are an innovative way for local stakeholders to learn about expected to climatic changes in their area and how they may affect their crops. The LTAC approach facilitates open and inclusive discussions regarding seasonal climate forecasts at various timescales, their effects on crops, mitigation techniques to mitigate prospective crop losses, and agronomic recommendations to farmers. LTAC facilitates discusses among stakeholders about the management of local agroclimatic information in order to find best practices for climatic adaptation, which are subsequently shared with other local technicians and farmers via a local Agroclimatic Bulletin. This newsletter summarises the committee's seasonal and climate projections, as well as recommendations for climate-smart actions for each crop type (Diana et al., 2021).

Since 2019, Cambodia has piloted the DeRISK project concerning LTAC, led by the International Institute of Rural Reconstruction (IIRR) with technical assistance from the Alliance of Biodiversity International and CIAT, in collaboration with the Department of Agricultural Land Resource Management (DALRM) at the Ministry of Agriculture, Forestry and Fisheries, RIMES, and PDAPP of Battambang and Kampong Speu provinces. The DeRISK initiative executed LTAC for two years, specifically during the rainy seasons of 2021 (June – November) and 2022 (June – November), concentrating on rice and cassava (Yim et al., 2022). Since early 2023, IIRR has been implementing LTAC in two additional provinces, Prey Veng and Takeo, under the AMD project, concentrating exclusively on rice cultivation due to time constraints. This article presents an overview of LTAC implementation and its structure, based on two LTAC experiences.

Overview of LTAC implementation in Cambodia

LTAC in Cambodia has implemented by follow the general guideline and manual of global LTAC global (Diana et al., 2021). Instead of eight steps in global LTAC activities diagram designed by Climate Change Agriculture and Food Security (CCAFS-CGIAR), Cambodia modified into 5 steps, but keeping almost the same implementation activities, as seen in Figure below.

The main LTAC implementation steps in Cambodia are follows:

- Step 1: Establishment of LTAC at targeted areas
 - Under the guidance of the regional office of CIAT, IIRR coordinated with GDA-MAFF and DOM-MOWRAM to designate the focus point from each targeted PDAFF (Battambang, Kampong Spue, Prey Veng, and Takeo). This approach required time for IIRR, GDA-MAFF, and PDAFF to fully comprehend the goal, procedure, and resources necessary for LTAC. Battambang and Kampong Spue were the first provinces to implement LTAC in Cambodia, presenting a significant challenge for PDAFF, IIRR, and GDA-MAFF to comprehend and prepare for participation.
 - Before to the official consultation aimed at establishing a shared understanding of the objectives, plans, and roles for the co-development and dissemination of agroclimatic bulletins for farmers, many preliminary meetings were held to identify the appropriate focal person and expert from relevant institutions.
 - The formal consultative workshop was held in plenary sessions and breakout technical working group talks to encourage involvement from all participants.
 - In the plenary session, IIRR presented the whole LTAC system and gathered participants' perceptions and previous experiences. The expert from DOM-MOWRAM also emphasised the necessity of both short-term and long-term climatology, which is crucial for decision-making in crop cycles.
 - During the breakout session, members in the small group discussed on interpreting climate information and its use in accordance with the crop calendar. The participant also addressed the specific duties of the LTAC member and their strategies for disseminating this information to farmers.
- Step 2: Creating agroclimatic bulletin
 - Following the familiarisation of LTAC members with one another and their understanding of climate data and the rice crop calendar, IIRR and GDA-MAFF convened technical workshops to co-creating the agroclimatic bulletin. Members of the LTAC in each province, along with representatives from district agricultural offices and agricultural cooperatives, were requested to offer comments and suggestions in light of varying climatic conditions (wetter, normal, drier).
 - LTAC members evaluate the climate data during a three-month period and deliberate on the rice crop decision trees, taking into account three climatic scenarios: wetter, normal, and drier. The crop decision trees were developed in advance by IIRR prior to the official gathering of LTAC members. Crop decision trees were advised for each stage of crop production, including variety selection, land preparation, transplanting,

irrigation, nutrient management, weed control, harvesting, and pest and disease management. The crop choice tree table was meticulously developed based on the insights and recommendations of the local agricultural officer and representatives of the agricultural cooperative.

- LTAC members also offer feedback on the design of the Agroclimatic bulletin, delineate the responsibilities of each member, and establish a dissemination schedule prior to distribution to farmers. In Battambang and Kampong Speu, the LTAC member also deliberated on the design for the SESAME application, but Prey Veng and Takeo concentrated solely on the printed agroclimatic bulletin.
- Step 3: Dissemination of agroclimatic bulletin
 - The dissemination event took place at the commune council office, before to the rice crop production season.
 - During the dissemination event, farmers received training on how to understand the agroclimatic bulletin and who to contact for additional clarity. During the training session, the trainer from IIRR and PDAFF also showed farmers how to utilise the SESAME program and read it through the Telegram channel for the case of Battambang and Kampong Speu.
 - The dissemination event was limited to a single morning or afternoon session, so farmers were unable to ask detailed questions. However, IIRR and PDAFF provided contact information for agricultural district officers or PDAFF in each province.
- Step 4: Promoting the application of agroclimatic advisories
 - IIRR collaborated with district-level agricultural officers and cooperative leaders to promote the use of agroclimatic bulletins to manage CDT-related climate challenges and increase rice productivity.
- Step 5: Monitoring and evaluation for improvement of results and process
 - IIRR worked with PDAFF to undertake fieldwork to assess how farmers used the agroclimatic bulletin. During the fieldwork, the team gathered user feedback to help enhance the next cycle of the agroclimatic bulletin.

Time is the primary barrier for completing these stages, particularly in the first year. Battambang and Kampong Spue can better support the LTAC method due to their prior experience; nevertheless, Prey Veng and Takeo continue to confront obstacles because this is their first year of implementation. Thus, LTAC takes at least two to three cycles to efficiently coordinate production, diffusion, advisement, and revision in response to user feedback.



Figure 2. Activities diagram of LTAC implementation in Cambodia – experienced from DeRISK at Battambang and Kampong Spue and from AMD at Prey Veng and Takeo

Contribution of government and other stakeholders in LTAC and related climate services ecosystem

LTAC has likely contributed as the demonstration project for agricultural climate advisory services via local committees organised by the DeRISK project in Battambang and Kampong Spue, as well as AMD in Prey Veng and Takeo provinces, rather than through an official government mandate. LTAC has emerged as the new approach to Cambodia, whether at the national or provincial level. Nonetheless, IIRR plays a vital role in coordinating the workflow with GDA-MAFF and DOM-MoWRAM to establish LTAC and complete all necessary procedures. Although all financial support came from either DeRISK or AMD, the government at the national, provincial, and local levels has significantly contributed to the following activities.

1) Technical support

DOM-MoWRAM played an important part in offering technical assistance on interpreting short-term and long-term climatic data. The GDA-MAFF, specifically the Department of Agricultural Land Resources Management (DALRM), offered technical solutions in response to wetter, normal, and drier climatic conditions.

- The PDAFF and agriculture district officers from designated provinces collaborate with pertinent officials to deliver technical solutions for all stages of rice cultivation across differing scenarios of wet, normal, and dry conditions.

2) Data support

- DOM-MoWRAM and PDoWRAM exchange temperature data for validation during the consultation meeting in step 2 of LTAC.
- PDAFF offered comprehensive agricultural data pertaining to rice cropping cycles, total harvested areas, methodologies employed in rice cropping systems, and inputs utilised in these systems.

3) Coordination and communication from national to provincial and district agriculture unit

- The PDAFF in designated provinces plays a crucial role in coordinating among its experts, agricultural district officers, and local authorities at both district and commune levels.
- The PDAFF has also organised all arrangements for steps 2 and 3 in the LTAC and collaborated with IIRR to conduct fieldwork that incorporates user feedback from step 5.
- The PDAFF serves as the primary contact for users seeking advice or clarification regarding the agroclimatic bulletin.

4) Venue and logistic support

- PDAFF consistently supplied office space and meeting venues for LTAC meetings
- PDAFF and agricultural district offices also facilitated the transportation of the agroclimatic bulletin for user dissemination.
- PDAFF collaborated closely with agricultural cooperatives to identify public locations for displaying the AO-sized agroclimatic bulletin.

Relevance, usefulness and effectiveness of LTAC in Cambodia

We conducted the focus group discussions with farmers and the in-dept interviewed with users to understand the relevance, usefulness, and effectiveness of agroclimatic bulletins. Exploring user perceptions of effectiveness ascertains whether the utilisation of these bulletins results in concrete advantages, like enhanced crop yields, diminished losses, and heightened resilience to climate disturbances. This work is crucial for enhancing the design and distribution of agroclimatic information, ensuring its accessibility, applicability, and effectiveness, thus fostering climate resilience in rice cultivation.

Perception of users on the relevance of agroclimatic bulletin and services provided by LTAC

The relevance of agroclimatic bulletins is the ability to deliver essential climate data tailored for cultivation of rice. Rice is the sensitivity crop to meteorological conditions, so it is needed the accurate data on precipitation, temperature, and humidity for maximum growth and production. This section illustrates farmers' perceptions of relevance upon receiving the agroclimatic bulletin and associated services, including brief training and instruction on its utilisation.

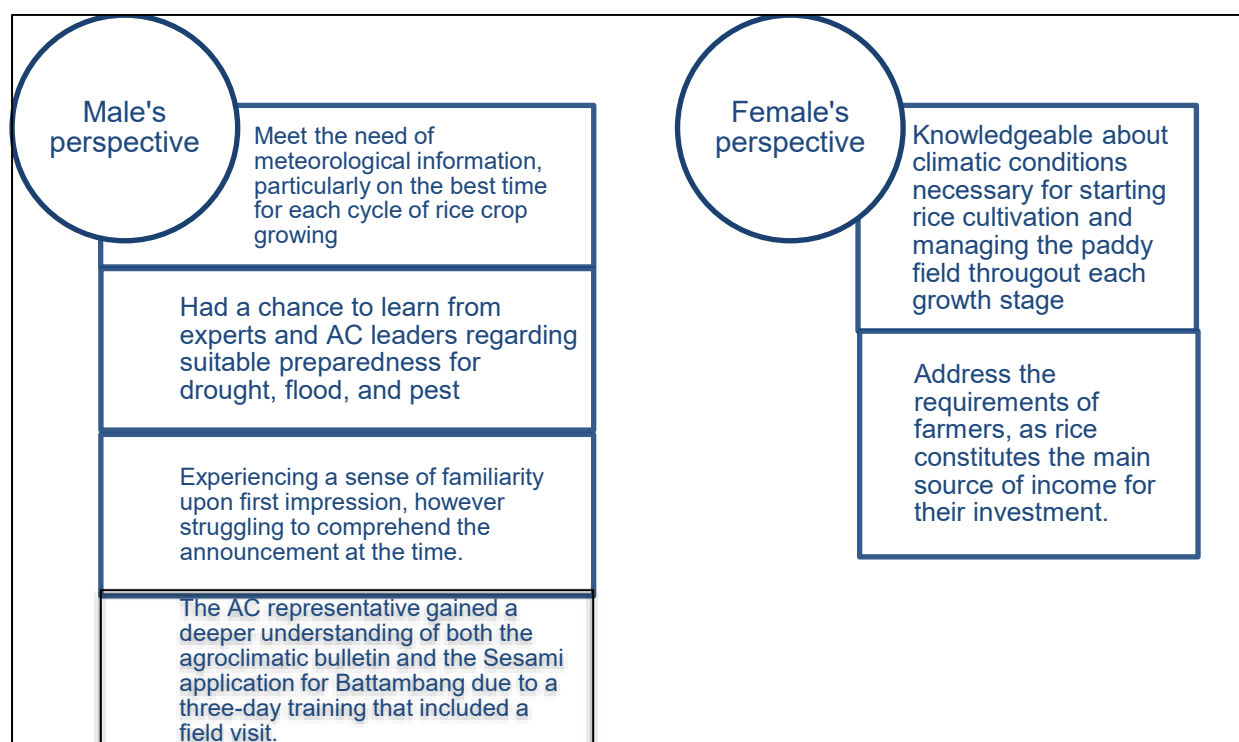


Figure 3. Perceived relevance of agroclimatic bulletin and services from LTAC

Based on focus group discussions with agroclimatic bulletin users in Battambang and Prey Veng, we could synthesise the male group's perspective on the relevance of the agroclimatic bulletin and services provided by LTAC as follows:

- The agroclimatic bulletin, featuring services offered by LTAC, is highly relevant to their requirements, particularly the meteorological data, as it enables them to figure out the best time for starting rice cultivation in each cycle, whether it be two or three cycles annually.
- Male users also experienced a sense of familiarity upon the first dissemination event provided by PDAFF, agricultural district officer, and IIRR. The first impression during received the agroclimatic bulletin, male users recognized it is relevance due to it contains the climate information and detail instruction to deal with difference climate condition and climate events such as drought, flood, and pest.

- Had a chance to learn from each other and expert from PDAFF and AC leaders during the training and dissemination agroclimatic bulletin event
- Specifically, to AC leader or representative (not all AC members) had a chance to learn more deeper through several training and field visit on how to design the agroclimatic bulletin, how to use it either in printing version or through SESAMI application.

It seems not notably difference for female users, but they specific on how they feel relevance to their need as follows.

- Can understand how to read climate information in order to apply for their rice cultivation
- Aware of the appropriate strategies to address the possible climate problems that may affect to their rice in order to avoid the loss of their main investment and income sources.

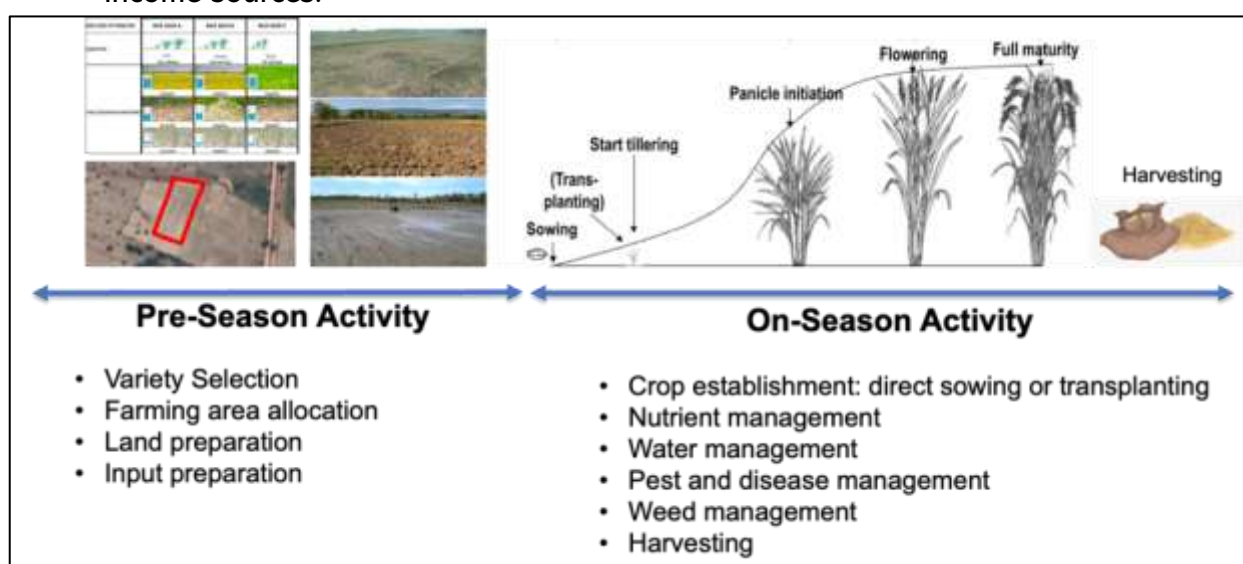


Photo 1. Decision making in rice cultivation concerning pre-season and on-season activities

Perceived usefulness from agroclimatic bulletin users

Understanding the usefulness of agroclimatic bulletins is crucial for making sure that this bulletin adequately assist farmers in confronting climate-related problems. The utility of agroclimatic bulletins encompasses design, content, visual presentation, dissemination methods, and explanatory processes. This insight helps in recognising gaps in content, accessibility, or dissemination strategies that could constrain their effectiveness. The agroclimatic bulletin is essential in assessing the impact of these techniques on enhancing agricultural productivity, resource efficiency, and climate resilience. Ultimately, recognising their use is essential for enhancing their design and facilitating their adoption. The usefulness from using agroclimatic bulletin and related services provided by LTAC are described due to the information from focus group discussions and in-dept interviews with users.

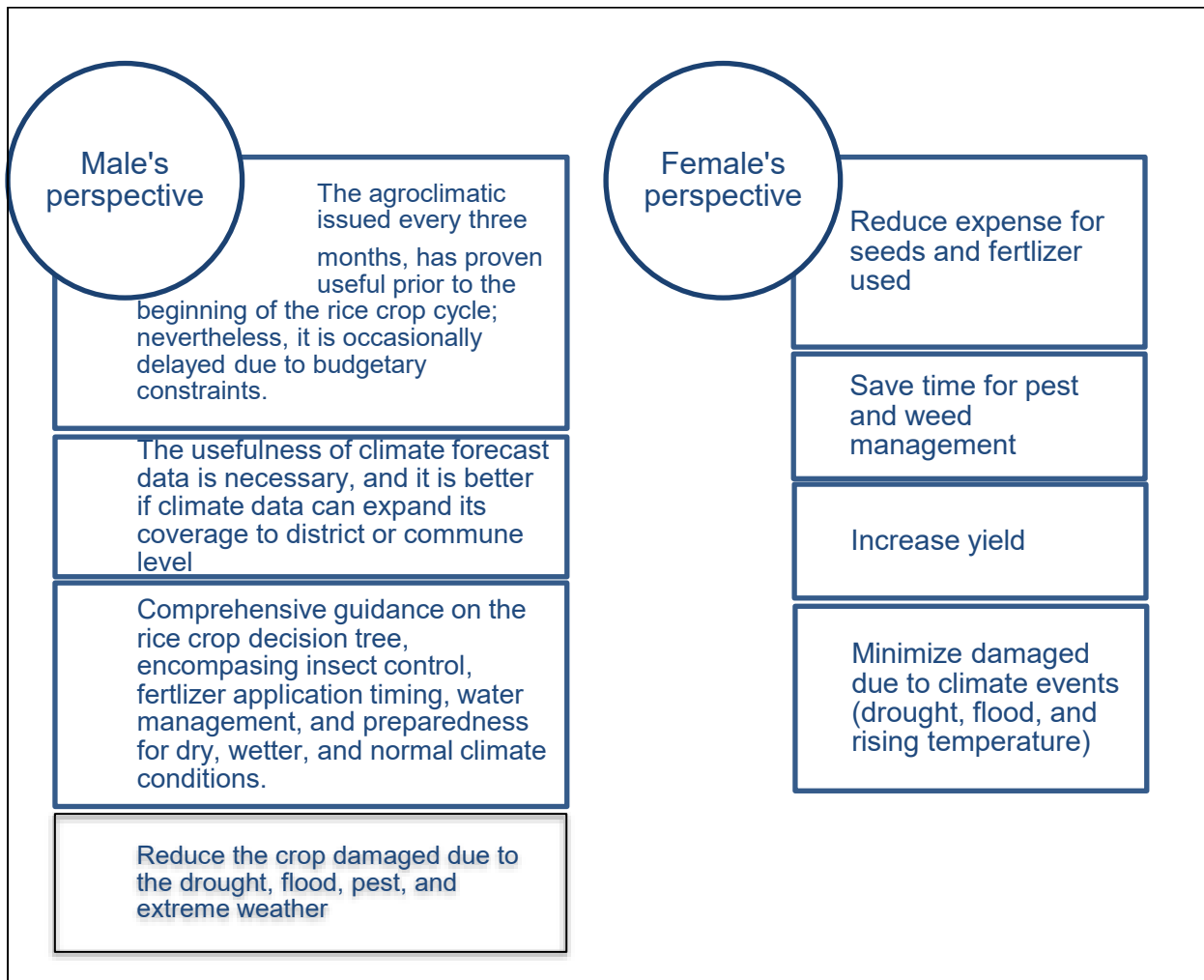


Figure 4. Perceived usefulness of agroclimatic bulletin and services from LTAC

We tried to check whether the perceived usefulness from agroclimatic bulletin is difference between male and female users. As seen in Figure below, the male users appreciated the agroclimatic bulletin in following usefulness. The updated of agroclimatic bulletin in every three months is very useful for farmers to follow the change of climate conditions. It enhances the capacity of preparedness and adaptive strategies to climate change and improve rice productivity. This regularly updated also provide a platform for communication between rice farmers and experts to discuss the general climate and technology issues and strategies for improving technology for effective climate adaptation. Agroclimatic bulletins frequently provide guidance on insect and weed problems that may arise after intense occurrences, assisting women in addressing these challenges promptly. By integrating this information with their understanding of local conditions, women may implement tailored strategies to protect their crops, such as adjusting planting schedules, providing protective treatments, or temporarily suspending specific activities to minimise losses. Male users also recognised the utility of agroclimatic bulletins via rice crop decision trees across various climatic scenarios. Farmers can acquire knowledge on implementing practices such as land preparation, pest

management, fertiliser application, water management, and optimal timing for cultivation, regardless of whether they encounter dry, wet, or normal conditions, as seen in Figure 3 below.

Farmers, utilising suitable procedures, acknowledged the advantages of adopting methods from agroclimatic bulletins and advisory services provided by LTAC, particularly in considerably reducing crop loss caused by pests, excessive water, or drought. The female group users refer usefulness of accessing agroclimatic bulletin to economic value as they mostly appreciated on the following effectiveness. Female group recognized that when the follow the guideline of growing rice in each stage mentioned in agroclimatic bulletin they can reduced significantly the expense for seeds during broadcasting stages. They also know how to apply fertilizer with proper amount during land preparation and growing stages of the rice. Agroclimatic bulletins are essential for optimising time for women involved in rice production by delivering timely and accurate meteorological and climate data, together with recommendations on variety selection, water management, and pest and weed control.

Women, frequently managing numerous obligations both on and off the farm, derive advantages from these bulletins as they facilitate decision-making processes, including the identification of optimal timings for planting, irrigation, pest management, and weed control. Agroclimatic bulletins empower women by mitigating traditional activities and uncertainties linked to uncertainty weather conditions. This not only increases production in rice cultivation but also empowers women by enabling them to manage their time more efficiently. Agroclimatic bulletins frequently provide guidance on insect and weed problems that may arise after intense occurrences, assisting women in addressing these challenges promptly. By integrating this information with their understanding of local conditions, women may implement tailored strategies to protect their crops, such as adjusting planting schedules, providing protective treatments, or suspending specific activities to minimise losses.

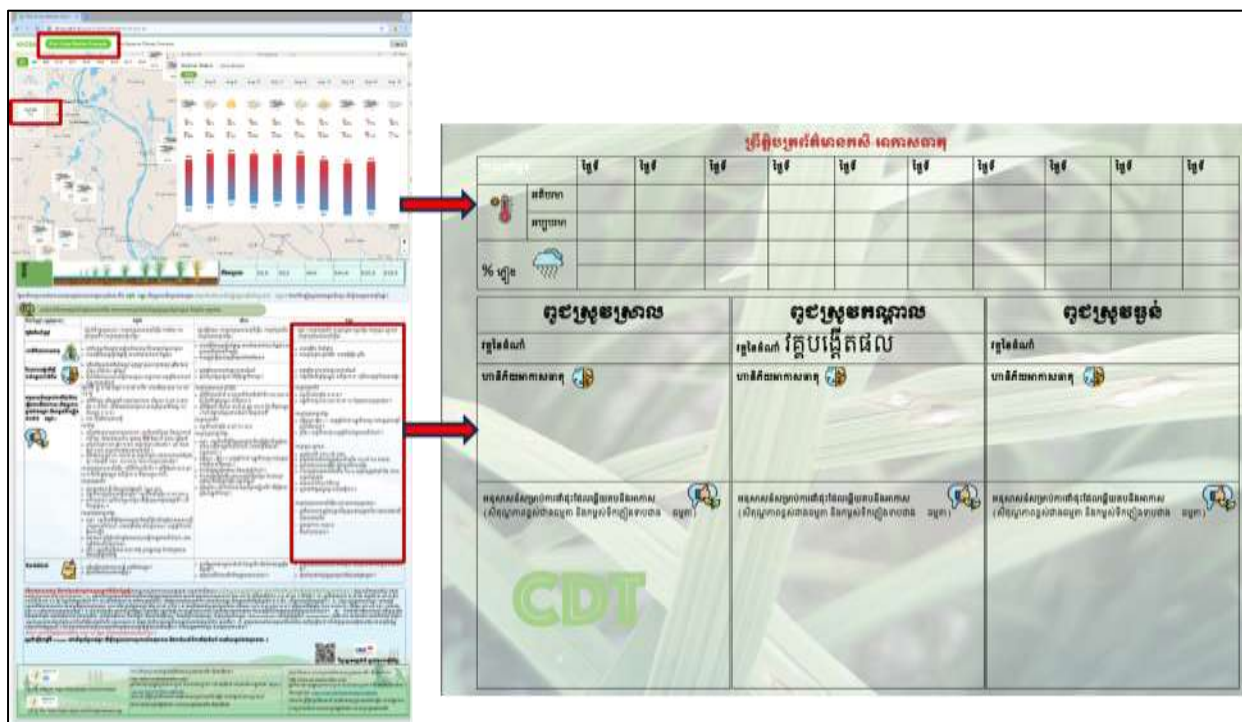


Photo 2. Detailed instruction for rice (short-term, medium-term, and long-term variety) based on climate conditions

Good and limitations user experience with agroclimatic bulletin

Gathering positive and negative feedback from users of agroclimatic bulletins is essential for human-centered design to enhance relevance, utility, and efficacy. User feedback offers critical insights into the practical application of bulletins in agricultural settings and underscores the difficulties farmers encounter in obtaining or comprehending the information. The user feedback allows the next LTAC to improve the bulletins to better serve farmers' needs, ensuring they are accessible, actionable, and tailored to specific rice producing conditions.

Numerous positive experiences have been reported by users regarding the use of agroclimatic bulletins as follows. The printed edition of the agroclimatic bulletin is available in two sizes. A0 paper for public display and A3 size for delivery to individual farmers. The printed agroclimatic bulletin is of high-quality due to its durability, clarity, and ease of preservation. High-quality printing in A3 size ensures that the material, including text, charts, and stays clear. Users of agroclimatic bulletins have indicated that these printed versions offer exceptional guidance for rice cultivation at all stages, making them a vital source for enhance rice productivity. These bulletins provide explicit, step-by-step recommendations on vital activities including land preparation, seed selection, planting, irrigation, pest management, weed control, and harvesting.

The bulletins assist farmers in optimising their methods for optimal productivity by aligning recommendations with particular meteorological conditions and stages of crop development. This extensive support enables users to adapt their methods to changing

weather circumstances while keeping high standards of crop management over the growing season. Users used agroclimatic bulletins as they provide detailed instructions to address various weather situations.

These bulletins include meteorological forecasts and timely data on precipitation, temperature, and other climatic conditions important to rice cultivation. Farmers utilized this information to forecast extreme precipitation, drought conditions, and severe temperatures to save their crops. Farmers can plan irrigation and enhance drainage in accordance with forecasts of drought and excessive precipitation. The weather forecast enhances decision-making from planting to harvesting, ensuring rice production safety and minimising crop damage. Agroclimatic bulletin users get knowledge on optimal planting times based on precipitation forecasts, effective use of water resources during arid periods, and strategies to control pest by certain climatic conditions. The bulletins frequently incorporate visual aids such as figures and explanations, which simplify technical ideas and render the material comprehensible to rice farmers. By consistently engaging with and applying this knowledge, users enhance their technical proficiency in rice cultivation while simultaneously developing resilience to climate-related threats, so improving production and sustainability.

Meanwhile, agroclimatic bulletin also shows the limitations that they faced based experience as follows. Agroclimatic (AC) farmers may not receive the bulletin regularly based on the crop cycle, which makes it difficult to maximise its benefits. Farmers must receive these updates regularly to adapt to changing weather, pest outbreaks, and other climate factors throughout the crop cycle. However, intermittent access to these bulletins may cause farmers to miss important planting, irrigation, fertilisation, pest management, and harvesting information. Delivery inconsistency can lead to incomplete preparedness, poor resource usage, greater vulnerability to extreme weather, and lower crop yields. Lack of regularity in getting these critical updates impairs agroclimatic bulletins' usefulness in helping farmers adapt to and minimise climate change risks, underlining the need for more dependable and widespread dissemination systems.

The current agroclimatic bulletin do not have the reminder or notification system for climate data or early warning systems for natural disasters is a substantial impediment to efficient agriculture planning and disaster readiness. In the absence of prompt notifications or reminders, farmers may fail to obtain essential updates regarding imminent extreme weather occurrences, such as storms, floods, or droughts, in sufficient time to implement preventive measures. Furthermore, in the absence of a reminder system, farmers may neglect or forget critical warnings that could improve crop resilience or guide pest and disease management. Farmers think that the current version of the agroclimatic bulletin can be challenging to comprehend due to its use of technical terminology and its incorporation of English. Some recommendations were not comprehensible to farmers; therefore, visual and photo illustrations are necessary. Farmers noted that the agroclimatic bulletin lacked information on specific varieties or types of fertilisers and pesticides suitable for particular climatic conditions, necessitating additional guidance on which brands to purchase for their rice cultivation practices.

Constraints, opportunities, and key improvements for sustainable implementation of LTAC

Understanding the constraints, opportunities, and areas for improvement of LTAC is crucial for determining the feasibility of long-term investment in LTAC. Identifying constraints is important to understand the obstacles that hinder farmers from using agroclimatic bulletin and related advisory services from LTAC. Exploring opportunities allows LTAC to customise agroclimatic bulletin content and distribution strategies to meet the users' need, include advanced technology such as digital applications, and foster collaborations with government agencies and NGOs. Furthermore, recognising funding alternatives for investments in infrastructure, equipment, and training pertinent to LTAC can markedly improve its accessibility and effectiveness.

Constraints of LTAC implementation

The constraints of LTAC services, particularly on agroclimatic bulletin and LTAC advisory services to farmers in Cambodia were captured from key-informant interviews, in-depth interviews, technical group meeting, and consultative workshop. The most frequent mentioned on constraints of LTAC implementation from LTAC members including IIRR, MAFF-DALRM, DOM-MoWRAM, PDAFF, DoWRAM, and agricultural district officers are follows. Cambodia still lacks accurate climate forecast data at the district or commune level. This issue leads to insufficient climate projections for farmers in a specific location. The present climate data was obtained from Cambodia Climate Services for Agriculture '<https://khcsa.pdel.net/>', and it is limited to existing weather stations, which may not adequately cover highly accurate areas, as seen in Photo 3 below. Although this climatic data was reviewed with PDoWRAM, it remains unavailable for downscaling at this time. In the absence of reliable climatic data projections, farmers may lose confidence in LTAC. This constraint was raised by DALRM, PDAFF-Battambang, PDAFF-Kampong Spue, PDAFF-Prey Veng and during the technical meeting on the 30th October 2024.

Current climate advisory services through agroclimatic bulletins lack interactive communication, limiting timely advice for farmers. The existing LTAC services through agroclimatic bulletin distribution constitute a one-way communication process. Subsequent to the distribution of the bulletin by the LTAC member, there was a single training session for users and limited opportunities for field visits to conduct spot checks with users. Consequently, the existing distribution mechanism predominantly facilitates one-way communication. The absence of interactive approaches in LTAC limits real-time communication, preventing farmers from seeking clarification, offering input, and timely adapting the material to their individual needs. Although LTAC members are available to respond to consumer enquiries via phone call or Telegram, farmers have expressed hesitation in doing so.

In Battambang and Kampong Spue, LTAC not only supplied the agroclimatic bulletin but also incorporated it into the SESAMI system operated by RIMES¹, which offers a 3-day high-resolution weather forecast for daily decision-making, a 10-day weather forecast divided into two pentads for weekly planning, a monthly outlook for activities necessitating longer lead times, and a 3-month outlook for long-term seasonal planning. Furthermore, there is no designated task force or advisory committee available to promptly receive comments and responses as required by the farmers. The engagement team is also absent to promote the usage of the agroclimatic bulletin among farmers, whether in printed format or via digital platforms such as Telegram, Facebook Messenger, and the Sesami application.

Another barrier is that users are restricted by their digital literacy. Agroclimatic bulletins are not consistently distributed in advance of the cropping cycle. The delivery of agroclimatic bulletins was sometimes delayed due to late of the budget disbursement period and administrative procedure of project implementer. Late fund disbursement may delay the timely printing and dissemination. These setbacks can be particularly troublesome because the usefulness of agroclimatic bulletins is dependent on their prompt delivery, which ensures farmers have the information they need to coordinate their activities with present and anticipated climatic conditions. The project for agroclimatic bulletins places not enough emphasis on human-centered design, especially in terms of time provided for exploration, creation, validation, distribution, and feedback gatherings. To meet deadlines or cost constraints, LTAC implementations frequently prioritised technical outputs or speedy implementation, leaving little room for iterative, user-centred approaches.

Furthermore, inadequate finance and sufficient time can discourage investment in time-consuming design processes. For instance, distribution is difficult in Takeo province and Prey Veng because officials at the national level do not explain the bulletin at the commune level. As a result, the commune council is the only one responsible for distributing it without providing any explanations. The predominant participants participated in LTAC distribution were senior and under-aged young. According to key informant interviews, numerous smallholder farmers and younger individuals in the agricultural workforce are now employed as factory workers, resulting in a decline in those engaged in farming. Also, according to in-dept interviewed with users at Battambang province, she (herself) and other farmers may require several years to fully trust and adapt to the bulletin. The agricultural district officer in Battambang and a representative of agricultural cooperative in Prey Veng province also indicated that farmers need further time to adapt, especially concerning agricultural practices under difference climate conditions. Another female respondent from Svay Rieng province

¹ <https://rimes.int/specialized-expert-system-agro-meteorological-early-warning-climate-resilient>

indicated that to realise the LTAC bulletin, it is essential to have one exemplary champion farmer model who implements the LTAC bulletin.

The LTAC's sustainability should be looked over rather than relying solely on external donor funding. The LTAC committee is referred to as "informal" because no institution recognises it; instead, they rely completely on their individual institutes. In some cases, the cooperation with local officials was difficult; the commune distrusts our objectives, suspecting political agendas from outside groups. Another consequence was that agricultural officers offered training, however the only cost incurred was the training duration. Personal and institutional budgets continue to be the primary source of printing, paper, and computer resources. The LTAC members agreed that a technical working group dedicated to both water and agricultural techniques should be official endorsed by relevance ministries (MAFF and MoWRAM).

Opportunities of LTAC implementation

Beside constraints, LTAC also have many opportunities after implemented several years. According to key-informant interviews with LTAC members and stakeholders during technical meeting and Agroclimatic bulletin users, LTAC has many great opportunities for improving and scaling up for effectively in larger scale. The main opportunities noticed by stakeholders in Cambodia are follows. Farmers in the targeted districts throughout four provinces (Battambang, Kampong Speu, Prey Veng, and Takeo) have recognised and valued the significance of the agroclimatic bulletin. Farmers in the targeted areas are currently aware of the significance of seeking regular weather forecasts, encompassing both short-term and long-term climatic projections, to implement appropriate strategies at every stage of rice cultivation. Farmers are also understanding of the role of LTAC and begin to trust the technical assistance offered by extension workers. Farmers have basic digital literacy to access general information. By utilising farmers' digital literacy, LTAC members can expand their outreach, enhance service tailoring, and facilitate the wider adoption of cultivation of rice across varying climatic conditions.

LTAC members has the ability for ongoing implementation. With several years of expertise, LTAC members at the provincial level have the capability to on their own generate the agroclimatic bulletin and establish digital communication with farmers. They require simply infrastructure and budgetary backing for their activity. A increasing number of development partners are focussing on climate services and climate ambition (FAO-PEARL, SAAMBAT, ASSET, MET-KASEKOR, etc.), presenting a significant opportunity for synergy and broader scale. Existing digital operators on climate advisory, extension services, and bundle services in Cambodia are welcome to cooperate to integrate agroclimatic bulletin and related services to their applications (Tonle Sap App, Digital Agricultural Suite, Mekong Farm App).

Key improvements for sustainable implementation of LTAC in Cambodia

Long-Term Agroclimatic (LTAC) services, notably agroclimatic bulletins, require substantial improvements to ensure their effectiveness and long-term impact on climate resilience for rice production in Cambodia. Following the technical meeting on October 30, 2024, and the consultative workshop on December 18, 2024, participants indicated that key improvements should address challenges in accessibility, timeliness, relevance, sustainable financing, and user engagement, allowing farmers to make informed decisions in the face of changing climatic conditions. DALRM and other MAFF stakeholders agreed that LTAC members should be drawn from the existing 'Technical Working Group on Agriculture and Water' (TWG-AW), which was created in 2006. However, this technical working group should include members from the private sector, including input suppliers in the targeted district, because it may be a strong local institution for building trust with farmers and harmonising with Cambodian policy.

Regarding scaling up LTAC, public-private partnerships (PPPs) are critical for providing effective climate agriculture services because they pool resources to manage the climate risk to rice cultivation. Public institutions supply scientific skills, policy frameworks, and a mandate to help smallholder farmers, whereas private companies provide resources, innovation, and market-driven solutions. Together, they form a collaborative effort to provide services such as agroclimatic bulletins, weather forecasts, and climate-smart agricultural solutions. Building trust with farmers or users is one of the most difficult aspects of LTAC implementation, so benefit-oriented and re-design of LTAC using the human-centered approach in terms of scoping, exploration, co-creation, and validation; otherwise, LTAC cannot provide services based on user needs and preferences. Resource and technical assistance are still urgently required to continue the implementation until the government and corporate sector decide to invest. LTAC members are already in a good position, so if they have seed funds for product testing, public-private partnerships, and technical experts on standby to support agricultural data analysis.

Conclusion

The LTAC strategy is founded on the premise that pertinent stakeholders engaged in the creation, translation, distribution, and utilisation of climate services collaborate to create and distribute agroclimatic bulletins for farmers. It is still a very early stage for Cambodia not only adoption from farmers, but the LTAC members have just fulfil their capacity. Due to these several years of implementation of LTAC, farmers and relevant stakeholders have started to appreciate the co-design, relevance, and effectiveness of agroclimatic bulletin and related services provided by LTAC. Agroclimatic bulletin not only provide a clear instruction under difference climate scenarios but also pave the way of awareness raising for farmers to start pay attention on climate projection and early warning system.

Nevertheless, certain recommendations should be prioritised as strategies for improving the effectiveness of LTAC in agricultural climate services, whether disseminated by printed or digital agroclimatic bulletins, as outlined as following. The institutional system must be formally structured, delineating roles and duties, accompanied by a framework

for monitoring, learning, and assessment. Research and development initiatives aimed at enhancing technical capabilities across public and commercial sector service providers to connect short and medium-term projections with implementable recommendations. Enhancing the integration of MAFF's "Digital Centre," which consolidates resources from many agricultural departments into DCAS+ products, will optimise the precision of advising services.

Climate and agricultural modelling. Automated examination of climatic data via crop biophysical models and pest and disease distribution models presents a significant opportunity to enhance early warning systems. Furthermore, LTAC process should be reframe based on human-centred design as follows. Conducting a scoping exercise is crucial to identify targeted farmers, evaluating capacity and resources from LTAC, and assessing the challenges of rice agriculture due to climate risks as evidence. Identified farmers' preferences is necessary for the co-creation and partnership in the dissemination of climate advisory services to farmers, particularly involving commercial sector entities such as digital service providers, input suppliers, and traders. Prototype of a product from climate advice services, inviting private sector feedback and investment should be done for cost-effective. Establishing a timeline for the distribution, monitoring, and validation of services is also a cost-effective strategy for increasing adoption.

References

- Alliance Bioversity & CIAT. Local Technical Agroclimatic Committees. Retrieved 15th January, 2024, from <https://alliancebioversityciat.org/projects/local-technical-agroclimatic-committees>.
- Ayim, C., Kassahun, A., Addison, C., & Tekinerdogan, B. (2022). Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature. *Agriculture & Food Security* 11, 1-16.
- CIAT. Local Technical Agroclimatic Committees (LTAC). Retrieved 14th May, 2024, from [https://alliancebioversityciat.org/tools-innovations/local-technical-agroclimatic-committees-ltac#:~:text=Local%20Technical%20Agroclimatic%20Committees%20\(LTAC,thes%20can%20affect%20their%20crops](https://alliancebioversityciat.org/tools-innovations/local-technical-agroclimatic-committees-ltac#:~:text=Local%20Technical%20Agroclimatic%20Committees%20(LTAC,thes%20can%20affect%20their%20crops).
- Diana, G.-M., Carlos, N.-R., Martínez-Barón, D., María, L. A., Tatiana, G., David, M. J., . . . Julián, R.-V. (2021). *Local Technical Agroclimatic Committees (MTA): A detailed guide for implementing, Step-by-Step. 2nd Ed.* Cali: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
- Fan, S., & Rue, C. (2020). The Role of Smallholder Farms in a Changing World. In S. Gomez y Paloma, L. Riesgo, & K. Louhichi (Eds.), *The Role of Smallholder Farms in Food and Nutrition Security* (pp. 13-28). Cham: Springer International Publishing.
- FAO. (2021). Small family farmers produce a third of the world's food. Retrieved 18th May 2024, from <https://www.fao.org/newsroom/detail/Small-family-farmers-produce-a-third-of-the-world-s-food/en>.
- FAO. (2023). *Loss and Damage in Agrifood Systems - Addressing Gaps and Challenges* Rome: Food and Agriculture Organization of the United Nations.

- Giles, J., Bich, N. V. T., Khanam, F., Khaung, Y., Soksophors, Y., Le, T. T., . . . Swaans, C. (2023). *Digital landscape assessment for climate services : Asian Mega Deltas*. Hanoi: The International Center for Tropical Agriculture (CIAT).
- Giles, J., Soksophors, Y., Vu, N. T. B., Chou, P., Heng, K., Bora, C., Swaans, K. (2024). *Opportunity Profile for Digital Climate Advisory and Bundled Services (DCAS+) - Lower Mekong Basin, Cambodia*. CGIAR.
- Kansiime, M. K., Mugambi, I., Rware, H., Alokkit, C., Aliamo, C., Zhang, F., . . . Romney, D. (2022). Challenges and Capacity Gaps in Smallholder Access to Digital Extension and Advisory Services in Kenya and Uganda. *Frontiers of Agricultural Science and Engineering* 9(4), 642-654. doi:<https://doi.org/10.15302/J-FASE-2021423>
- Loboguerrero, A. M., Boshell, F., León, G., Martinez-Baron, D., Giraldo, D., Recaman Mejía, L., . . . Cock, J. (2018). Bridging the gap between climate science and farmers in Colombia. *Climate Risk Management*, 22, 67-81. doi:<https://doi.org/10.1016/j.crm.2018.08.001>
- Mapiye, O., Makombe, G., Molotsi, A., Dzama, K., & Mapiye, C. (2021). Towards a Revolutionized Agricultural Extension System for the Sustainability of Smallholder Livestock Production in Developing Countries: The Potential Role of ICTs. *Sustainability*, 13(11), 18. doi:10.3390/su13115868
- Meemken, E.-M., & Bellemare, M. F. (2020). Smallholder farmers and contract farming in developing countries. *J Proceedings of the National Academy of Sciences*, 117(1), 259-264.
- Mukherjee, A., & Maity, A. (2015). Public–private partnership for convergence of extension services in Indian agriculture. *J Current Science*, 1557-1563.
- Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M. M. B., Allen, S. K., Boschung, J., . . . Midgley, P. M. (2013). *Climate Change 2013: The Physical Science Basis* Cambridge: Cambridge University Press
- Thi Hoa Sen, L., Chou, P., Dacuyan, F. B., Nyberg, Y., & Wetterlind, J. (2024). Barriers and enablers of digital extension services' adoption among smallholder farmers: the case of Cambodia, the Philippines and Vietnam. *International Journal of Agricultural Sustainability*, 22(1), 2368351. doi:10.1080/14735903.2024.2368351
- Timlin, D., Paff, K., & Han, E. (2024). The role of crop simulation modeling in assessing potential climate change impacts. *Agrosystems, Geosciences & Environment*, 7(1), e20453. doi:<https://doi.org/10.1002/agg2.20453>
- Whitton, J., & Carmichael, A. (2024). Systemic barriers preventing farmer engagement in the agricultural climate transition: a qualitative study. *Sustainability Science*. doi:10.1007/s11625-024-01504-7
- Yim, S., Hyung, K. K., P.M., S. C., Angelica, B., & Khieng, P. (2022). *Local technical agro-climatic committee implementation guide: experiences from Battambang and Kampong Speu provinces in Cambodia*. Phnom Penh: IIRR, Alliance Bioversity & CIAT, RIMES and DALRM.

How Has the Socioeconomic Situation of Tribal Villages in Northern Thailand's Highlands Changed Over the Past Decade?

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Abstract

This study aims to analyse the change of socioeconomic situation of tribal villages in northern Thailand over the past decade from 2010 till 2022. This study uses the results of the evaluations of the implementation of the Highland Development Project Using the Royal Project System in Specific Areas in 3 periods: 2010-2013, 2014-2018 and 2019-2022. Key areas of evaluation include economic and social conditions, environmental impact, and the effectiveness of project strategies. This study uses descriptive analysis to compare the socioeconomic situation of Tribal Villages in Northern Thailand's Highlands. The study analysed various socio-economic and environmental factors affecting households in the surveyed areas. Key findings include improvements in basic infrastructure such as electricity, water supply, and sanitation over the years. However, agricultural land availability remains a concern, with many households feeling they lack sufficient land for farming. Economically, households have diversified their agricultural production, with crops like rice, corn, and coffee playing significant roles. Participation in government projects led to higher incomes, though income inequality remains moderate. Cash income has increased over time, but non-cash income has declined. Household debt has decreased, yet savings remain low. Poverty levels show improvement compared to 2016, but a significant portion of households still fall below the poverty line. Food security is a challenge, particularly in some regions where protein and fruit intake are insufficient. Major livelihood issues include high production costs, market uncertainties, and transportation difficulties.

Keywords: socio-economics, highland, poverty, Northern Thailand and sustainable development

JEL code: D19, O13, O18

SDG classification: SDG 1, SDG 2

Introduction

Highland Research and Development Institute (Public Organization) together with the Office of the Narcotics Control Board (ONCB) and other 18 related agencies undertake a project to expand the Royal Project to find the sustainable solutions for the problem of opium growing areas in order to improve people's quality of life under the master plan (The Royal Project Expansion Project to Solve the Problem of Sustainable Opium Growing Areas). This project has been operating for 3 phases: Phase 1 (2010 - 2013) which operates in 115 villages with recurring problems in opium cultivation, Phase 2 (2014 - 2018) which continued operations in areas with recurring opioid planting problems, totalling 126 villages and Phase 3 (2019 - 2022) namely "Highland Development Project Using Royal Project System in Specific Areas" which continues to operate in the area where the problem of repetitive opium cultivation in 118 villages. These villages are 4 new villages and 12 villages which are villages from Phase 2 which located in Mae Ramat District, Tak Province and have been adjusted to be the target area for the operation of the Le Tor Royal Project Development Canter.

From the implementation under the Highland Development Project Using Royal Project System in Specific Areas' (Phase 3, 2019 - 2022) action plan has emphasized on promoting and developing alternative occupations to generate income instead of opium cultivation for better quality of life, including conservation and restoration of natural resources and the environment, as well as developing self-reliant communities based on the knowledge base of the Royal Project under integration of operations with all sectors. Due to the long-term development efforts, studying the changes in the economic and social conditions is essential in order to reflect the outcomes of the development. Therefore, the objective of this study is to study the economic, social, natural resources and environment conditions in area of Highland Development Project Using Royal Project System in Specific Areas linked to the implementation under the Action Plan. The finding of the study could provide a framework for the work of the integrated joint agency, as well as continually develop targeted areas for sustainable development for the community to continue to be well-being.

Methodology

The population and the sample group were divided into 4 groups as follows: 1) Farming households under the Royal High Land Development Project to Solve Specific Area Problems during the 4-year period (2019 - 2022); the number of sample households was 1,003 sample; 2) 69 community leaders were interviewed (58 percent of the village in the project area from total of 118 villages), 3) Operational officers in 11 project area and 4) Participating agencies which are 20 agencies (including Highland Research and Development Institute (Public Organization)).

Analysis of economic and social conditions as well as important problems and obstacles, consisting of 5 main points as follows: 1) the physical characteristics and infrastructure necessary for subsistence in the implementation of the project. These data are analyzed using frequency, percentage and mean distribution. 2) Economic and market characteristics such as holding land area and agricultural area, farmer's occupation, sufficiency of rice production for consumption per household, household income, household expenses, debt and savings, marketing and access to capital. These data are analyzed using frequency, percentage and mean distributions. For income data, income distribution is analyzed. Income distribution analysis was performed by calculating the Gini index.

3) Demographic, social and organizational characteristics such as population structure and household dependence, education, and population health, access to the state welfare system, situation of the opium growing area and drug epidemics in the area. These data were analyzed using frequency, percentage and mean distribution. For the analysis of household dependence, it was analyzed by calculating the dependency rate. 4) Characteristics of natural resources and the environment were analyzed in 3 issues: (1) the situation of natural resources and the environment (forest, soil and water); (2) natural resource and environmental conservation activities carried out in the area with community participation and (3) Measures for restoring and restraining forest encroachment and destruction. The information in issue 1 will use the analysis of data from satellite images to analyze the condition of natural resources and the environment. For the data in issues 2 and 3, an analysis of the data in terms of frequency and percentage is used to illustrate the activities and measures taken.

5) Problems and limitations of the population and opinions, suggestions, satisfaction and development needs of farming households. These data were analyzed to distribute the data in terms of frequency, percentage and mean. For the analysis of poverty problem, the poverty line analysis at the farmer household level was used to analyze the poverty gap and the proportion of poor farming households. In the analysis of each topic, the data on the results of the surveys conducted during 2021 in the overview of all areas in the project were compared with the results of the project performance assessment in Phase 1 (in this report, the phase 1 assessment project is called the 2012 survey year) and the project performance assessment in Phase 2 (in this report, the phase 2 assessment project is called 2017 survey year).

Results and Discussion

Physical characteristics and infrastructure necessary for livelihood and agriculture

Physical characteristics and infrastructure in this study were considered in terms of availability of electricity, the sufficiency of water for consumption, for household and for agriculture including the use of toilets and house structure. The results of the study found that in all issues in all areas in 2021, the number of sample households that had electricity and toilets used or had more water sufficiency has increased compared to the 2012 and 2017 survey years. However, in 2021 there was more insufficient land for agriculture than in 2012 and 2017. In the case of the sample households who commented that the land holding was insufficient, 63.60% of the sample households will wait to allocate more land and 29.33 percent of the sample households will occupy them by clearing new areas. As for the appearance of the houses each survey years did not show the differ in house structure, with most of the sample households using tile for roofing. The structure of the house is made of wood and using wood as wall coverings in houses and folklore.

Economic and market characteristics.

Considering the size of the land holdings over the three period surveys, most of the sample farm households surveyed had a distribution of land holdings in four range (0.25-5, 5.25-10, 10.25-20 and 20.25-50 rai) in similar proportions. In the use of farming areas of the sample households, a variety of crops were grown in each center. If considering in all areas, the types of crops that have a lot of sample households grow are rice in all three period of surveys mainly for household consumption. This is followed

by maize in the 2021 survey, 32.40 percent of households grew maize, and this trend is increasing from the 2012 and 2017. Maize is not a crop promoted by the project, but maize can be sold easily. In terms of coffee which is the third crop has 24.64 percent of households (in 2021) having coffee in the area. For coffee in some areas, it is a traditional plant but has received additional promotion and support from the project in terms of seedlings inputs and knowledge in terms of production, care and development of coffee quality from the project.

Mango, avocado, legumes and passion fruit are supported crops from the project and have been planted by farmers' households since 2014 – 2015. As for peppers and tomatoes which are traditional crops in some areas such as Omkoi center, the project promotes the reduction of chemical use and quality standards at the GAP level. Tomatoes are already marketable in the area. For the chili, the project help farmers to find a market. Pumpkin is a plant that the project help to promote both production and marketing. Regarding the issue of sufficiency of rice production for consumption per household, the results showed that most households had enough rice for consumption (percentage of sample households that are able to produce enough rice for consumption throughout the year are 74.80% (2012), 83.70% (2017), and 82.61% in 2021).

The primary source of cash income of the sample households that generated the highest income for households in the 2021 survey found that in all centers including each center income from crop production is the main source of income for most households except for Phi Pan Nuea center, where most households (73.39 percent) had their main source of income from non-farm occupations from collecting longan outside the area. In the 2021 survey, it was found that, overall, all the sample households had an average annual total income of 3,802 USD. Of these, it was cash income of 3,376 USD per year or accounted for almost 88.81% of the total household income (in all this cash income which was cash income from agriculture amounting to 2,413 USD per household and cash income outside of agriculture amounting to 963 USD per household). The remaining 11.19 percent was non-monetary income which averaged 425 USD per year. Compared to the results of the 2012 and 2017 survey, the overall household income in 2021 decreased by 3.13 percent from 2012, with a decrease in non-cash income especially in the non-cash income from the agricultural sector which decrease of 72.84% from 2012 and from the same decrease in non-farm cash income of 20.65% when compared between 2021 and 2017. Total household income in 2021 increased from in 2017 at a rate of 22.69%, which is an increase from the part of cash income that increased by 37.90% (from 2,448 USD per year in 2017 to 3,376 USD per year in 2021); Cash was down 35.84% compared to 2017.

When considering only the cash income of the agricultural sector in 2021, there is a tendency to increase from 2012 and 2017 at the rate of 117.65 and 57.24, respectively (cash income in the agricultural sector in 2012, 2017 and 2021 are 1,108, 1,543 and 2,413 USD, respectively), due to farmers having to change more types of crops and growing crops according to market demand, resulting in an increase in agricultural cash income from 2012 and 2017. Considering the participation in the project, it was found that in 2021, households participating in the program had a household income of 3,938 USD per year, which is 16.44 percent more than non-participating households (3,382 USD per year). Participating households earn more than non-participating households in all income categories.

If income is considered in terms of income distribution or income inequality to assess the situation of income distribution in the area using the income inequality coefficient (Gini-coefficient). It was found that the overall income distribution in 2021 has the Gini-coefficient of the total income, total cash income and non-cash household incomes were 0.4537, 0.5164 and 0.4366, respectively, which overall were in the range showing that the income distribution was at the “moderate” level for all three income categories. Compared to 2012 and 2017, all three types of income distributions showed better distributions than in 2017 (less values) and similar distributions to 2012 distributions. Considering in 2021, across all income categories, both participating and non-participating groups had a moderate income distribution. In terms of cash income within the participating groups (0.5295), there was a slightly different distribution of income from the non-participating groups (0.4695).

If considering the cash expenditures of households in both household expenditures and agricultural expenditures, it was found that household cash expenditures were valued at 1,540 1,528 and 2,366 USD per year in 2012, 2017 and 2021, respectively. Most of the expenditures were part of household cash expenditures. The value in 2021 was 1,754 USD per year accounted for 74.15% of total cash expenditures. This is an increase from 2012 (1,020 USD per year) and 2017 (988 USD per year). When looking at the highest-value household expenses every year compared to total expenditures were food, vehicle fuel, clothing, housing and miscellaneous household expenses, cost for education and communication expenses. Agricultural expenditures were valued at 519 539 and 611 USD per year in 2012, 2017 and 2021 respectively.

When considering cash income versus total cash expenditures of households, net cash income increased in 2021 compared to 2012 and 2017 which the value of 781 920 and 1,010 USD in 2012, 2017 and 2021 respectively, as a result of the increase in cash income and the increase in proportion is greater than the increase in total cash expenditure. If considering the groups participating in the project and not participating in the project, it was found that the farmers participating in the project had the average agricultural expenditure amount of 672 USD per year, which was 33.29% more than non-participating farmers with an average agricultural expenditure of 448 USD per year. However, the participating farmers had an average cash income of 3,502 USD per household while farmers who did not participate in the program had an average cash income of 2,986 USD per year. The farmers participating in the program had an average net income of 21.14 percent more than those who did not participate.

Overall debt condition of most of the sample households (75.60 percent) in 2021 had no household debt burden. This is different from the survey in 2012 where 44.88% of the sample households had no household debt burden. In 2021, most of their funding came from village funds and banks, with average debt per household at 647 USD per household in 2021 which is less than the survey in 2012 (737 USD per household) and 2017 (1,043 USD per household). When considering the participation in the project, it was found that farmers who did not participate in the program had average outstanding debt of 750 USD per household more than farmers participating in the project with average debt of 609 USD per household. or more than 18.81 percent.

As for savings, a survey in 2021 found that the majority of the sample households had no savings (69.99 percent). When considering the savings, the sample household's savings value declined over a three-year period. Average savings per household were USD479, USD375 and USD195 per household in 2012, 2017 and 2021, respectively.

Farmers participating in the project had an average savings of 222 USD per household and farmers who did not participate in the project averaged 122 USD per household or more than 44.97 percent of farmers who did not participate in the program.

The household poverty profile in this study compares the total household income with the total household poverty line calculated by the total poverty line comprising the food poverty line and the non-food poverty line. It was found that in the year of the 2021 survey, in all areas, farmer households had a household poverty line equal to 2,927 USD per year per household. The average food poverty line was 2,002 USD per year and the average non-food poverty line was 924 USD per year. This indicates that if a household with an average total income of about 2,922 USD per year or more that household will not be poor. However, if the household has an average total income of less than 2,922 USD per year, it is considered to be in poverty but is not considered food poverty. Each household has a different poverty line and using the figures above is only a rough estimate. If a household has an average total income of about 1,977 USD per year or less, it is considered food poverty.

When considering the poverty gap, a value that represents the gap between the living standards of the poor in communities that fall below the poverty line (considering only households whose total income is less than the poverty line) to indicate to what extent these poor people have a lower gross income level than the poverty line. The results showed that in 2021, the overall sample households had a poverty gap of 23.04 percent and a food poverty gap of 12.73 percent. These indicate that, on average, the sample households had a total income below the poverty line 23.04 percent, a relatively small gap, and their total income was 12.73 percent below the food poverty line. There is less poverty gap when considering the total poverty line. Compared to 2012 and 2017, the 2021 poverty gap was improved over both years, the survey showed, with a smaller poverty gap. When considered among the participating and non-participants, it was found that among the participating groups, the values of both the total poverty gap and the food poverty gap were less (better than) than those who did not join project.

When considering the poverty status of the sample households as a whole, it was found the decreasing trend of poor households considering total income compared to the total poverty line. In 2021, the proportion of poor households (53.79%) was lower than in 2017 (66.67%), but still higher than in 2012 (43.41%), which had similarly to total income, in 2021, total income will be higher than in 2017, but still less than in 2012. When considering food poverty only, the proportion of households in food poverty is higher than in 2017. The proportion of households with total income below the food poverty line in 2021 was 36.37 percent less than in 2017 (61.84%) and similar to the proportion of food poverty-stricken households in 2012 (34.96%). The proportion of household's poverty in the project participated group and non-participated group had the same proportions. However the participating groups (53.60% (total poverty) and 35.60% (food poverty)) had slightly lower proportions of households in poverty than those who did not participate (54.37% each (total poverty) and 40.00% (food poverty)).

The main source of distribution of agricultural products (products that generate a lot of income) in the 2021 survey for all centers and the individual centers were selling to middlemen, both from the middlemen who entered the area and the farmers transported their products to middleman outside the area followed by selling the produce in the community market.

Demographic, social and organizational characteristics

In the 2021 survey, the total sample household population was 4,452, divided into 51.66% males and 48.34% females of the total sample households. The dependency rate of farm households in this study found that, in all areas, farm households had a dependency rate of 45.06% in 2021 (meaning that 100 working-age farmers had to support approximately 45 non-labor-age populations). The dependency rate is lower than the dependency rate in 2012 (61.78%) and in 2017 (51.27%). In the 2021 survey, the majority of the sample households, 98.18 percent, were entitled to government health care. Most, 97.80 percent, used government welfare in the form of a gold card. If considering the medical treatment of the sample households when they were sick, the overall sample households in all areas would use public health services at the district hospitals.

When considering the problem of substance abuse at the household level, it was found that in 2021, the number of sample households (36.68%) had household members who was addicted to substance abuse, which decreased compared to 2012 (43.78%) but increased when compared to 2017 (23.22%). In addition, in the 2021 survey, there were households in which members of the household were addicted to methamphetamine (53.87% of the drug-addicted sample households) and opium (37.11% of the drug-addicted sample households) and found cannabis and snuff in the area too.

Natural resources and environment characteristics

During the 2021 and 2017 survey years, most of the sample households commented that soil fertility had not changed over the past two years. Whereas in the 2012 survey, only 50.74 percent of the sample households commented that soil fertility was unchanged, and 30.44 percent of the sample households commented that soil fertility declined slightly in the 2012 survey year. Most of the sample households in the 2017 and 2021 surveys reported that there was no soil problem in farming areas. Most the sample households surveyed also commented that the community forest was in good condition and fertile.

Major problems and limitations of the community

Overall, in the 2021 survey, the percentage of households with adequate (49.75%) and insufficient (48.25 percent) of food consumption. However, when considering each center, it was found that the center group with the percentage of households with insufficient food for consumption in the percentage of households greater than 50 percent are 4 out of 11 centers, namely Mae Hae Luang Center, Huai Nam Yen, Khun Tuen Noi and Phi Pan Nuea. These centers had relatively low cash income compared to other centers. For the type of food that the sample households reported insufficient were the protein diet group consisted of meat, eggs, milk and dairy products, and fruit. As for problems in the occupation of households in 2021, it was found that in all areas, problems with high levels of severity were as follows: transportation problems, shortage of funds, high production cost, low production prices, outbreaks of insect pests, lack of water resources, lack of occupational knowledge, no market, low production volume and no fixed occupation.

Project satisfaction and development needs of households.

In the 2021 survey, data were collected on the level of sample households' satisfaction with the work of staff of integrated agencies and government officials in community areas.

It was found that the level of satisfaction was very high for teacher, health workers, village headman and staff of the HRDI. While the staff of other agencies, the sample households, gave a moderate level of satisfaction. The satisfaction of each survey year is quite different. For the satisfaction level of the sample households towards the overall project/activity of the project according to 5 strategies, namely 1) career development and marketing 2) strengthening community development 3) conservation and rehabilitation of natural resources and the environment 4) infrastructure development that are necessary for life; and 5) drug problem solving. The results showed that in the overview of all areas the sample households showed high levels of satisfaction with the activities in all five strategies.

In general, in all areas, the sample households had a high level of demand in all aspects of development except for the development of the infrastructure necessary for life and the development of the infrastructure necessary for production and marketing, the sample households had the highest demand.

Conclusion

The study highlights the significant progress achieved in the northern highland communities through long-term development efforts, particularly in transitioning from opium cultivation to sustainable livelihoods. Improvements in physical infrastructure, such as increased access to electricity, water, sanitation, and better housing, demonstrate an uplift in the quality of life. Economically, crop diversification, especially toward market-driven and supported crops like maize, coffee, and high-value fruits, has contributed to a substantial increase in agricultural cash income. Households participating in development programs consistently reported higher income, lower debt, and better poverty outcomes compared to non-participating households. Despite these gains, challenges remain. Insufficient agricultural land, rising food insecurity in some centers, and persistent substance abuse issues call for continued attention. The income gap, though moderate, reflects ongoing inequality that needs to be addressed. Furthermore, the decline in savings and continued reliance on middlemen for crop sales point to the need for stronger financial literacy and market access.

On the social front, access to health care is widespread, and the dependency rate has decreased, indicating demographic improvement. Community satisfaction with local government services and integrated development efforts remains high, especially in areas of education, health, and drug rehabilitation. Environmental conditions appear stable, with perceptions of good soil fertility and well-maintained community forests. However, some farming challenges, such as pest outbreaks, water shortages, and lack of stable markets, continue to affect productivity and income stability.

Overall, the data suggests that while the development programs have significantly improved living standards and economic conditions, sustained support and targeted interventions are still necessary. There is a strong demand among households for further infrastructure development, improved market access, and occupational support to ensure continued growth and resilience in these highland communities.

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References

- Ngamsomsuk, K., Ruangsaat, W., Promphichai, T., and Thavornnan, N. (2010). Socioeconomic Conditions of Farmers in Royal Project Development Centers Areas in the Year 2008/2009. Final Research Report submitted to the Highland Research and Development Institute (Public Organization). Faculty of Agriculture, Chiang Mai University.
- Ngamsomsuk, Kamol, Ruangsaat, Wirot, Promphichai, Thanyarat, Chatweerach, Buralak, and Sittisaman, Natthawut. (2014). Evaluation and Study of Socioeconomic Conditions in the Royal Project Extension Areas in the Year 2013. Research Report submitted to the Highland Research and Development Institute (Public Organization).
- Ngamsomsuk, K, Promphichai, T., Asavaprommitchai, P., and Boonwong, W. (2018). Evaluation of the Implementation of the Master Plan for the Royal Project Extension to Sustainably Solve Opium Cultivation Problems, Phase 2 (2014–2018). Final Research Report submitted to the Highland Research and Development Institute (Public Organization). Faculty of Agriculture, Chiang Mai University.

Community Participation in the Conservation and Development of Coastal Mangrove Forests: Theoretical Perspectives and Implications for Vietnam

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Abstract

Mangrove forests play a crucial role in the economic, environmental, and social aspects of many countries, including Vietnam. However, due to climate change and economic activities, mangrove forests have significantly declined over time. Community participation is an important strategy for mangrove forest conservation and development. However, the existing literature lacks sufficient evidence to compare various community participation theories and recommend a suitable theoretical approach for developing countries like Vietnam. This paper addresses this gap by reviewing three common community participation theories: Arnstein's ladder of participation (1969), Pretty's participation framework (1995), and the people-centered theoretical framework. The results show that while all three theories have their advantages and limitations, Pretty's and Arnstein's models, though useful for classifying levels of participation, do not fully reflect the context of natural resource management in Vietnam. In contrast, the people-centered theoretical framework is highly compatible with Vietnam's national context and is easier to apply an essential factor given the limited awareness of both officials and local communities.

Keywords: community participation, mangrove forest, conservation, development

JEL code: Q57, O13

SDG classification: SDG 1, SDG 2

Introduction

Coastal mangrove forests are among the most productive and biologically diverse ecosystems in the world, providing critical services such as shoreline protection, carbon sequestration, biodiversity conservation, and livelihood support for millions of people living in coastal areas (Adolph, 2016; Anh et al., 2024; Astuti et al., 2018; Fathima Mafaziya Nijamdeen et al., 2023; Ntibona et al., 2022; Sam et al., 2023; Stone et al., 2008). In Vietnam, where over 3,000 kilometers of coastline are dotted with mangrove systems, these forests play an especially vital role in mitigating the impacts of climate change, including sea-level rise and increased storm frequency (Anh et al., 2024; Thuy et al., 2024; Truong, 2021). However, rapid urbanization, aquaculture expansion, and insufficient enforcement of environmental regulations have led to significant degradation of mangrove ecosystems over the past decades (Anh et al., 2024; Truong, 2021).

Amid these environmental pressures, community participation has emerged as a key approach in the conservation and sustainable development of mangrove forests (Adolph, 2016; Astuti et al., 2018; Bamberg et al., 2015; Baráth et al., 2024; Chamberland-Fontaine et al., 2022; Kangas, 1994; Stone et al., 2008; Susilo et al., 2017; Thuy et al., 2024; Ullah et al., 2021; Zhang et al., 2020). Theoretical perspectives from environmental governance, participatory resource management, and social-ecological resilience underscore the value of engaging local communities not only as beneficiaries but also as active stewards of natural resources (Adhikari et al., 2014; Baráth et al., 2024; Ntibona et al., 2022; Stone et al., 2008). Yet, despite growing recognition of its importance, the role of communities in mangrove conservation in Vietnam remains inconsistently implemented and poorly understood, particularly in relation to policy frameworks, institutional mechanisms, and socio-cultural dynamics (Anh et al., 2024; Chu Manh Trinh, 2011; Thuy et al., 2024; Truong, 2021).

This research addresses the need for a clearer conceptual and practical understanding of community-based approaches to mangrove conservation. It aims to: (i) synthesize key theoretical perspectives on community participation in forest management; (ii) analyze the relevance and applicability of these theories in the context of Vietnam's coastal zones; and (iii) propose policy implications and institutional recommendations to enhance local engagement in mangrove conservation and development.

This study is particularly relevant for policymakers, development practitioners, environmental NGOs, and local communities who are seeking more inclusive, equitable, and effective approaches to natural resource management. It contributes to the literature by integrating interdisciplinary theoretical insights with context-specific analysis, thereby offering a more comprehensive framework for understanding community roles in mangrove governance. While several studies have examined the ecological or economic aspects of mangrove management, fewer have systematically investigated the interplay between theory and practice in promoting community participation—especially in the Vietnamese context.

The structure of this paper is as follows: Section 2 presents the methodological approach. Section 3 reviews theoretical foundations related to community-based natural resource management and discusses key findings and lessons from Vietnam, and Section 4 concludes with directions for future research.

Methodology

This study adopts a qualitative research design using a theory-based literature review approach to examine and compare conceptual frameworks of community participation

relevant to the conservation and development of mangrove forests, particularly in the Vietnamese context. The objective is to analyze the applicability, advantages, and limitations of three widely recognized theoretical models: Arnstein's Ladder of Participation, Pretty's Typology of Participation, and the People-Centered Framework.

Literature search and selection criteria

Relevant academic literature, policy documents, and case studies were collected through systematic searches in multidisciplinary databases such as Scopus, Web of Science, Google Scholar, and JSTOR. The search focused on peer-reviewed articles, book chapters, and grey literature published between 1990 and 2024. Keywords used included "community participation," "community participation theory," "mangrove forest conservation and development," "natural resource management," "Arnstein," "Pretty," "people-centered framework," and "Vietnam."

Inclusion criteria were as follows:

- Theoretical or conceptual studies discussing participation frameworks.
- Empirical studies focusing on mangrove conservation involving local communities.
- Policy-related documents addressing participatory environmental governance in Southeast Asia, with an emphasis on Vietnam.

Documents not available in English or Vietnamese or lacking relevance to community-based natural resource management, were excluded.

Analytical framework

The review applied a comparative conceptual analysis, which involves identifying and interpreting key components of each theoretical model and evaluating their relevance to the socio-political and environmental context of Vietnam. The three selected theories were analyzed using the following criteria:

- Levels and forms of participation
- Underlying assumptions about community roles and agency
- Adaptability to local governance structures and institutions
- Emphasis on empowerment, inclusion, and sustainability
- Relevance to coastal mangrove forest contexts in developing countries

This analytic lens allowed for a structured comparison, highlighting not only the theoretical distinctions among models but also their practical implications for policy and community-based interventions in Vietnam.

Contextualization for Vietnam

To assess the contextual suitability of each model, findings were interpreted in relation to the Vietnamese governance system, community organization, socio-cultural dynamics, and historical experiences with coastal forest management. The analysis also incorporated case-based insights from government reports, NGO publications, and Vietnamese academic sources to bridge theory with practice.

Results and Discussion

Ladder of participation of Arnstein

According to (Cornwall, 2008), one of the theoretical frameworks on participation is based on Sherry R. Arnstein's Ladder of Participation in 1969 (Arnstein, 1969), which describes the level of citizen participation in the decision-making process. This theoretical framework divides the level of participation into 8 levels, from Non-Participation to Citizen Control. This model focuses specifically on the power and level of control that citizens have over policies and programs that affect them. Although the scale has been pointed out by scientists as having advantages such as the model being presented in the form of an image of an 8-level ladder, it is easy to understand and distinguish the levels of participation, from "manipulation" to "citizen control" or can also be translated as community control. The scale helps to determine the actual level of participation, from symbolic to actual control over the decision-making process. The scale has also been applied in many different fields such as urban planning, community development, education as well as natural resource and environmental management, helping to assess the level of participation in many different contexts (Arnstein, 1969; Cornwall, 2008).

Criticisms of this scale are that it is a linear model, lacking flexibility. Arnstein describes participation in a rigid hierarchy, implying that higher levels are always better than lower levels (Cornwall, 2008). However, in reality, complete control by the people is not always the optimal solution, especially in issues related to mangrove conservation and development, where coordination among many stakeholders such as authorities, experts and communities is required. This theoretical framework seems to be inappropriate in the context of a developing country like Vietnam, where people's participation is not just "manipulated" or "completely controlled", but can be cooperation between stakeholders – something that Arnstein's model does not mention. In addition, the scale only focuses on power and control, not mentioning the livelihood, interests and responsibilities of the people.

Pretty's typology of participation

According to research, the theoretical framework of participation according to the Pretty model "Pretty's Typology of Participation" can help classify participation based on the level of community initiative and power. Accordingly, this theoretical framework helps classify people's participation into 7 levels, from the lowest level "Passive Participation" to the highest level "Self-Mobilization". It can be said that this is an important theoretical framework on community participation. The scale helps to classify in detail and at multiple levels. Compared to Arnstein's scale (1969), Pretty's scale is more specific, helping to identify more clearly the level of participation from passive to active. This theoretical model emphasizes community autonomy (communities have the ability to make their own decisions and mobilize their own resources to contribute to sustainable development (Cornwall, 2008; Pretty, 1995). However, this theoretical framework only focuses on the level of participation, not mentioning the motivation, rights and responsibilities of people (Cornwall, 2008). Pretty only describes the types of participation without explaining why people choose to participate or refuse to participate, and the theoretical framework does not consider the mechanism of people's benefits - the key factor to maintain long-term participation.

People-centered framework

The People-Centered Framework in natural resource management emerged in the 1980s and 1990s as a response to the failures of top-down, state-led approaches that often ignored the needs, knowledge, and rights of local communities. It draws from participatory development, sustainable livelihoods frameworks, and community-based resource management paradigms. The framework is rooted in the idea that natural resources are best managed when the people who depend on them are actively involved in their management and decision-making. It recognizes local communities not just as beneficiaries but as key stakeholders and agents of change (Chambers, 1997; Court & Wijesuriya, 2020; Ostrom, 2015; Pretty, 1995).

In Vietnam, the motto "People know, people discuss, people act, people monitor" was first officially proposed by the Communist Party of Vietnam during the 5th Congress (1981-1986). Specifically, on November 28, 1984, the Central Party Secretariat (Term V) issued Directive No. 53-CT/TW "On strengthening the Party's mass work", emphasizing: "We must truly respect the collective mastery of the working people, and well implement the slogan 'people know, people discuss, people do, people inspect' in production, distribution as well as in all work directly related to the masses. Later, this motto was expanded with elements such as "people supervise" and "people benefit". At the 13th National Congress, the Party added it to "people know, people discuss, people do, people inspect, people supervise, people benefit" (Communist Party of Vietnam, 2021). Recently, in studies on agricultural extension and community development, many authors have emphasized the role of assessing people's needs to see whether people need programs/policies or not. In addition, the content of participation is also considered in terms of people's contribution and people's management (people need, people contribute and people manage) (Do, 2021b, 2021a). Accordingly, the theoretical framework of people's participation when placing people as the subject/center, demonstrating the connection between people's rights and obligations in the conservation and development of mangrove forests can be specified in the Table 1.

Table 1. Community participation theory when putting people at the center in mangrove conservation and development

Participation	Explain	Community participation in mangrove conservation and development
Need	Reflects the actual needs of the people, emphasizing that all policies and development programs must originate from the practical needs of the community.	Local people are the ones directly affected by the degradation or development of mangrove forests. Therefore, it is essential to assess both their actual needs and their awareness of the benefits that mangroves provide: Livelihoods: Do local people depend on mangrove forests for resources such as aquatic products, timber, or medicinal plants? Environmental Protection: Are they aware of the role mangroves play in protecting coastlines, reducing erosion, and mitigating the impacts of storms and rising sea levels? Socio-cultural Aspects: Do mangrove forests hold any cultural or traditional significance for

Participation	Explain	Community participation in mangrove conservation and development
		the community? Does participating in the conservation and development of mangroves help strengthen community bonds?
Aware of	Emphasize the people's right to access information regarding policies, plans, and projects that affect their lives; create conditions that enable them to clearly understand the objectives, content, and impacts of development programs.	People need to be provided with comprehensive information on the following: the benefits of mangrove forests (such as ecosystem protection, disaster prevention, and livelihood improvement); conservation and development policies (including forest laws, reforestation programs, and sustainable livelihood models); and opportunities for participation (such as community projects, technical support, and financial assistance). It is essential to ensure that information is accessible and appropriate to the community's education level and characteristics through workshops, local media, and visual guidance.
Discuss	Promote democratic participation in the decision-making process by allowing local people to discuss and contribute their opinions on relevant issues; this helps enhance the transparency and effectiveness of policies and projects.	Local people should be involved in the decision-making process concerning: • Mangrove forest planning (e.g., areas for conservation and zones for sustainable use); • Appropriate conservation models (such as reforestation, controlled harvesting, and ecotourism); • Benefit-sharing mechanisms (including resource use rights and policy-based support). Consultation mechanisms may include village meetings, group organizations, and opinion surveys to ensure that the community genuinely has a voice in mangrove forest management.
Contribute	Emphasize the role of local people in contributing resources—such as finances, labor, knowledge, and experience—to the implementation of development activities. This helps strengthen their sense of responsibility and	Local people can participate in various ways: Contributing labor – such as planting trees, patrolling and protecting forests, nurturing natural regeneration, and clearing weeds; Sharing indigenous knowledge – including traditional practices of sustainable harvesting and natural conservation experience; Collaborating with authorities and businesses through engagement in sustainable livelihood models like aquaculture and ecotourism.

Participation	Explain	Community participation in mangrove conservation and development
	ownership over the projects.	
Implement	Demonstrate the direct participation of local people in the implementation of development activities; this helps enhance the practical capacities of the community and ensures the sustainability of the projects.	Local people can directly participate in activities such as: planting and restoring mangrove forests; practicing sustainable resource use (e.g., reducing chemical use in aquaculture, avoiding excessive deforestation); and developing green livelihood models (such as mangrove-shrimp farming and community-based tourism). Government authorities and non-governmental organizations should provide technical support, supply seedlings, and offer skills training for the community.
Control	Emphasize the role of local people in monitoring the implementation of policies and development programs; their involvement helps reduce corruption and waste, ensuring the effectiveness of the activities.	Local people can participate in monitoring through: Community patrol groups (to detect and report forest violations); Evaluating the effectiveness of conservation programs (such as assessing whether mangrove forests are growing and if the environment is improving); Monitoring law enforcement (by identifying violations and reporting them to authorities).
Manage	In addition to monitoring, local people also have the right to participate in the management of resources, programs, and development projects; this ensures the effective operation of these initiatives, tailored to the real conditions of the local area.	Local people's proactive involvement in the conservation and development of mangrove forests can be reflected in their participation in co-management models for mangrove forests, where they: Collaborate with local authorities in managing mangrove forest resources; Establish groups/associations to oversee sustainable resource extraction and livelihood development; Apply technology in mangrove forest management, enhancing the effectiveness and sustainability of conservation efforts.
Benefit	It is essential to affirm that the ultimate goal of all development policies is to bring benefits to the people,	Ensure the economic and social benefits that local people receive by participating in the conservation and development of mangrove forests:

Participation	Explain	Community participation in mangrove conservation and development
	creating the motivation for the community to actively participate in sustainable development programs.	Sustainable livelihoods (such as ecotourism, integrated aquaculture, beekeeping, etc.); Improved living environment (such as reduced erosion, enhanced water quality, and biodiversity protection); Financial benefits (including support from forest environmental services payments, REDD+ projects for emission reductions, and forest protection compensation schemes).

Source: Adapted from (Communist Party of Vietnam, 2021), (Do, 2021b, 2021a)

With this approach, the theory of citizen participation is centered around involving the people in decision-making and the implementation of development programs. Compared to some theoretical frameworks developed worldwide, this theory offers a comprehensive approach to analyzing public involvement in the conservation and development of mangrove forests. It not only emphasizes the community's right to participate but also highlights the proactive role and tangible benefits received by the people, ensuring long-term sustainability in resource management, both in general and specifically in mangrove forest management. Accordingly, studies highlight the simplicity and practical applicability of this approach. The levels of involvement: "need, know, discuss, contribute, act, monitor, manage, benefit" directly reflect the extent of public participation in a project or program. This theoretical framework is considered easy to implement in areas such as rural development, community development, and public policy (Do, 2021b, 2021a). The participatory approach is an important method in analyzing rural agricultural policies (P. Le Nguyen et al., 2024). Especially, this framework fits well with the reality in Vietnam, as previous studies have shown its widespread application in community development programs and forest and agriculture management policies.

The framework also considers and emphasizes sustainability, especially at the "monitoring, managing" levels, ensuring that communities can continue activities after the project ends and encouraging community responsibility while reducing reliance on the state or support organizations. However, this analytical framework is also considered to have certain limitations, such as a lack of analysis of motivation and power dynamics (this framework does not focus on factors that determine participation, such as economic, cultural motivations, or political power within the community); the framework also does not fully reflect different forms of participation, making it difficult to express the actual control the people have over the decision-making process. Based on the overview of the theory of community participation from literature, we can draw some evaluations of the theoretical frameworks through the following Table 2.

Table 2. Compare several theoretical frameworks on citizen participation in mangrove conservation and development.

No	Theoretical framework	Level of detail	Emphasis on power	Suitable for Vietnam	Easy to apply
1	People-centered framework	xx	X	xxx	xxx
2	Pretty's Classification of Participation	xxx	Xx	xx	xx
3	Arnstein's Ladder of Participation	xxx	Xxx	x	x

Note: x: Low level; xx: Medium level; xxx: High level

Source: Compiled by the authors' group (2025)

Despite some limitations, based on our overview, applying the people-centered participation theoretical framework is suitable for Vietnam's context. It emphasizes the active role of people and their rights to benefit from conservation and development activities related to mangrove forests, thereby sustaining long-term community participation. In practice, successful mangrove conservation models in Vietnam have demonstrated the smooth collaboration of stakeholders, including the role of local people, authorities, and businesses. People not only participate but also have roles in monitoring, benefiting from, and making decisions, which is not fully addressed by Pretty's or Arnstein's theoretical models. With its comprehensiveness and adaptability to the Vietnamese context, this theoretical framework not only helps analyze the current state of people's participation in mangrove conservation but also proposes feasible solutions to strengthen their role. This is the most suitable framework to ensure the sustainability and effectiveness of mangrove conservation programs in Vietnam.

Thus, while Pretty's participation framework and Arnstein's participation ladder are useful models for classifying levels of participation, they do not fully reflect the natural resource management context in Vietnam. In contrast, using the people-centered participation framework in studies on enhancing participation in mangrove conservation and development in Vietnam is entirely appropriate, as it aligns very well with the country's context and is easy to apply (which is essential given the current limited awareness among both officials and citizens).

Conclusion

Mangrove forests are vital to the economic stability, ecological resilience, and social well-being of coastal communities, particularly in countries like Vietnam. However, the degradation of these ecosystems, driven by climate change and unsustainable economic practices, underscores the urgent need for effective conservation and development strategies. Community participation has been widely recognized as a key component of sustainable mangrove management. Yet, the lack of a coherent theoretical foundation

tailored to developing country contexts remains a significant gap in both policy and practice.

This study contributes to bridging that gap by critically reviewing three prominent theoretical models of community participation: Arnstein's ladder of participation, Pretty's participation typology, and the people-centered theoretical framework. While Arnstein's and Pretty's frameworks offer valuable classifications for understanding levels of participation, they are limited in their applicability to the complex socio-political and institutional realities of Vietnam. In contrast, the people-centered theoretical framework, with its emphasis on empowerment, contextual relevance, and adaptability, emerges as a more appropriate and actionable foundation for promoting meaningful community engagement in mangrove conservation efforts in Vietnam.

The findings of this study offer both theoretical and practical implications. Theoretically, it highlights the need to move beyond hierarchical or typological models toward more integrative and context-sensitive approaches. Practically, it supports the development of participatory policies and programs that are not only inclusive but also aligned with local capacities, values, and institutional constraints. Future research should focus on empirical validation of the people-centered framework in various coastal provinces of Vietnam and explore mechanisms for capacity building among local stakeholders and policy implementers.

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References

- Adhikari, S., Kingi, T., & Ganesh, S. (2014). Incentives for community participation in the governance and management of common property resources: The case of community forest management in Nepal. *Forest Policy and Economics*, 44, 1–9. <https://doi.org/10.1016/j.forpol.2014.04.003>
- Adolph, R. (2016). *Community based natural resource management of mangrove forests: The case study of Southern Thailand*. Colorado.
- Anh, H. H., Beaulieu, A., Da Hanh, T. M., & Tru, L. C. (2024). Economic effects of a controlled mangrove-to-pond coverage ratio policy on mangrove conservation and shrimp farming: A case study in vietnam using instrumental regression analysis. *Trees, Forests and People*, 16(29), 100579. <https://doi.org/10.1016/j.tfp.2024.100579>
- Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Planning Association*, 35(4), 216–224. <https://doi.org/10.1080/01944366908977225>
- Astuti, S., Muryani, C., & Rindarjono, M. G. (2018). The Community Participation on Mangrove Conservation in Sayung, Demak from 2004-2016. *IOP Conference Series: Earth and Environmental Science*, 145(1). <https://doi.org/10.1088/1755-1315/145/1/012087>

- Bamberg, S., Rees, J., & Seebauer, S. (2015). Collective climate action: Determinants of participation intention in community-based pro-environmental initiatives. *Journal of Environmental Psychology*, 43, 155–165. <https://doi.org/10.1016/j.jenvp.2015.06.006>
- Baráth, L., Bakucs, Z., Benedek, Z., Fertő, I., Nagy, Z., Vígh, E., Debrenti, E., & Fogarasi, J. (2024). Does participation in agri-environmental schemes increase eco-efficiency? *Science of the Total Environment*, 906(September 2023). <https://doi.org/10.1016/j.scitotenv.2023.167518>
- Chamberland-Fontaine, S., Thomas Estrada, G., Heckadon-Moreno, S., & Hickey, G. M. (2022). Enhancing the sustainable management of mangrove forests: The case of Punta Galeta, Panama. *Trees, Forests and People*, 8(May), 100274. <https://doi.org/10.1016/j.tfp.2022.100274>
- Chambers, R. (1997). Whose reality counts? Putting the first last. In *Intermediate Technology Publications*. Intermediate Technology Development Group.
- Chu Manh Trinh. (2011). Resource and environmental co-management in Cu Lao Cham marine protected area, Quang Nam province. *Vietnam Journal of Marine Science and Technology*, 11, 79–95.
- Communist Party of Vietnam. (2021). *Documents of the 13th National Congress of the Party*.
- Cornwall, A. (2008). Unpacking “Participation” Models, meanings and practices. *Community Development Journal*, 43(3), 269–283. <https://doi.org/10.1093/cdj/bsn010>
- Court, S., & Wijesuriya, G. (2020). The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM). *Encyclopedia of Caribbean Archaeology*, 193–194. <https://doi.org/10.2307/j.ctvx1hst1.97>
- Do, K. C. (2021a). *Textbook on Agricultural Extension Methods*. Vietnam Agricultural University Publishing house.
- Do, K. C. (2021b). *Textbook on Agricultural Extension Organization*. Vietnam Agricultural University Publishing house.
- Fathima Mafaziya Nijamdeen, T. W. G., Ratsimbazafy, H. A., Kodikara, K. A. S., Ashara Nijamdeen, T. W. G. F., Thahira, T., Peruzzo, S., Dahdouh-Guebas, F., & Hugé, J. (2023). Mangrove management in Sri Lanka and stakeholder collaboration: A social network perspective. *Journal of Environmental Management*, 330(July 2022). <https://doi.org/10.1016/j.jenvman.2022.117116>
- Kangas, J. (1994). An approach to public participation in strategic forest management planning. *Forest Ecology and Management*, 70(1–3), 75–88. [https://doi.org/10.1016/0378-1127\(94\)90076-0](https://doi.org/10.1016/0378-1127(94)90076-0)
- Mai, N. T., Huong, T. T. L., Dat, T. T., & Truong, D. D. (2023). An Empirical Study of Financial Efficiency and Stability of Shrimp–Mangrove Farming Model in Nam Dinh Province, Red River Delta, Vietnam. *Sustainability (Switzerland)*, 15(7). <https://doi.org/10.3390/su15076062>
- Nguyen, P. Le, Le, T. T. L., Pham, T. T. T., & Luu, V. D. (2024). *Textbook on Agricultural and Rural Development Policies*. Vietnam Agricultural University Publishing house.

- Nguyen, V. V., Nguyen, H. T. T., Phan, T. T. T., & Lee, C. H. (2023). Determinants of locals' willingness to participate in human–elephant conflict management: Evidence from Dong Nai Biosphere Reserve, Vietnam. *Trees, Forests and People*, 14(September), 100435. <https://doi.org/10.1016/j.tfp.2023.100435>
- Ntibona, L. N., Shalli, M. S., & Mangora, M. M. (2022). Incentives and disincentives of mangrove conservation on local livelihoods in the Rufiji Delta, Tanzania. *Trees, Forests and People*, 10(August), 100326. <https://doi.org/10.1016/j.tfp.2022.100326>
- Ostrom, E. (2015). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press. <https://doi.org/https://doi.org/10.1017/CBO9781316423936>
- Pretty, J. N. (1995). Participatory learning for sustainable agriculture. *World Development*, 23(8), 1247–1263. [https://doi.org/10.1016/0305-750X\(95\)00046-F](https://doi.org/10.1016/0305-750X(95)00046-F)
- Sam, K., Zabbey, N., Gbaa, N. D., Ezurike, J. C., & Okoro, C. M. (2023). Towards a framework for mangrove restoration and conservation in Nigeria. *Regional Studies in Marine Science*, 66, 103154. <https://doi.org/10.1016/j.rsma.2023.103154>
- Stone, K., Bhat, M., Bhatta, R., & Mathews, A. (2008). Factors influencing community participation in mangroves restoration: A contingent valuation analysis. *Ocean and Coastal Management*, 51(6), 476–484. <https://doi.org/10.1016/j.ocecoaman.2008.02.001>
- Susilo, H., Takahashi, Y., & Yabe, M. (2017). The opportunity cost of labor for valuing mangrove restoration in Mahakam Delta, Indonesia. *Sustainability (Switzerland)*, 9(12). <https://doi.org/10.3390/su9122169>
- Thuy, P. T., Hue, N. T., & Dat, L. Q. (2024). Households' willingness-to-pay for mangrove environmental services: Evidence from Phu Long, Northeast Vietnam. *Trees, Forests and People*, 15(November 2023), 100474. <https://doi.org/10.1016/j.tfp.2023.100474>
- Truong, D. D. (2021). Villagers' Perception and Attitude Toward Wetland Values and Conservation in Vietnam: A Case Study of Xuan Thuy Ramsar National Park. *Frontiers in Sociology*, 6(December), 1–11. <https://doi.org/10.3389/fsoc.2021.763743>
- Ullah, A., Sam, A. S., Sathyan, A. R., Mahmood, N., Zeb, A., & Kächele, H. (2021). Role of local communities in forest landscape restoration: Key lessons from the Billion Trees Afforestation Project, Pakistan. *Science of the Total Environment*, 772, 145613. <https://doi.org/10.1016/j.scitotenv.2021.145613>
- Vietnam National Assembly. (2017). *Law on Forestry*.
- Zhang, Y., Xiao, X., Cao, R., Zheng, C., Guo, Y., Gong, W., & Wei, Z. (2020). How important is community participation to eco-environmental conservation in protected areas? From the perspective of predicting locals' pro-environmental behaviours. *Science of the Total Environment*, 739(155), 139889. <https://doi.org/10.1016/j.scitotenv.2020.139889>

Institutionalization of the Livelihood Network Program (iLivePro): A Policy Option to Support Alternative Livelihoods for Fishers in Surigao del Norte, Philippines

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Abstract

Marine Protected Areas (MPAs) play a crucial role in fisheries management and food security, with a potential long-term benefit of 20 percent increase in future fish catch through spillover effects (Cabral et al., 2020). With fish providing nearly 20% of animal protein intake for 3.3 billion people and supporting the livelihoods of approximately 10-12% of the global population (FAO), the economic and nutritional significance of “blue foods” cannot be overstated. However, MPAs often impose socio-economic trade-offs, particularly for small-scale fishers comprising 91% of the sector’s workforce (World Bank). To address these challenges, MPAs must be integrated into broader fisheries management frameworks that balance conservation objectives with economic resilience, stakeholder engagement, and equitable resource access (Weigel et al., 2014). This paper dissects the proposed policy alternative which institutionalizes the Livelihood Network Program (iLivePro), a market-based and multi-institutional intervention that aims to mitigate the economic externalities of establishing an MPA by promoting livelihood diversification and sustainable resource use in Surigao del Norte. Anchored in the blue food system framework, iLivePro supports fisherfolk in transitioning to alternative economic activities such as ecotourism, small-scale aquaculture, and resource-based enterprises, reducing dependence on overexploited marine resources while enhancing economic resilience. Further, iLivePro aligns with global sustainability frameworks and national policies, transforming MPAs from potential drivers of socio-economic disruption into catalysts for sustainable blue growth. The successful institutionalization of iLivePro can serve as a replicable model for reconciling marine conservation with economic development, fostering long-term food security, and advancing a resilient blue economy in the Philippines.

Keywords: Marine Protected Areas, blue economy, livelihood diversification, fisheries management, and sustainable resource use

JEL code: Q22, Q56

SDG classification: SDG 1, SDG 2, SDG 10, SDG 11, SDG 14

Introduction

Over the years, the establishment of a marine protected area (MPA) has been one of the well-studied and promoted effective fisheries management to address decline of biodiversity and fish stocks (Sanchirico et al., 2002; Tupper et al., 2015; Kriegl et al., 2021). The benefits derived from a well-managed MPA, such as enhanced biodiversity, ecosystem services, and cultural value, are non-excludable and non-rivalrous, and often accrue over the long term. As such, establishing an MPA may result in a market failure, primarily because of its characteristics as public goods, externalities, and the absence of well-defined property rights. Specifically, fisheries lack well-defined and enforceable property rights making exclusive control over marine resources a challenge. Without clear property rights, there is little incentive for individual actors (or resource users) to invest or support in the restrictions implemented upon the establishment of MPA (TGCC, 2017). Resource users, driven by short-term economic interests, may prioritize immediate gains over long-term sustainability. This temporal mismatch in incentives can lead to underinvestment in conservation efforts or non-compliance with restrictions. Addressing these market failure aspects requires interventions beyond the traditional market mechanism. Multi-institutional, participatory, and innovative solutions are often necessary to overcome these challenges and ensure the sustainable management of marine resources within protected areas.

Fish stocks have been declining by an average of 20 percent over the past decade due to overfishing from expanding population, unregulated extraction, destructive fishing methods, habitat deterioration from anthropogenic (destructive fishing practices, pollution, and irresponsible coastal developments), and natural (climate change, boom of invasive species) disturbances are seriously threatening the fishery with collapse beyond recovery unless urgent actions are taken (FAO 2009, 2022; Chu & Karr, 2017; Licuanan et al., 2019;). Coastal communities in the Philippines are exceedingly dependent on a single resource, such as fish resource, and are vulnerable to economic shocks. The high pressures from 'expanding' fishing population and reliant to fisheries as source of protein is a pressing issue.

Decadal studies had shown the need to diversify the source of income of fishing households. Economic activities like ecotourism, sustainable agriculture, or small-scale enterprises may enhance economic resilience, mitigating the adverse effects of fluctuating fish stocks. While government-initiated programs have minimal adoption and success rates. (Technology incubation and verification), effective resource management often requires the active involvement of those directly dependent on these resources (Agrawal & Gibson, 1999; Ulrich, 2014).

Role. As defined by Kelleher (1999), marine protected area (MPA) is “any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical, and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment”. MPAs play a pivotal role in the sustainable management and conservation of the Philippines' rich marine biodiversity. MPAs in the Philippines primarily intends to conserve and protect marine ecosystems, including coral reefs, seagrasses, and diverse marine species. The Philippines is recognized as a global biodiversity hotspot, hosting a vast array of marine species. MPAs act as sanctuaries that safeguard this biodiversity, providing a refuge for endangered species, supporting fisheries replenishment, and contributing to overall ecosystem health. The establishment and management of MPAs in the Philippines are governed by the National Integrated Protected Areas System (NIPAS) Act of 1992. This legal framework provides the basis for the creation, administration, and protection of terrestrial and marine protected areas.

Policy makers and other fishery management bodies can optimize the sustainability goals in fisheries by not only relying on a single management theme in each fishery, by improving focus on large scale fishers, by incorporating underexplored sustainability indicators, and by adapting current trends and proven-to-be effective management themes (Zondervan and Zondervan, 2022). Successful coastal resources and fisheries management is often achieved in community-based managed areas where there is strong community support and unity along with leadership with strong political will.

Prior efforts. Establishment of marine protected areas (MPAs) has been considered by many as among the most effective means to mitigate the impacts of overfishing and arrest further deterioration of coastal ecosystems. Recently, there have also been increasing works toward MPA networks that incorporate connectivity, both social (e.g., sharing of experiences and resources) and biophysical (e.g., larval dispersal, adult home range) in MPA establishment, to increase the effectiveness and efficiency of MPA management. However, there have been issues with equity and undesirable socioeconomic implications in MPA establishment as often, too much emphasis has been placed on the state of the resources and less on the socioeconomic considerations resulting in further displacement of the resource users particularly the poor fishers. Some displaced fishers would oppose MPA establishment, especially where alternative livelihood opportunities are lacking, because of its immediate economic implication as affected fishers would have to exploit farther fishing grounds.

The table below presents three existing policies that lay the foundation for fisheries management and sustainable development in the country. RA 8550 as amended by RA 10654, EO 72, and MC 54 lay a foundation for fisheries management and sustainable development, these policies primarily concentrate on conservation, management, and regulation of fisheries and may not adequately address the socio-economic aspects of transitioning fishers to alternative livelihoods. This then may cause the delay of accomplishing the objective of MPA specially the social impact is expected in the long term.

The Livelihood Network Program will specifically target and design livelihood diversification to cater to the specific needs of fishers in Surigao del Norte as it recognizes the importance of localized strategies, considering the unique challenges and opportunities of the region. Institutionalizing a livelihood network puts a strong emphasis on community participation and empowerment, aiming to involve fisherfolk in the decision-making process regarding alternative livelihoods. This is a specific approach not explicitly outlined in existing policies. Moreover, RA 8550 and EO 72 aims to promote sustainable development but may lack specific provisions for a comprehensive support system to facilitate the shift to alternative livelihoods. The network shall provide a holistic support framework, including training, financial assistance, and market linkages. Meanwhile, MC 54's moratorium on commercial vessel licenses aligns with the broader goal of preventing overfishing. Thus, this network integrates enforcement strategy providing an avenue for affected fishers to explore sustainable economic activities during the license moratorium period.

The iLivePro program as a fisheries management strategy will establish mechanisms for collaboration between national and local authorities to ensure effective implementation of both existing policies and iLivePro and secure funding to enhance the capacity of local institutions in Surigao del Norte to administer and sustain the program activities. The iLivePro initiative fills crucial gaps in the existing policy landscape by offering a targeted and community-driven approach to fisheries management and sustainable livelihoods in Surigao del Norte. Recognizing and supporting this initiative is pivotal for achieving a

balanced and inclusive approach to the conservation of aquatic resources and the well-being of fishing communities.

Table 1. List of fisheries-related policies and salient features related to the policy proposed.

Fisheries-related policies	Salient features
RA 8550 – Philippine Fisheries Code of 1998 as amended by RA 10654 (2015)	• Provide the legal framework for the conservation and management of fisheries and aquatic resources in the Philippines. • Define rules for fisheries management, resource conservation, and protection. • Addresses IUU fishing activities. • Specifies the guidelines for sustainable fishing practices.
EO 72 – Institutionalizing the Philippine Agenda for Sustainable Development for the Seas of Mindanao, Sulu, and Celebes Sea (1993)	• Focuses on sustainable development in specified maritime areas, including Mindanao, Sulu, and Celebes Seas. • Emphasizes integrated coastal management. • Aims to address issues such as overfishing, habitat destruction, and pollution. • Supports sustainable development goals for maritime regions.
MC 54 – Moratorium on the issuance of Commercial Vessel Licenses (1993)	• Imposes a temporary suspension on the issuance of new licenses for commercial fishing vessels. • Intended to prevent overfishing and promote sustainable fisheries management. • Forms part of broader efforts to address the depletion of fishery resources.

Programs and Projects that highlights livelihood aspect of the fishing community

- A. Fishery Sector Program (1989-1996)
- B. Fishery Resource Management Project (1998-2006)
- C. Sustainable Management Coastal Resources Project (2007-2010)
- D. Regional Fisheries Livelihoods Program (2009-2013)
- E. Livelihood Enhancement for Agricultural Development Program (2000)
- F. Community-based Rural Tourism Project (2004-2016)

The list of programs presented above collectively underscores historical commitment of the government to sustainable fisheries management and community development in the Philippines. Emphasizing principles of sustainability, community engagement, and livelihood diversification, these initiatives have laid the groundwork for the proposed livelihood network model. The historical trajectory reflects a growing awareness of the need to balance ecological conservation with the socio-economic well-being of fishing communities. As the policy concept seeks to institutionalize the Livelihood Network Program (iLivePro) in support of alternative livelihood options for fishers in Surigao del Norte, it aligns seamlessly with the overarching goals of these past programs. The proposed program builds upon the lessons learned, aiming to enhance community resilience, diversify livelihoods, and foster sustainable practices, thus contributing to the continued evolution of fisheries management in the Philippines.

Specifically, Fishery Sector Program (1989-1996) emphasized sustainable fishing practices and resource management to ensure long-term viability of fisheries, aligning with the principles of the proposed livelihood network model; Fishery Resource Management Project (1998-2006), prioritized the conservation of fishery resources, addressing concerns related to overfishing, habitat degradation, and depletion and implemented measures to support the livelihoods of fishing communities, setting a precedent for considering economic aspects in fisheries management; Sustainable Management Coastal Resources Project (2007-2010) is an integrated coastal management approach emphasizing sustainable practices and aligning with the holistic perspective of the proposed livelihood network model; Regional Fisheries Livelihoods Program (2009-2013) incorporated resilience-building measures, an essential aspect that the proposed model aims to enhance; Livelihood Enhancement for Agricultural Development Program (2000) promoted diversification of agricultural activities, showcasing a holistic approach similar to the proposed livelihood network model; and Community-based Rural Tourism Project (2004-2016) strengthen and supported ecotourism as an alternative livelihood (Courtney & Jhaveri, 2017; BFAR CNFIDP, 2016; CTI-CFF, 2013; Terje et al., 2020).

Methodology

The paper adopted the Policy Analysis Framework of Dunn (2017) with modifications to evaluate the proposed institutionalization of the Livelihood Network Program (iLivePro) as a policy option for mitigation the socio-economic trade-offs of Marine Protected Areas (MPAs) and enhancing fisherfolk resilience and promoting sustainable blue economy in Surigao del Norte, Philippines.

Results and Discussion

Problem structuring

Scope and severity of the problem

Establishment of MPAs in Surigao del Norte without the proposed Coastal Livelihood Network may result to further marginalization of the poor fishers could pose more serious problems in coastal communities – ‘displaced’ fishers may face economic challenges, loss of income and may resort to potentially unsustainable resource-based livelihood activities. It may also result in changes in access rights to marine resources within and around the

MPA that may cause conflicts over resource access, particularly if traditional fishing grounds are restricted. Figure 1 presents the policy argument structure for the problem structuring.

Lack of alternative livelihood opportunities may hinder the successful transition of displaced fisherfolk to new income-generating activities. Without viable alternatives, affected communities may struggle to cope with the economic implications of restricted fishing. Disruption of social and cultural practices linked to fishing traditions can also result to loss of cultural identity and social cohesion, affecting the overall well-being of the community. Inadequate enforcement of MPA regulations and low community compliance, illegal fishing may persist, undermining the conservation goals of the MPA.

In the absence of the Livelihood Network Program (iLivePro), negative externality may arise causing irreversible consequence in the long run like increase vulnerability of the marine ecosystem to disease, coral bleaching, and other environmental stressors, negatively affecting biodiversity. Loss of valuable food sources, disruption of the marine food web, and potential economic hardship for communities dependent on fisheries among few. There may also be overexploitation of fish stocks ecosystem imbalance, increased conflicts over marine resources, risk of stagnation in 'localized' economic growth, reduced livelihood options, increased vulnerability to economic shocks, hinder community development, reduced effectiveness of support programs, and increase dependency on unsustainable practices.

Further, limited community involvement in the decision-making process or lack of participation in the MPA management may lead to resistance, non-compliance, and reduced effectiveness of MPA. Empowering communities through participation can foster a sense of ownership and responsibility. Local communities may experience conflicts over resource access, particularly if traditional fishing grounds are restricted. Clear communication and negotiated access rights are crucial because the disruption of social and cultural practices linked to fishing traditions may hinder community support. Loss of cultural identity and social cohesion can occur, affecting the overall well-being of the community. Inadequate enforcement of MPA regulations and low community compliance. Illegal fishing may persist, undermining the conservation goals of the MPA. Effective enforcement mechanisms and community education are critical. Increased tourism in and around the MPA. While tourism can provide economic opportunities, it may also lead to environmental degradation, competition for resources, and changes in local dynamics. Sustainable tourism management is essential. Vulnerability of communities overly dependent on fisheries to economic shocks. Communities without diversified income sources may struggle during periods of fluctuating fish stocks. Promoting economic resilience through alternative livelihoods is crucial.

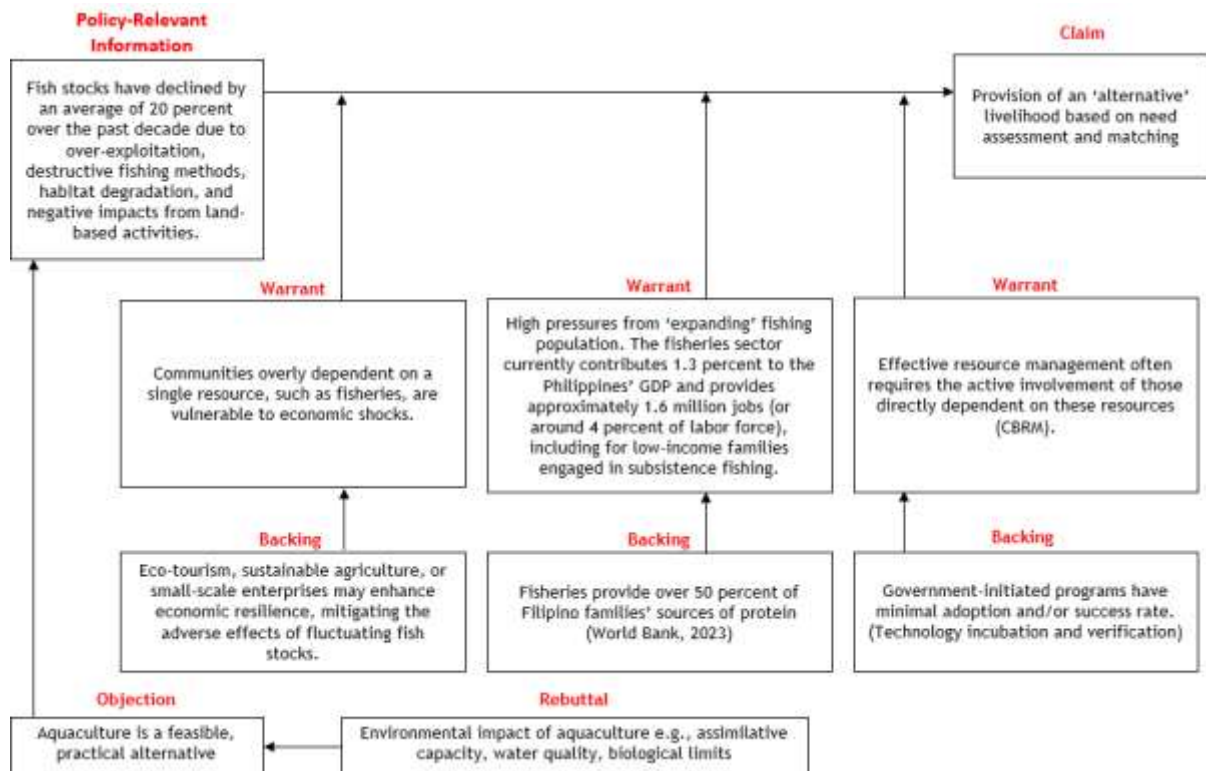


Figure 1. Policy argument structure for the problem restructuring

Problem statement

Alarming decline of fish stock for the target species, indicator species, and major species alongside the deterioration of marine ecosystem e.g., coral reefs. The social and psychological stress resulting from the conflict of resource use and displacement of fishers has environmental, social, and economic implications. – total well-being of the community. Uncertainty and transition during the shift of location (farther from the “traditional” fishing ground, may imply higher fishing cost) or the kind of activity (another kind of livelihood) for the source of food and income.

Major stakeholders have direct influence or impact in the successful implementation of this coastal livelihood network. Collaborative governance networks between resource managers, community groups, non-governmental organizations strengthen the social connectivity. These include regulating agencies e.g., DENR, BFAR, and funding government agencies, industry partners, local government units, utilities provider, barangay council, resource users e.g., fishers, tourist.

The Livelihood Network Program will provide a holistic multi-institutional support to the fisher directly affected by the restrictions imposed upon the establishment of a marine protected area. The support will provide a venue that will capacitate the fishers to participate in the enterprise development and skill-based employment resulting to a more stable and reliable source of household income. As fishers earned income not derived from fish specific-resource and unsustainable fishing practices, this will lessen fishing pressure in the area and promote cooperation towards coastal protection and management.

Consequently, the decline in the fishing effort will improve reef health condition (i.e., percent coral cover), substantially increase fish stock of reef fish (target, indicator, and major species), and decrease cases of IUU fishing practices e.g., poaching within the MPA area. The collaboration among MPA partners shall improve community participation in resource management by creating a sense of ownership resulting to voluntary compliance and cost-effective enforcement strategy

Forecasting and Recommendation

Description of the policy alternative

In the absence of the Livelihood Network Program, negative externality may arise causing irreversible consequence in the long run. The iLivePro ensures that absence of alternative livelihood option may decrease vulnerability of the marine ecosystem to disease, coral bleaching, and other environmental stressors, negatively affecting biodiversity. Loss of valuable food sources, disruption of the marine food web, and potential economic hardship for communities dependent on fisheries bombards fishing communities. Overexploitation of fish stocks ecosystem imbalance, and increased conflicts over marine resources. Risk of stagnation in 'localized' economic growth, reduced livelihood options, increased vulnerability to economic shocks, heighten conflict over resource use, weakened resilience to environmental changes, and increased pressure on enforcement agencies. Hinder community development, reduce effectiveness of support programs, and increase dependency on unsustainable practices.

Description of the policy

The Coastal Livelihood network is a multi-institutional livelihood network program that will provide access to opportunities through enterprise development and employment. It involves series of activities that will include the following:

- a) "Multi-Institutional" collaboration.
- b) Identification and institutionalization through an organizational structure among "target" or "pre-selected" stakeholders/MPA partners to encourages mutually beneficial planning, decision-making, and implementation of the specific programs to achieve the objectives.
- c) This collaboration ensures streamlining of goals and processes within and among government and non-government institutions with the same mandates – thus, it avoids duplication of efforts and enhances the overall effectiveness of the policy.
- d) Science-based Needs Assessment – participatory livelihood assessment with the intention to match product-skills-services with existing demand in the market.
- e) Matching – the policy is a tailor-fit (resource-based, site-specific, governance-specific) livelihood option that will address the unique needs and aspirations of the displaced fish-resource users. The network shall be a community of MPA partners who agree and commit to contribute their knowledge and skill expertise, grants, governance, and data that will capacitate fishers 'turned' into micro-entrepreneurs and industry workers secure a sustainable income outside fishing – as an incentive to their participation in the sustainable management of their own marine protected area.

- f) The policy shall institutionalize the implementation of a three-year livelihood program by phase.

Policy recommendation

The declining fish stocks and deterioration of marine ecosystems in Surigao del Norte necessitate a holistic approach to address the socio-economic, environmental, and cultural implications of establishing marine protected areas (MPAs). The proposed Livelihood Network Program (iLivePro) recognizes the challenges posed by MPA establishment, including potential displacement of fishers and lack of alternative livelihoods. The market failure aspects associated with public goods, externalities, and unclear property rights underline the need for multi-institutional and participatory solutions. iLivePro aims to provide holistic support to fishers affected by Marine Protected Area (MPA) establishment through multi-institutional collaboration, tailored livelihood options, and community participation. The policy seeks to diversify livelihoods, reduce fishing pressure, and enhance environmental conservation within the MPA, emphasizing a structured three-year program for long-term success. Figure 2 presents the activities, inputs, partners, and success indicators for the implementation of the program when institutionalized.

Month 1 to Month 6 (3-6 months)	Month 7 to Month 13 (8 months)	Month 14 to Month (36 months)
Activity: • "Multi-Institutional" collaboration • Identify potential funding sources, including government budgets, grants, private sector investments, and international aid. • Propose a sustainable funding model for the policy initiatives. Inputs: • Partner's Commitment thru MOA, MOU, MOP agreed and signed List of 'target' partners: • Government agencies (regulating e.g., DENR BFAR), • Non-government organizations and international groups • Academe • Industry partners • Local government and barangay units Success Indicators: • Number of MOA, MOU, MOP signed (with explicit roles and responsibilities specified)	Activity: • Science-based Needs Assessment • Needs Matching Inputs: • Conceptual Framework and Methods • Training Module • Communication, Education, and Public Awareness (CEPA) Materials List of 'target' partners involved: • GAs, NGOs, IP for funding support • Academe for technical expertise • LGUs and BC for field assistance and community participation. Success Indicators: • Completed terminal report (guidelines for the capacity-building) • List of market for product, skills, and services that market needs • Number of trainings conducted required in the market • Number of community partners trained • % of employment (with reference on interventions)	Activity: • Feedbacking Inputs: • Program objectives (for review) • Market Facilitation List of 'target' partners: • Government agencies (regulating e.g., DENR BFAR) • Non-government organizations and international groups • Academe • Industry partners • Local government and barangay units Success Indicators: • Improved trend of reef health condition and fisheries • % Employment Facilitation • % Credit granted or accessed • % Product Development and Marketing

Figure 2. Phases of implementation

The institutionalization of iLivePro to address the displacement of stakeholders arising from the establishment of MPAs in Surigao del Norte presents a pathway for resilience and blue food economy to thrive. MPAs is a widely recognized marine and fisheries management approach, but with lack of appropriate support mechanisms, it can exacerbate the vulnerability of small-scale fishers and intensify socio-environmental

friction. This policy analysis adopting the framework of Dunn affirms that a successful marine and fisheries management approach must be transdisciplinary. iLivePro emerges as a timely and strategic policy response. In the problem structuring, when MPAs are established without alternative livelihoods, fishers face economic displacement, weaken social cohesion, and increased dependence on unsustainable practices. In the forecasting, the policy outcome highlights the risk of continue marginalization and environmental degradation. It mitigates the direct impact of externalities from establishing MPA and complements existing Philippine regulatory frameworks such as the Philippine Fisheries Code of 1998 (RA 8550), Executive Order 72, and Memorandum Circular 54, among others. The iLivePro policy alternative presents a replicable model of participatory governance and ecological-socioeconomic integration. It is merely an “add on” but an essential instrument for achieving the long-term success of MPAs in the Philippines.

Conclusion

The institutionalization of iLivePro presents a science-based and evidence-informed policy response to the socio-economic friction arising from the establishment of MPAs in Surigao del Norte. Adopting the PAF of Dunn, the iLivePro is scientifically, economically, and cohesively evident. From the scientific standpoint, a well-managed MPAs can increase fish biomass by 20% overtime, but this depends on reducing the fishing pressure during the recovery period. The proposed policy alternative supports ecological imperative by facilitating fisher's transition into sustainable livelihood alternatives such as tourism, aquaculture, and resource-based enterprises. In terms of economics, MPAs often result to negative externalities by limiting access to fishing grounds, disproportionately impacting small-scale fishers. With the iLivePro, this market failure is internalized by translating socio-economic cost into “need-skill matched” livelihood opportunities.

This policy alternative presents a science-based replicable model for marine and fisheries management that aligns with blue economic development goals, correcting distorted incentives, and ensuring equitable outcomes.

References

- Agrawal, A., & Gibson, C. C. (1999). Enchantment and Disenchantment: The Role of Community in Natural Resource Conservation. *World Development*, 27(4), 629–649.
- Bureau of Fisheries and Aquatic Resource (2016). Comprehensive National Fisheries Industry Development Plan (2021-2025) every 5 years (quinquennial). ISSN 2815-2131
- Chu, E. W., & Karr, J. R. (2017). Environmental Impact: Concept, Consequences, Measurement. Reference Module in Life Sciences.
- Courtney, C.A. & Jhaveri, N.J. (2017). Marine Tenure and Small-scale Fisheries: A Sourcebook on Good Practices and Emerging Themes. Washington, DC: USAID Tenure and Global Climate Change Program.
- Dunn, W.N. (1994) Public Policy Analysis an Introduction. Prentice Hall, Upper Saddle River. Scientific Research Publishing. (2019). Scirp.org.

- Dunn, W. N. (2017). *Public Policy Analysis*. Routledge.
- FAO Fisheries and Aquaculture Report No. 932 (2009). Report on the FAO/UNEP Expert Meeting on Impacts of Destructive Fishing Practices, Unsustainable Fishing, and Illegal, Unreported and Unregulated (IUU) Fishing on Marine Biodiversity and Habitats.
- FAO. (2022). *The State of World Fisheries and Aquaculture 2022*. FAO.
- Jones, P.J.S. (2014): *Governing Marine Protected Areas: Resilience through Diversity*. Abingdon, Oxon: Routledge.
- Kelleher G. (1999). *Guidelines for Marine Protected Areas*. Gland, Switzerland and Cambridge, UK: IUCN.
- Kriegel, M., Elías Ilosvay, X. E., von Dorrien, C., & Oesterwind, D. (2021). *Marine Protected Areas: At the Crossroads of Nature Conservation and Fisheries Management*. *Frontiers in Marine Science*, 8.
- Lester, J. P., & Wilds, L. J. (1990). The utilization of public policy analysis. *Evaluation and Program Planning*, 13(3), 313–319.
- Licuanan, W. Y., Cabreira, R. W., & Aliño, P. M. (2019, January 1). Chapter 23 - The Philippines (C. Sheppard, Ed.). ScienceDirect; Academic Press.
- Munyi, F. (n.d.). *The Social and Economic Dimensions of Destructive Fishing Activities in the South coast of Kenya*. Item Type Report.
- Sanchirico, J. N., Cochran, K. A., & Emerson, P. M. (2002). *Marine Protected Areas: Economic and Social Implications*. <https://www.cbd.int/doc/case-studies/inc/cs-inc-rf-04-en.pdf>
- Steadman, D. (2021). Towards ecological and social impact through collaborative governance of a seascape of marine protected areas in Honduras. *Oryx*, 55(4), 507-518.
- Terje Løbach, T., Petersson, M., Haberkon, E. and Mannini, P. 2020. Regional fisheries management organizations and advisory bodies. Activities and developments, 2000–2017. FAO Fisheries and Aquaculture Technical Paper No. 651. Rome, FAO.
- Tolentino-Zondervan, F., Zondervan, N.A. (2022). Sustainable fishery management trends in Philippine fisheries, *Ocean & Coastal Management*, Volume 223, 106149, ISSN 0964-5691.
- Tupper, M., Asif, F., Garces, L. R., & Pido, M. D. (2015). Evaluating the management effectiveness of marine protected areas at seven selected sites in the Philippines. *Marine Policy*, 56, 33–42.
- Ulrich, D. R. (2014). *Challenges to stakeholder participation in coastal resource management: Allen, Northern Samar, Philippines*. Oregon State University. 1-71.

Migration Decisions Among Agricultural Households and Their Implications for Livelihood Vulnerability and Food System Resilience in Indonesia

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Abstract

Migration decisions among agricultural households in Indonesia significantly influence livelihood vulnerability and food system resilience. The declining interest of rural youth in agriculture, driven by environment, socioeconomic factors, and aspirations for better opportunities, leads to increased migration. This trend impacts labor distribution, regional development, and household resilience. Guided by the New Economic Labor Migration (NELM) theory, this study explores migration as a household strategy for income diversification and risk mitigation. The research aims to identify migration patterns, analyze key influencing factors, assess the Livelihood Vulnerability Index (LVI) of migratory and non-migratory households, and evaluate the broader impact of youth migration on household vulnerability. The conceptual framework considers various determinants, including education, income, land tenure, and family size, while also examining the role of remittances in strengthening household financial stability and agricultural investment. Conducted in East Java, the study surveys 400 horticultural farmers using Slovin's formula. It applies descriptive analysis for migration distribution, logistic regression for migration determinants, multiple regression for influencing factors, and Propensity Score Matching (PSM) to assess migration's impact on vulnerability. Findings from this study will offer valuable policy insights into rural labor retention, financial inclusion, and adaptive strategies for enhancing agricultural sustainability. Understanding migration's role in livelihood vulnerability can guide interventions to strengthen rural resilience and food security.

Keywords: migration, livelihood vulnerability, agricultural households, rural youth, and remittances

JEL code: Q01, O15

SDG classification: SDG 1, SDG 10, SDG 13

Introduction

The agricultural sector is critical to ensuring global food security, rural development, and poverty reduction. However, demographic trends show a continuous reduction in the number of young people seeking careers in agriculture, with many choosing alternate options in cities or non-agricultural sectors. This trend is affected by a variety of causes, including shifting socioeconomic dynamics, perceptions of agriculture as a low-status career, restricted access to resources and technology, and ambitions for improved living conditions.

Out-migration of young people is a common feature in most rural areas in both developed and developing countries. Out-migration also happens because of a lack of prospects in the local labor market, particularly in rural areas undergoing economic collapse (Stockdale, 2006). Particularly highly educated youth tend to move away from these places (Thissen et al., 2010). Therefore, migration has the potential to bring in or eliminate human resources, so that regional development prospects cannot be separated from the current migration process (Stockdale, 2006).

The New Economic Labor Migration (NELM) theory represents a significant shift from traditional views on migration by emphasizing the role of household strategies rather than individual decisions. Unlike classical economic theories focusing solely on wage differentials and employment opportunities as the primary drivers of migration, NELM highlights the importance of broader socio-economic factors and the collective decision-making processes within households. According to NELM, migration allows families to diversify their income sources, mitigate risks associated with local economic conditions, and improve their overall financial stability. This theory also considers the impact of remittances on regional economies, suggesting that money sent back by migrants can contribute to development and poverty reduction in their home communities. By integrating these broader considerations, NELM provides a more comprehensive understanding of the complexities behind labor migration and its multifaceted effects on both sending and receiving regions.

The availability of farm laborers in Indonesia is currently mostly at the age of 45 years and over, with a low average education and still using conventional farming methods. Data from the Extension and Agricultural Human Resource Development, Ministry of Agriculture states, that there is a decrease in agricultural labor absorption of 0.64% per year (Indonesian Ministry of Agriculture, 2023). This shows that the interest of young workers in this sector is very poor, where young workers prefer to work in other sectors such as industry and trade which resulted in the amount of young labor migration from village to city, increasing the unemployment rate. According to (Bezu & Holden, 2014), youth unemployment is an increasingly international challenge. The social and economic crisis is not only in rural areas but also in urban areas, where the number of migrating youths is increasing rapidly.

Based on data on the education level of youth who migrate, the majority of them have a lower-middle level of education. A total of 36% of youth are high school graduates, followed by 17% of junior high school graduates and 17% of elementary school graduates. Meanwhile, 11% of youth did not complete primary education, and 3% never attended school at all. On the other hand, only 4% have a Diploma degree, 11% have a Bachelor's degree, and very few, namely 1%, continue to the Postgraduate level (Statistic of Migration, Indonesia, 2024). This data shows that most of the migrating youth come from groups with relatively low levels of education, which can have an impact on their limited access to formal jobs with high wages. As a result, remittances sent home tend

to be smaller than those sent to migrants with higher levels of education. These low remittances can hinder the welfare of recipient households and prolong the cycle of economic dependence on low-educated labor migration.

Based on this case, the existence of this research hopes to know the factors that Java and the interest of the community to work on the agricultural sector in East Java. Knowing these factors can be a policy recommendation to the government to improve and reallocate labor absorption to the agricultural sector. According to (D'Antoni et al., 2012) government policy can be the right choice to slow the drift of youth, a more educated workforce of the agricultural labor force, and preserve the migration of the next generation of farmers from agriculture. Thus, specifically, the objectives of this research are to know the dynamics of labor in the agricultural sector in East Java, analyze the factors that influence the interest of the people in the agricultural sector in East Java and formulate policies to attract labor to the agricultural sector.

The general objective of the present study was to identify and analyze the factors of youth migration and their impact on the vulnerability of farming households. The specific objectives of this study are:

- 1) To identify the respondents' distribution of migration decisions.
- 2) To examine the respondents' social, environmental, economic, and political factors level that influence the decision to migrate or stay in the agricultural sector.
- 3) To assess the Livelihood Vulnerability Index (LVI) of migratory and non-migrating farming households.
- 4) To analyze the impact of rural youth migration on the vulnerability status of farming households.

Theoretical and Conceptual Framework

The theoretical framework of the study integrates the sustainable livelihood approach (SLA) and the new economics of labor migration (NELM) to analyze migration decisions and their impact on livelihood vulnerability. The SLA framework, as proposed by DFID (1999), emphasizes that livelihood outcomes are shaped by various vulnerability contexts, including climate change and drought. These vulnerabilities interact with background factors, such as sociocultural, economic, political, and environmental conditions, which influence the availability of capital/assets. Households then adopt specific livelihood strategies, which ultimately determine their level of vulnerability-whether it improves or worsens.

Complementing this, the NELM framework (Stark & Bloom, 1985) explains migration as a decision influenced by social, economic, and environmental factors, as well as individual and family-level considerations. This perspective highlights that migration is not purely an individual choice but a household strategy to diversify income sources and mitigate risks. The decision to migrate or stay is linked to financial outcomes: migrants may send remittances, improving household resilience, or they may not, leaving families without additional financial support. These two theoretical perspectives are interconnected, as migration decisions directly impact household livelihood strategies and, consequently, their vulnerability status. The framework thus provides a holistic view of migration as both an economic and survival strategy within rural agricultural households.

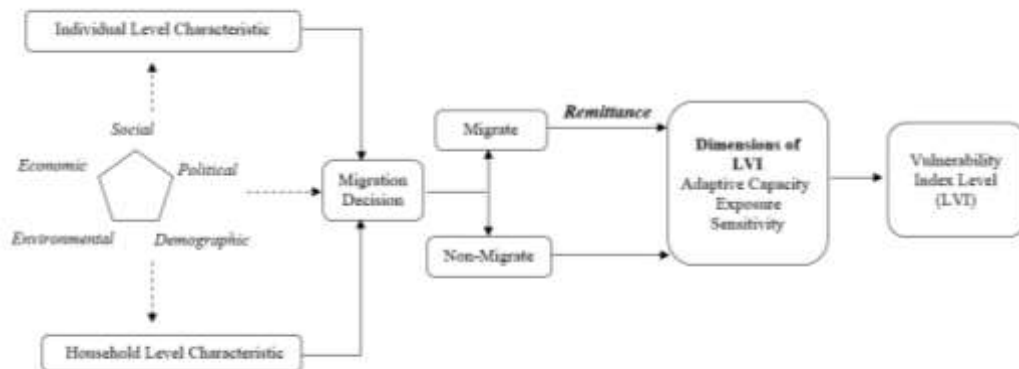


Figure 1. Conceptual Framework for Study on Migration Decision Among Agriculture Households and its Impact on Farmer's Vulnerability Livelihood in Indonesia

Source: Authors' own illustration based on the literature

Methodology

This research will be conducted in September-November 2025. This study uses multi-stage cluster sampling to determine the research location of this study. This method selects clusters (groups) in several successive stages, usually from larger and more general groups to smaller and more specific groups. The first step is choosing the provinces using judgment sampling. Three provinces are chosen considering that they have the highest farmers number in Indonesia, and the result is East Java.

The total number of crops and horticultural farmers in East Java provinces is 5,364,878 people. Using a formula of Slovin with an error tolerance of 5% (0,05), we got the number of samples needed in this study is $399,97 \approx 400$ farmers. This number will be distributed based on the percentage of the population in each subsector, as follows:

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{5,364,878}{1 + 5,364,878 (0.05)^2} = 399,97 = 400$$

The sampling designs and sampling procedure

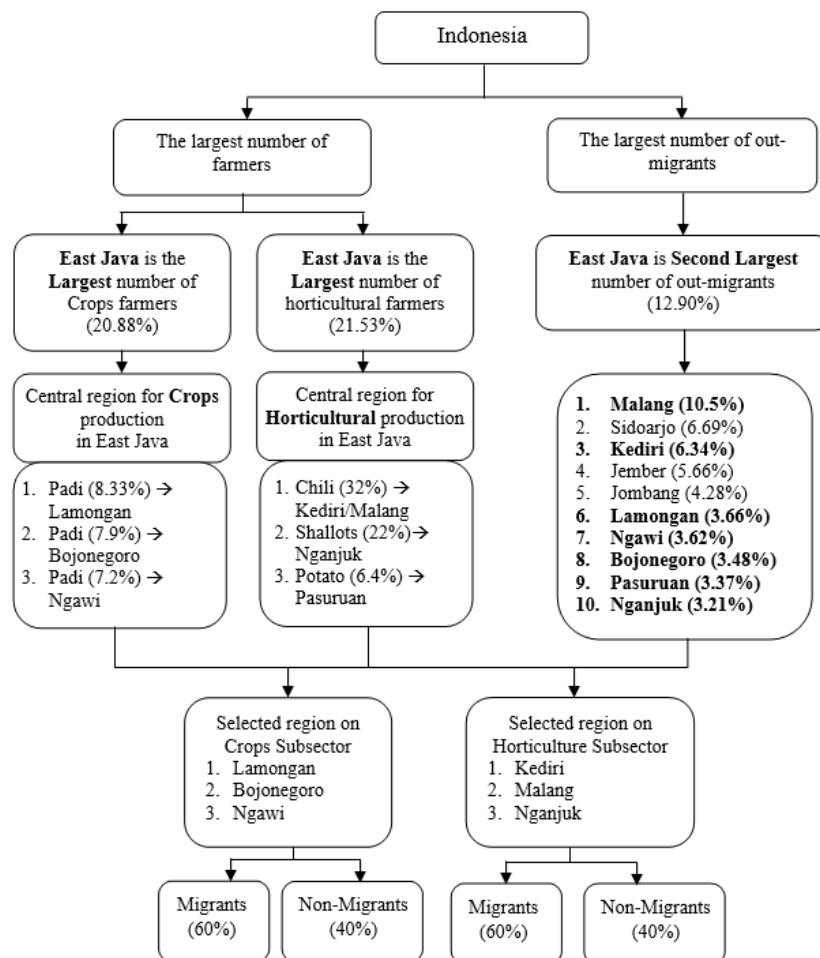


Figure 2. Sampling Design

Source: adopted from (Iwuanyanwu et al., 2017)

In the second stage of sampling an equal number of households were selected at random from each of the remaining three strata. This number was determined by a rule that in this study designed to create roughly equal probabilities of selection across communities of different sizes. The table 3.3 presents data on the number of samples collected across different provinces in Indonesia, focusing on both horticultural and crop farming households. The total number of samples surveyed is 402, categorized into two groups: households with migration (60%) and households without migration (40%).

For horticultural commodities, a total of 156 samples were collected from three districts: Kediri/Malang (Chili), Pasuruan (Potato), and Nganjuk (Shallots). Each district contributed 52 samples, with 31 households experiencing migration and 21 households without migration. For crop farming, a total of 246 samples were collected from three districts: Lamongan, Ngawi, and Bojonegoro, all producing paddy. Each district contributed 82 samples, with 49 households experiencing migration and 33 households without migration. The distribution of migration and non-migration households follows a fixed proportion, where 60% of the households in each category reported migration, while

40% did not. This dataset serves as a foundation for analyzing the impact of migration on farming households and their livelihood vulnerability.

Data Analysis Techniques

Labor supply is a function of wages therefore the amount of labor supplied will be influenced by the level of wages. Meanwhile, labor supply is influenced by a person's decision whether they want to work or not. This decision depends on a person's behavior to use the time, whether it used for work, or used for other activities that are comfortable or they have leisure time (unproductive but consumptive), or a combination of both. When associated with the wage rate, then the decision to work someone will be influenced also by the high low income of someone. If labor income is relatively high enough, then the workforce tends to reduce the time allocated for work (Guo et al., 2015).

The movement of agricultural labor to non-agriculture is influenced by various factors, both economic and non-economic factors (Tocco et al., 2012). The results of indicates that there are five groups of factors that influence the decision to move jobs from the agricultural sector to the non-agricultural sector namely: 1) individual characteristics (age, education, experience, gender, marital status, and ethnicity); 2) family characteristics (number of children, age of child, and family size); 3) characteristics of agricultural business (size of land tenure, size of farming, agricultural output, farming system, and agricultural productivity); 4) financial characteristics (non-occupational income, agricultural subsidies, social benefits, and non-fixed income); and 5) location characteristics and labor market (labor absorption rate, access to employment, population density, urbanization, and location of territory). Meanwhile, reallocating labor in a sector from fewer producers to more productive producers will increase output in that sector, change prices and relative income (Işcan, 2014).

a. Logistic Regression

A logistic model is a regression model specifically designed to handle regression analysis with a dependent variable in the form of a nominal variable whose dependent variable has a value of more than 1 expressed nominally. This research uses logistic model regression analysis which is needed to answer whether the components of individual characteristics, family characteristics, agricultural business characteristics, location characteristics, and financial characteristics influence decision-making to migrate or stay in the agricultural sector. The variables used in the model are as follows.

The model uses a binary dependent variable indicating whether a household has migrating members (1) or not (0). The independent variables include demographic factors such as youth age, gender, education, and marital status, as well as parents' age and education and household size. Social and spatial influences are captured through the number of migrating relatives and the distance to urban centers. Institutional and economic conditions are reflected in access to informal support, cooperative or private assistance, microfinance, farm size, land ownership, and household debt. Environmental factors include water or irrigation availability and the intensity of disasters experienced by the household. Together, these variables help explain the determinants of household migration decisions.

The probability response from the multinomial logit model with 2 alternative dependent variables is formulated as follows:

$$pr\left(y = \frac{j}{x}\right) = \frac{\exp(X_{\beta j})}{[1 + \sum_{j=1}^2 \exp(X_{\beta j})]}$$

Where j shows alternative choices of job interests desired by young people which include choices in: migrate and stay in agricultural sectors. Meanwhile, X is a vector that is expected to influence the four alternative choices, which include X_1 - X_{17} . Factors that are expected to influence include individual characteristics (age, education, student status, marital status, first child status); farming characteristics (amount of land owned); family characteristics (number of siblings, age of parents, education of parents, number of siblings who work in business, number of siblings who work in non-agriculture, and number of siblings who migrated).

b. Livelihood Vulnerability Index

Calculating the LVI: composite index approach. Ten major components were selected for inclusion in the LVI:

- 1) Natural Risk
- 2) Family Risk
- 3) Human Capital
- 4) Natural Capital
- 5) Physical Capital
- 6) Financial Capital
- 7) Social Capital
- 8) Health Status
- 9) Status of Food
- 10) Economic Pressures

Each major component is made up of several sub-component indicators. According to (Shreevastav et al., 2021) along with an explanation of how indicators were calculated, the survey question used to gather data for each indicator, the source for the inspiration for each question, and potential sources of bias for each indicator. The indicators chosen for this case study in Indonesia were based on a literature review of previous assessments of each of the major components and the practicality of collecting the needed information through household surveys.

Because each of the sub-components is measured on a different scale, it was first necessary to standardize each sub-component indicator as an index. The equation used for this conversion was adapted from the method used for the Human Development Index to calculate the life expectancy index which is the ratio of the difference of the actual life expectancy and a pre-selected minimum, and the range of pre-determined maximum and minimum life expectancy (UNDP 2007):

$$\text{index } S_d = \frac{S_d - S_{min}}{S_{max} - S_{min}}$$

In this formula, S_d is the original sub-component indicator in a district as collected through the household surveys and, because the goal of this assessment is to create a relative index for comparing vulnerability between the districts in the sample, the minimum and maximum values for each sub-component indicator ($S_{\min}$ and $S_{\max}$ respectively) were determined by the extremes of the entire study sample (in this case, both districts) for each indicator. After each sub-component indicator was standardized, the standardized indicators that make up each of the ten major components (M_d = Natural Risk (NR), Family Risk (FR), Human Capital (HC), Natural Capital (NC), Physical Capital (PC), Financial Capital (FC), Social Capital (SC), Health (H), Food (F), and Economic Pressure (EP)) were averaged together to calculate the value of each major component:

$$M_d = \frac{\sum_{i=1}^n \text{index } s_{di}}{n}$$

where index s_i are the indexed sub-component indicators for each district that make up each major component, M_d and n is the number of sub-component indicators in each major component.

Once values for each of the seven major components for each district were calculated, they were averaged together to obtain the LVI value for each district using the following formula:

$$LVI_d = \frac{\sum_{i=1}^{10} W_{M_i} M_{di}}{\sum_{i=1}^{10} W_{M_i}}$$

Or

$$LVI_d = \frac{W_{NR}NR_d + W_{FR}FR_d + W_{HC}HC_d + W_{NC}NC_d + W_{PC}PC_d + W_{FC}FC_d + W_{SC}SC_d + W_HH_d + W_FF_d + W_{EP}EP_d}{W_{NR} + W_{FR} + W_{HC} + W_{NC} + W_{PC} + W_{FC} + W_{SC} + W_H + W_F + W_{EP}}$$

where LVI_d , the livelihood vulnerability index in a particular district, equals the weighted average of the seven major components for each district. The weights of each major component, W_M , are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI (Sullivan et al. 2002). In this study, the LVI is on a scale from 0 (least vulnerable) to 0.5 (most vulnerable).

c. Propensity Score Matching

To analyze the impact of rural youth migration on the vulnerability status of farming households, this study begins by constructing a model of the factors influencing youth migration.

$$\text{Migration}_i = 1 (\alpha + \beta x_i + \varepsilon_i > 0)$$

In the equation above, where migration I represent the presence or absence of youth migration in fam household I , α refers to a constant term, β stands for an estimated coefficient, x_i is a control variable, and ε_i is a random disturbance term.

As stated above, we can observe households with migrants (remittance-receiving) and households with migrants (non-remittance-receiving) in the dataset. However, a simple

comparison of these two groups may lead to biased estimators because of a possible identification problem; unobserved determinants of poverty may be correlated with receiving remittances. Some authors use instrumental variables to overcome this problem; however, it is difficult to determine and test the correct instrument (López-Videla & Machuca, 2014).

In this type of method, each treated observation (remittance-receiving household) is matched to a fixed number of control observations (non-remittance-receiving household) based on a propensity score. With this approach, this analysis can calculate robust estimators to determine the effects of remittances on households' poverty levels. This method makes it possible to construct counterfactuals to find out what would happen to a remittance-receiving household's poverty level if the household does not receive remittances.

In matching estimators, two important assumptions are made: conditional independence assumption (CIA) (*unconfoundedness*) and common support. P_i^1 is referred to as the value of P if the household head receives remittances and P_i^0 otherwise for the receiving remittances households. Then the two assumptions can be formally expressed as:

$$(P_i^1, P_i^0)_{\pi} \mid X_i; \text{ and} \\ 0 < P(T_i = 1 \mid X_i) < 1$$

where T is a dummy variable indicating remittance-receiving remittance household (T=1, receiving remittance) and X is a set of socio-demographic variables.

where $P(X_i)$ is the propensity score or the probability of the observations to receive remittances given X. This matching method is known as propensity score matching. Basically, what this method implies is that if receiving remittances is independent of the observables covariates X_i , then it must be independent of $P(X_i)$. With this, the dimensionality problem is reduced to one dimension.

The propensity score is calculated using a probit model subject to all the observable covariates that may determine receiving remittances. We estimate each observation (T=1 and T=0) probability to receive remittances and then test for the balancing property ($P(X \mid T=1) = P(X \mid T=0)$). As suggested by (Heckman & Todd, 1997) some observations of the control group with weak common support are dropped to make inferences of causality. If the balancing property is not satisfied, then another specification of higher order terms and interactions of covariates are included in the probit model, until the balancing property is satisfied.

Once the propensity scores are estimated and the balancing property is satisfied, we estimate a univariate nonparametric regression to obtain the average treatment effect on the treated (ATT) between the remittance-receiving households and the non-remittance-receiving households, which can be defined as:

$$ATT = E_{\Delta_{\pi}} = 1 = EP_i^1 - P_{iTi}^1 = 1 = EP_{iTi}^1 - EP_{iTi}^0 = 1$$

This analysis uses three (3) types of matching criteria to obtain robust ATT. First, use a nearest-neighbor matching criterion, which matches remittance-receiving households with the closest propensity score of non-remittance-receiving households. Then, use a

kernel matching criterion, which uses a weighted average for non-remittance-receiving households to construct the counterfactual match for each remittance-receiving household (Khandker, S., 2010). Finally, we use a stratification criterion to match treated observations with control observations. This type of matching criterion separates observations into different strata and then matches similar observations within each stratum.

1. Significance / Contribution

The results of this research provide insight into the factors that influence migration at the individual and family levels as well as the impact of remittances in Indonesia on the level of household vulnerability. Findings obtained from the study will help to know the factors affecting the migration of agriculture households, which can be well used as baseline data for planning development for the agriculture sector, as well as formulating policy and measures to deal with problems likely to occur out of migration and the movement of labor out the agriculture sector.

When remittances flow to households, the funds are often used for daily consumption, education, health, and investment. In a more productive scenario, a portion of remittances can be invested in the small business and industrial sectors, which in turn creates jobs and improves people's livelihoods. With increased employment opportunities, migration rates may decrease as local people have better employment options within the country. Furthermore, with reduced migration rates, financial capital and human resources remain in the country, which strengthens the local economic structure. This can lead to the establishment of production and export-based communities, which not only reduces dependence on remittances but also increases the competitiveness of the local economy. Thus, this positive cycle leads to a more resilient economy and a more prosperous country. Therefore, this research can provide insights for policymakers in designing optimal strategies to utilize remittances as an instrument of sustainable regional economic development.

Migration decisions among agricultural youth and farm households are influenced by various socio-economic, demographic, and environmental factors. Understanding these factors is crucial in analyzing the dynamics of rural livelihoods and their vulnerability to economic and environmental stressors. Based on existing literature and empirical studies, several hypotheses have been formulated to explore the determinants of migration and its implications for rural households.

Table 2. Expected Result of Study

Codes	Hypothesis Statement	Functional Relationship	References
H ₁	Age of youth significantly influences toward decision-making to migrate	-	Nienkerke et al., 2023 Matsumoto et al., 2006 Nandy et al., 2021 Herrera, Catalina; Sahn, 2013 Ackah & Medvedev, 2012

Codes	Hypothesis Statement	Functional Relationship	References
H ₂	Gender of Youth significantly influences toward decision-making to migrate (<i>1=male</i>)	+	Matsumoto et al., 2006 Nandy et al., 2021 Herrera, Catalina; Sahn, 2013
H ₃	Education of youth significantly influences toward decision-making to migrate	+	Bezu & Holden, 2014a Bello et al., 2021 Nienkerke et al., 2023 Wafula et al., 2022 Matsumoto et al., 2006 Nandy et al., 2021
H ₄	Marital Status of Youth significantly influences toward decision-making to migrate (<i>1=single</i>)	+	Matsumoto et al., 2006 Nandy et al., 2021 Ackah & Medvedev, 2012
H ₅	Parent's age significantly influences toward decision-making to migrate	+	Wirakusuma et al., 2023 Mberu, 2006 Akhter et al., 2024 Akhter & Bauer, 2014 Ackah & Medvedev, 2012 Thorat et al., 2011
H ₆	Parental education significantly influences toward decision-making to migrate	+	Wirakusuma et al., 2023 Herrera, Catalina; Sahn, 2013 Ackah & Medvedev, 2012
H ₇	Family Size or number of siblings significantly influences toward decision-making to migrate	+	Wirakusuma et al., 2023 Islam & Guha, 2020 Thorat et al., 2011
H ₈	Number of relatives who migrated significantly influences toward decision-making to migrate	+	Islam & Guha, 2020
H ₉	Distance from farm to urban centers significantly influences toward decision-making to migrate	-	Matsumoto et al., 2006 Delazeri et al., 2022
H ₁₀	Households had access to informal support significantly influences toward decision-making to migrate		

Codes	Hypothesis Statement	Functional Relationship	References
H ₁₁	Households received support from cooperatives and private organizations significantly influences toward decision-making to migrate (<i>1=received support</i>)	+	Breitenbach & Foguesatto, 2023
H ₁₂	Households had access to microfinance significantly influences toward decision-making to migrate (<i>1=access to credit</i>)	-	Bello et al., 2021 Daudu et al., 2023b
H ₁₃	Area of farming owned significantly influences toward decision-making to migrate	-	Bezu & Holden, 2014a Bednařiková et al., 2016 Nienkerke et al., 2023 Wafula et al., 2022 Mberu, 2006 Matsumoto et al., 2006 Nandy et al., 2021 Akhter & Bauer, 2014 Ackah & Medvedev, 2012
H ₁₄	Household's land ownership significantly influences toward decision-making to migrate (<i>1=self-owned</i>)	-	Wirakusuma et al., 2023
H ₁₅	Household debt significantly influences toward decision-making to migrate (<i>1= has debt</i>)	+	Nienkerke et al., 2023
H ₁₆	Availability of water sources or irrigation significantly influences toward decision-making to migrate (<i>1=has access water resources</i>)	-	Nienkerke et al., 2023 Wafula et al., 2022 Ackah & Medvedev, 2012
H ₁₇	The intensity of disasters that hit households in one year (<i>1=yess</i>)	+	Islam & Guha, 2020
H ₁₈	Migratory farming households have higher LVI scores than non-migrating farming households	+	Banerjee et al., 2019
H ₁₉	Households receiving remittances from migrating family members were found to have significantly lower levels of vulnerability than	+	Wirakusuma et al., 2023 Banerjee et al., 2019

Codes	Hypothesis Statement	Functional Relationship	References
	households not receiving remittances		

Conclusion

The study underscores that migration among agricultural youth and households in Indonesia is a multifaceted phenomenon driven by socio-economic, environmental, and institutional factors. Using the frameworks of Sustainable Livelihood Approach (SLA) and the New Economics of Labor Migration (NELM), this research positions migration not merely as a response to economic pressure but as a deliberate household strategy to diversify income and mitigate risks. The migration of rural youth, while offering financial relief through remittances, simultaneously affects household labor dynamics, agricultural productivity, and long-term food system resilience. Importantly, the findings reveal that households with migrant members generally exhibit different levels of vulnerability, depending on whether they receive remittances. This duality emphasizes the complex and often contradictory role of migration in shaping rural livelihood outcomes. The Livelihood Vulnerability Index (LVI) further highlights that migratory households may be more exposed to vulnerabilities, especially when remittances are irregular or insufficient. Therefore, while migration can be a survival strategy, its implications for sustainable agriculture and rural development demand careful policy consideration.

References

- Ackah, C., & Medvedev, D. (2012). Internal migration in Ghana: Determinants and welfare impacts. *International Journal of Social Economics*, 39(10), 764–784. <https://doi.org/10.1108/03068291211253386>
- Akhter, S., & Bauer, S. (2014). Household Level Determinants of Rural-Urban Migration in Bangladesh. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 8(1), 24–27. <https://pdfs.semanticscholar.org/1410/66abaca304b5b3a3104a826eae97742692a6.pdf>
- Akhter, S., Haque, S., & Nasrin, M. (2024). Data on the factors driving the decision of rural people to move into the city. *Data in Brief*, 53. <https://doi.org/10.1016/j.dib.2024.110037>
- Banerjee, S., Black, R., Mishra, A., & Kniveton, D. (2019). Assessing vulnerability of remittance-recipient and nonrecipient households in rural communities affected by extreme weather events: Case studies from South-West China and North-East India. *Population, Space and Place*, 25(2), 1–15. <https://doi.org/10.1002/psp.2157>
- Bednářiková, Z., Bavorová, M., & Ponkina, E. V. (2016). Migration motivation of agriculturally educated rural youth: The case of Russian Siberia. *Journal of Rural Studies*, 45, 99–111. <https://doi.org/10.1016/j.jrurstud.2016.03.006>
- Bello, L. O., Baiyegunhi, L. J. S., Mignouna, D., Adeoti, R., Dontsop-Nguezet, P. M., Abdoulaye, T., Manyong, V., Bamba, Z., & Awotide, B. A. (2021). Impact of youth-in-

- agribusiness program on employment creation in Nigeria. *Sustainability (Switzerland)*, 13(14), 1–20. <https://doi.org/10.3390/su13147801>
- Bezu, S., & Holden, S. (2014). Are rural youth in Ethiopia abandoning agriculture? *World Development*, 64, 259–272. <https://doi.org/10.1016/j.worlddev.2014.06.013>
- Breitenbach, R., & Foguesatto, C. R. (2023). Should I stay or should I go? Gender differences and factors influencing family farm business succession in Rio Grande do Sul, Brazil. *Land Use Policy*, 128(January). <https://doi.org/10.1016/j.landusepol.2023.106597>
- D'Antoni, J. M., Mishra, A. K., & Barkley, A. P. (2012). Feast or flee: Government payments and labor migration from U.S. agriculture. *Journal of Policy Modeling*, 34(2), 181–192. <https://doi.org/10.1016/j.jpolmod.2011.10.002>
- Daudu, A. K., Abdoulaye, T., Bamba, Z., Shuaib, S. B., & Awotide, B. A. (2023). Does youth participation in the farming program impact farm productivity and household welfare? Evidence from Nigeria. *Heliyon*, 9(4), e15313. <https://doi.org/10.1016/j.heliyon.2023.e15313>
- Delazeri, L. M. M., Da Cunha, D. A., & Oliveira, L. R. (2022). Climate change and rural–urban migration in the Brazilian Northeast region. *GeoJournal*, 87(3), 2159–2179. <https://doi.org/10.1007/s10708-020-10349-3>
- Heckman, J. J., & Todd, P. E. (1997). This content downloaded from 134.117.10.200 on Fri. *The Review of Economic Studies*, 64(4), 605–654.
- Herrera, Catalina; Sahn, D. (2013). *Determinants of Internal Migration Among Senegalese Youth*. February.
- Işcan, T. B. (2014). Allocative inefficiency and sectoral allocation of labor: Evidence from U.S. agriculture. *Economic Modelling*, 43, 305–320. <https://doi.org/10.1016/j.econmod.2014.08.006>
- Islam, B., & Guha, P. (2020). Factors affecting migration of labourers from domestic agriculture and its impact on household crop income in Assam. *Indian Journal of Agricultural Economics*, 75(4), 458–468.
- Iwuanyanwu, I., D., J. A. P., Njoku, C., Arc, T., Itu, P., & Erhabor, F. (2017). *Human Migratory Pattern : An Appraisal of Akpabuyo , Cross River State , Human Migratory Pattern : An Appraisal of Akpabuyo , Cross River State , Nigeria . July*. <https://doi.org/10.9790/0837-22070167991>
- Khandker, S., et al. (2010). Handbook on Impact Evaluation: Quantitative Methods and Practices. In *The World Bank* (Vol. 1, Issue 1).
- López-Videla, B., & Machuca, C. E. (2014). The Effects of Remittances on Poverty at the Household Level in Bolivia: A Propensity Score Matching Approach. *Políticas Públicas*, 2(1), 7–22. http://mpr.ub.uni-muenchen.de/55201/%5Cnhttp://mpr.ub.uni-muenchen.de/55201/1/MPRA_paper_55201.pdf
- Matsumoto, T., Kijima, Y., & Yamano, T. (2006). The role of local nonfarm activities and migration in reducing poverty: Evidence from Ethiopia, Kenya, and Uganda. *Agricultural Economics*, 35(SUPPL. 3), 449–458. <https://doi.org/10.1111/j.1574-0862.2006.00190.x>
- Mberu, B. U. (2006). Internal migration and household living conditions in Ethiopia.

- Demographic Research*, 14(June), 509–540.
<https://doi.org/10.4054/DemRes.2006.14.21>
- Nandy, A., Tiwari, C., & Kundu, S. (2021). India's Rural Employment Guarantee Scheme – How does it influence seasonal rural out-migration decisions? *Journal of Policy Modeling*, 43(6), 1181–1203. <https://doi.org/10.1016/j.jpolmod.2021.09.001>
- Nienkerke, I. M., Thorat, A., & Patt, A. (2023). From distress migration to selective migration: Transformative effects of agricultural development on seasonal migration. *World Development Perspectives*, 29(June 2022), 100483. <https://doi.org/10.1016/j.wdp.2022.100483>
- Shreevastav, B. B., Tiwari, K. R., Mandal, R. A., & Nepal, A. (2021). Assessing flood vulnerability on livelihood of the local community: A case from southern Bagmati corridor of Nepal. *Progress in Disaster Science*, 12, 100199. <https://doi.org/10.1016/j.pdisas.2021.100199>
- Stockdale, A. (2006). Migration: Pre-requisite for rural economic regeneration? *Journal of Rural Studies*, 22(3), 354–366. <https://doi.org/10.1016/j.jrurstud.2005.11.001>
- Thissen, F., Fortuijn, J. D., Strijker, D., & Haartsen, T. (2010). Migration intentions of rural youth in the Westhoek, Flanders, Belgium and the Veenkoloniën, The Netherlands. *Journal of Rural Studies*, 26(4), 428–436. <https://doi.org/10.1016/j.jrurstud.2010.05.001>
- Thorat, V. A. A., Dhekale, J. S. S., Patil, H. K. K., & Tilekar, S. N. N. (2011). Determinants of Rural-Urban Migration in Konkan Region of Maharashtra. *Agricultural Economics Research Review*, 24, 503–509.
- Tocco, B., Davidova, S., Bailey, A., Tocco, B., Davidova, S., & Bailey, A. (2012). Labour Adjustments in Agriculture: Evidence From Romania Labour Adjustments in Agriculture : Evidence From. *Studies in Agricultural Economics*, 116, 67–73.
- Wafula, W. M., Wasonga, O. V., Koech, O. K., & Kibet, S. (2022). Factors influencing migration and settlement of pastoralists in Nairobi City, Kenya. *Pastoralism*, 12(1). <https://doi.org/10.1186/s13570-021-00204-6>
- Wirakusuma, G., Prasada, I. Y., & Abdurofi, I. (2023). Impact of Migration on the Vulnerability of Poverty: a Case Study on the Agricultural Households in West Java Province, Indonesia. *International Journal of Business and Society*, 24(2), 576–590. <https://doi.org/10.33736/ijbs.5945.2023>

Empowering Women through Community-Based Livelihood Intervention to Improved Household Food Security and Strengthen Social Capital: The Case of Kiharong Women's Association in Maramag, Bukidnon, Philippines

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Abstract

Many people in the developing world continuously face food insecurity, resulting in challenges in meeting their food and nutrition needs. Addressing gender bias in the agriculture sector could be a key, yet insufficiently explored, avenue for driving sustainable agricultural growth. Women play a significant role in maintaining the pillars of food security—food production, food availability, and food accessibility. However, they continuously face enormous social, cultural, and economic constraints. This study aims to examine the outcomes of the Science and Technology Community-based for Inclusive Development (STC4iD) Program in empowering women to improve their access to and control over community resources, thereby strengthening relationships within households and communities. Employing surveys, interviews with key informants, focus groups, and reviews of secondary data as methods for data collection, the main objective is to assess the effectiveness of the community-based livelihood intervention in empowering women to improve household food security and build social capital. Results showed that the technical trainings improved participants' knowledge and promoted vegetable production in households, which also contributed to income generation. Social capital was strengthened, influenced by participants' main occupation, geographical location, and sources of income. The community-based livelihood intervention improved food availability and accessibility within households. The implementation of gender-sensitive social development programs, along with continuous community education and training, can effect changes in the social and economic situation of women and their communities.

Keywords: women empowerment, community development, food security, social capital, GESDA community

JEL code: O35, Q10, Q16

SDG classification: SDG 1, SDG 2, SDG 5, SDG 8, SDG 10

Introduction

“If women in rural areas had the same access to productive activities as men, agricultural land and farming production would increase and we could feed approximately 150 million more people” (FAO, 2011)

Women comprise approximately 49.72% of the global population and play vital roles as food producers, natural resource managers, income earners, and caretakers of household food and nutrition security. Despite their contributions, women’s work remains largely unrecognized, and their status has seen little advancement. While progress has been made in enhancing women’s capabilities, significant gender gaps in entitlements—resources that women can legally access—persist.

Equipping women with equal access to physical and human resources as men could significantly boost agricultural productivity. In fact, improvements in women’s education and status over the past 25 years have been instrumental in reducing child malnutrition rates by over half. According to Sraboni et al. (2014) highlights those empowering women is an effective strategy for improving family food security and nutrition. Empowerment involves enabling individuals to make informed choices and lead lives they value (Kabeer, 1999). Empowering women is key to achieve food security. These briefs consider different strategies for empowering women by strengthening their assets base—natural and physical capital, human capital, social and financial capital and by providing the legal and institutional framework to guarantee them command over resources.

The Sustainable Development Goals (SDGs), particularly SDG 5, target gender equality and women’s empowerment to increase opportunities for women and reduce gender disparities (Agarwal, 2018). Achieving these goals could foster sustainable economies, social harmony, and overall progress (Sarker et al., 2024). In line with the SDGs, the Philippine government acknowledges that closing the gender gap in agriculture can enhance food production and promote food security. Specific measures and initiatives have been launched to prioritize women as beneficiaries of government services and support.

The STC4iD program aims to demonstrate a technology transfer model in Geographically, Economically, and Socially Disadvantaged (GESDA) communities and social groups within the agriculture, aquatic, and natural resources (AANR) sector. The initiative is designed not only to assist the poor but to prioritize disadvantaged communities nationwide. The Project CLImB initiative specifically seeks to uplift the social and economic well-being of rural women in Bukidnon by enhancing farm efficiency and improving living standards for farming families.

This paper evaluates the effectiveness of community-based livelihood interventions in empowering women, focusing on improvements in household food security and social capital. It examines changes in women’s knowledge regarding farming and food security and analyzes factors that contribute to building social capital. Additionally, the study identifies challenges, lessons learned, and opportunities for future linkages and sharing of insights.

Objectives

The general objective of this paper is to examine the effectiveness of the Science and Technology Community-based for Inclusive Development (STC4iD) Program a community-based livelihood intervention in empowering women to improve household food security and build social capital. Specifically, this paper aimed to:

1. Assess the changes in the knowledge level in the farming and food security among women;
2. Analyze the factors that contribute to building social capital among women;
3. Discover challenges, learnings and opportunities that can be drawn to initiate sharing of lessons, draw synergies and develop future linkages; and;
4. Recommend key element features for a better and inclusive programs/ project in GESDA communities.

Methodology

The study was conducted in Barangay Kiharong, located in the municipality of Maramag, Bukidnon. Bukidnon, a province in Mindanao, was identified as the sixth poorest province in the Philippines, with a poverty incidence of 58.7% in 2015. The barangay was selected as a site for the STC4iD program due to its predominantly farming community, which faces challenges such as low agricultural productivity and significant land conversion. While many community members participated in local organizations, they required training in governance and financial management. Additionally, the local government aimed to enhance productivity and create investment and employment opportunities for residents.

The research utilized a combination of methods, including a desk review of project documents, focus group discussions, key informant interviews, and a survey of community-based organization members. Following data validation, the survey results were analyzed using descriptive statistical techniques, including frequency tables and averages. Themes emerging from the focus group discussions were also identified to provide deeper insights into participant perspectives.

This study is part of a larger assessment study covering all five sites of the STC4iD program. The evaluation's objective is to examine the extent to which the STC4iD program has contributed to technology transfer in GESDA communities. Specifically, the assessment focuses on the three operational approaches of the program-Social Technologies for Institution Building (STIB), Sustainable Livelihood through Community Enterprise Development (SLED) and Enabling Mechanisms Ensuring Sustainability (EMES).

Figure 1 summarizes the framework for the assessment of the STC4iD program and shows that with the three-year program implementation, recommendations can be identified for better and inclusive programs in GESDA communities.

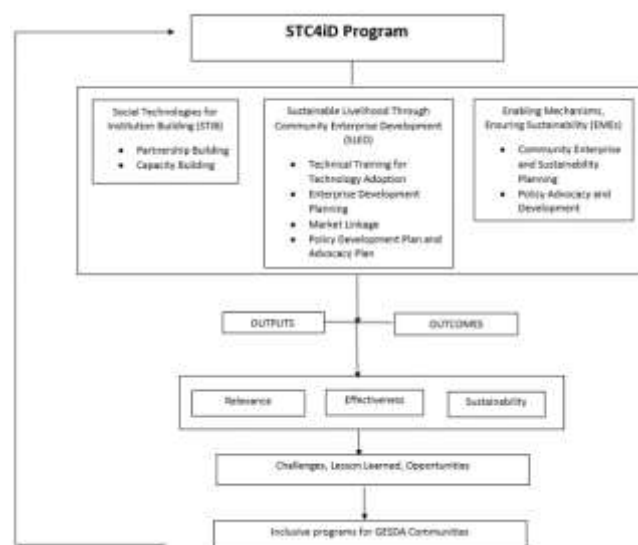


Figure 1. Project framework for the assessment of the STC4iD program

Results and Discussion

Socio-demographic profile

Sex, civil status, and position in the household. All of the 29 participants from Bukidnon were female, and among them only two were household heads. A large percentage (79.3%) were married, implying that the household heads were mainly their husbands.

Education. More than one-fourth of the participants had attended high school (27.6%), with some having graduated from high school (20.7%). Five of them attended college, and one graduated from college.

Occupation. About one-third of the participants (34.5%) had no occupation, while the rest worked as farmers, laborers, service workers, and barangay workers. Less than one-fourth (20.7%) indicated that they had other jobs not listed in the questionnaire.

Average HH size, average number of HH members earning income and estimated monthly income. The average household size of the participants was five people, with about two of the total number of household members earning an income. The average monthly income of the participants was PhP 9,241.

Estimated daily food expenses. The estimated daily food expenses of the participants at the time of the survey was PhP 247.24

Number of years residing in the community. Participants' average number of years in the community was 27 years.

Through the partnership of CMU and Barangay Kiharong, substantial outputs that correspond to the operational approaches were produced that were adopted by the Program. With the intent to capacitate the partner SUCs on Social Technologies for Institution Building (STIB), the project team established, in year 1, a number of MOAs and forged linkages with organized groups that led to the identification of community livelihood programs and the adoption of a communication plan that was specifically designed for the STC4iD Program. A community linkage was forged with Barangay Kiharong, Maramag, Bukidnon, where various livelihood activities were conducted such

as organic vegetable farming, mushroom production, goat raising, vermicomposting, and adoption of the Natural Farming Technology System (NFTS).

Year 2, which focused on the stakeholders' capacity building on Sustainable Livelihood through Community Enterprise Development (SLED), witnessed the establishment of a Vegetable Demo Farm in Kiharong, Maramag, Bukidnon, the formulation of an enterprise development plan, the development of capacity building modules, and the distribution of IEC materials to various stakeholders and target participants. Year 3 centered on ensuring the sustainability of program gains and benefits through the formulation of the Community Enterprise Sustainability Plan and the passing of a local resolution or ordinance.

Changes in farming techniques

The participants were asked of the changes in their farming techniques because of the program. The predominant response by 27 of 29 (93.10%) of the participants was the use of organic fertilizer and other techniques in organic farming. Others mentioned that they learned new techniques in planting vegetables in the garden and vertical gardening. One was quoted as saying "I am now motivated to plant vegetables in our backyard through applying what I have learned."

Table 1. Changes in farming techniques made by Kiharong participants as a result of the program

Changes in Farming Techniques	Percentage
Use of organic fertilizer and other techniques in organic farming	93.10
Vertical gardening	3.45

Food Accessibility/ Availability

The program provided positive effects to household food accessibility and food availability. In this study, food accessibility is defined as when individuals have adequate incomes or resources to acquire food (USAID, 1992) while food availability refers to when individuals have sufficient quantities of food available on a regular basis (FAO, 2006).

Specifically, vegetables become readily available in the garden which is both a source food when served on the table and as additional income for the family when sold in the market. Moreover, access to healthy food turns out to be easier. Participants encouraged the other farmers and fellow members of the organization to "plant vegetables in the backyard because it helps us access healthy food. In addition, these are fresh and safe from chemicals."

Food sources before the STC4iD program primarily came from sari-sari stores and the public market (Table 6). Other sources of food included own farm, government feeding program, and own livestock.

Table 2. Frequency distribution of Kiharong participants' ranking of sources of food before the program

Source	Frequency per Rank						Rank
	1	2	3	4	5	6	
Own Farm	11	0	12	3	2	1	3
Own Livestock	0	3	3	19	4	1	5
Public Market	7	11	7	4	0	1	2
Sari-sari Store	11	15	3	0	0	1	1
Government Feeding Program	0	0	1	2	1	14	4

After the program implementation, there was a significant shift in food sources with farms and livestock ranked as the first and second sources of food for household consumption (Table 7). Government feeding programs, sari-sari stores, and the public market became less frequent as choices for food sources. This result implies that the participants have become more self-reliant and self-sufficient leading to less dependence on the produce and resources of others for one of their basic needs, i.e., food.

Table 3. Frequency distribution of Kiharong participants' ranking of sources of food after the program

Source	Frequency per Rank						Rank
	1	2	3	4	5	6	
Own Farm	28	1	0	0	0	1	1
Own Livestock	0	16	2	11	0	1	2
Public Market	1	9	4	15	0	1	4
Sari-sari Store	0	3	23	3	0	1	3
Government Feeding Program	0	0	0	0	3	0	5

Social capital

Majority (93.3%) of the participants, likewise, exhibited a very high level of participation in the specified targets. Specifically, these are in the aspects of network building, partnerships with other institutions, and information exchange with people outside the program and organization. These aspects of social capital are seen as instrumental in establishing the wellbeing of a community (Chopra, 2002).

Table 4. Kiharong participants' participation in the specified targets

Target	Percentage	
	High (4)	Very High (5)
Network building	6.9	93.1
Partnerships with other institutions	6.9	93.1
Information exchange with people outside the program and organization	6.9	93.1

Challenges, learnings and opportunities

Challenges and learnings

Some challenges both in terms of their membership in the organization and in terms of the organization as a whole were identified by the participants. While the overwhelming majority did not indicate any problem, a few (6.9%) mentioned that conflicting schedules was a common problem encountered among the members. They suggested that because of this, members should be proactive in asking for information about the activities to be updated with the developments in these activities.

At the level of the organization, some problems cited were lack of cooperation (13.79%) and absenteeism (3.4%). To address these problems, members suggested holding regular meetings with open forums where members could be given the opportunity to speak up and share their ideas. One member suggested asking the members who were absent to be in-charge and serve as the facilitator in the next meeting.

Opportunities

The participants perceived that the program made the biggest contribution on their social and economic wellbeing as well as on the technical knowledge they learned.

As farmers, the benefitted from the additional farm inputs and tools. Also, the program specifically contributed to their increased knowledge of farming techniques and technologies which they were able to apply in their own farm and backyard garden. Their gardens, in turn, served as a free source of food for the family, which led to some savings for the family and was an additional source of income.

As members of the organization, the participants found that the program was instrumental in establishing social connections, particularly in creating strong bonds of friendship with other farmers and fellow members of the organizations. These connections motivated the members to become active and cooperative members of the organizations. Participants also noted that as members of the organization, they were given opportunities to attend training-workshops and field trips, providing greater chances for learning and improving themselves and their practice. They also

acknowledged that their membership in the organization allowed them to receive free farm inputs as well as technologies.

Similar positive contributions of the program were cited in their role as members of the community, which was a combination of improvements in their financial capital, human capital, and social capital. The program contributed as an additional source of living providing a “big help in income” which “provides for the family’s daily needs.” The knowledge gained and shared among the participants contributed a lot through gaining new ideas from the field visits and other capacity building activities. Social capital was enhanced with new friendships and networks established among the members of the organization. In the process, these positive contributions led to stronger ties among them resulting in more compliant and cooperative members who actively participate in various activities.

Conclusion

The KWA women were middle-aged mothers from large households with an income below the poverty and food threshold levels. Despite the pandemic, the STC4iD project, as applied in Kiharong, implemented a livelihood intervention which provided food and income, improved the technical skills of the women on farming, and made them more trusting, cohesive, cooperative, and informed. Aside from the enhanced social capital, the project helped increase the effort of the KWA members to generate income for their households.

The STC4iD project is an example of combining subsistence and income-generating activities in varied and typically shifting patterns to meet basic needs. The assessment of the STC4iD project has shown improved existing community capitals particularly human capital, financial capital and social capital in the which contribute to its sustainability. These accomplishments were a result of but not limited to a responsive community needs assessment, appropriate S&T interventions, public and private partnerships, effective program management, and the commitment of the members of community-based organizations as beneficiaries.

Women in the agriculture sector need a champion to look after their concerns and close the inequality gap. Countries that make opportunities equal for all, regardless of gender, age or religion, give more people the chance to improve their lives. As primarily agricultural country, closing the gender gap in the agriculture sector can reap significant dividends.

Acknowledgement (if any)

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References

- Agarwal, B. (2018). *Gender equality, food security and the sustainable development goals*. Elsevier Science Direct. 34. pp 26-32.
<https://doi.org/10.1016/j.cosust.2018.07.002>

- FAO. (2011). *The State of Food and Agriculture: Women in Agriculture- Closing the Gender Gap for Development*. United Nation News. ISBN: 9789251067680.
- Kabeer, N. (1999). Resources, agency, achievements: reflections on the measurement of women's empowerment. *Development Change*, 30, pp 435-465. [10.1111/1467-7660.00125](https://doi.org/10.1111/1467-7660.00125)
- Sarker, T., Sanchita, B., Anshita, Y., Isha, G, & Harsha, S. (2024). *Indigenous communities and sustainable development: A review and research agenda*. *Global Business and Organizational Excellence*. 43. 10.1002/joe.22237.
- Sraboni, E., Malapit, H.J., Quisumbing, A.R., Ahmed, A.U. (2014). Women's empowerment in agriculture: What Role for Food Security in Bangladesh? *World Development*., 61, pp11-52. <https://doi.org/10.1016/j.worlddev.2014.03.025>

Enhancing Farmers' Livelihoods: Exploring Opportunities and Challenges in the Agricultural Value Chain in S'ang District, Kandal Province

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Abstract

Cambodia, a Southeast Asian country, boasts significant agricultural production potential. This study explores the farm value chain, encompassing the processes of producing, processing, and distributing agricultural products from farm to collector. Its primary purpose is to analyse the opportunities and challenges within farm activities. By conducting semi-structured interviews with ten households in the S'ang district, Kandal province, the study reveals that farmers encounter various challenges in their value chain, notably the high input cost, lack of technical support, and government interventions and policies conducive to their needs. The findings may help policymakers decide how to expand and emphasize the importance of addressing grassroots to enhance the agricultural value chain and foster sustainable development in the sector.

Keywords: agricultural extension, farm knowledge, input costs, sustainable livelihoods

JEL code: Q15, Q16, Q18

SDG classification: SDG 1, SDG 2

Introduction

Background of research

The majority of Cambodia's economy is based on the agricultural sector. It plays the most important role in Cambodian society by ensuring food security and income resources at the grassroots and national levels. This sector is the main essential employment source for people in rural Cambodia as an indicator of livelihood support (Wokker et al., 2011). Also, it is a key economic pillar contributing to national development and economic growth and it still provides a key share of GDP compared to other sectors, for instance, industry and services with 22% of the country's gross domestic product of the country in 2022 and equivalent 15% of the total population employed in this sector (FAO, 2023).

The value chain has become more important in the area of agricultural development. Commodity production is not for the use of the commodity itself but rather for it to be exchangeable and therefore able to generate profit for its owner over and above the use-value of the eventual end user (Tausig, 1985). As an exchangeable commodity, the input components that comprise the commodity are qualitatively the same as any other commodity, no matter how they may differ through the symbolic medium of money and may be exchanged for any other number of commodities thought to be equivalent to other commodities. In Cambodia, the issues concerning the value chain are complex and multifaceted. The challenge for Cambodia is thus to understand and, more importantly, prioritize the constraints facing the market system and develop strategies to overcome these bottlenecks (Goletti, 2002). Also, the challenge for Cambodian rural development is to grasp the present situation prioritize the constraints to increase productivity generate improvements within the rice industry and develop strategies to overcome the existing obstacles. In addition, Cambodia's agricultural value chain faces challenges such as low productivity, low value-added, and unsustainable natural resource management. These might include limited access to irrigation, outdated farming methods, low-quality seeds, or inappropriate fertilizer. The findings and results of this study will become a key contribution to the involved agricultural institution, and policy implementation to support the grassroots level because the study will affect the farmers who are the actors in the value chain.

Research objectives of this study are as follows:

- a) To find the challenges agricultural value chain of farmers in the study area;
- b) To investigate the opportunities of farmers in the agricultural value chain to support their livelihoods.

Case study

Cambodia, one of the developing countries has got the intervention from the development partner into the value chain for the development of this country. In 2007, the Australian Centre for International Agricultural Research implemented the Cambodia Agricultural Value Chain Program (CAVAC). This program aims to increase farmer incomes by improving the quality and quantity of rice and vegetables produced. Together with farmers, government officials, and businesses, CAVAC identifies the root problems keeping farmers from producing more rice and vegetables, and productivity by constructing and rehabilitating irrigation infrastructure.

Then, in 2018, the ADB announced the Agricultural Value Chain Infrastructure Improvement Project. This project aimed at improving Cambodia's agriculture sector by

strengthening post-harvest and logistic facilities for agricultural production and service infrastructure and enhancing business partnerships in several provinces in the country. In Kandal province, several studies showed farmers' challenges in the value chain stage. Seed quality, high prices of inputs in-kind loan with chemical shop, flooding, fluctuation of prices in the market, lack of marketing information access, and the limitation of government and extension service provision remain happening in crop production among value chain actors (Pheakdey, 2014). Although the province has a high potential resource in rice production, it does not meet the required standard for export (CDRI, 2013). In addition, agricultural cooperatives can promote sustainable rice farming by providing financial, social, and technical support (Bunthan & Ryuichi, 2019), and the shortage of intervention from the involved institution to reduce the costs, particularly fertilizer and pesticides, and produce higher yields of export quality paddy will fetch better market prices.

In Vietnam, the performance between innovation and financial relationship has shown a positive connection to the market orientation to improve the agricultural value chain (Ambler et al., 2020). According to Ho et al. (2018), the difficulties in farming activities could be decreased through contract farming and several factors related to input such as education improvement, gender of head, crop type, and technology innovation that may impact farmers' income. So far, in Thailand, crop type is a unique opportunity for the business network to help small farmers grow high quality. Supermarkets are the important actors connecting to the farmers for retailing quality produce from the cultivation practice of farmers participating (Srimanee & Routray, 2012). It is one of the countries in Southeast Asia that strongly applies technology for its unique crop variety. The adoption of modern varieties has increased the productivity of rice land by increasing the yield per area per season and the number of crops that can be grown on the same plot in one year (Patrawart & Sriurai, 2010).

Furthermore, the development of business skills among farmer groups and related to business practices can facilitate value chain development (Rerkasem, 2017). In conclusion, the case study shows that farmers in rural areas strongly depend on farm production as their main income source. Farming experience, yield, productivity, and prices had a significant influence on producers' participation, but vegetable farm size showed a negatively significant effect. In this challenge, the business knowledge role is an essential factor in assisting farmers in reducing their dependence on any actors in the value chain who reduce the price. The policy implemented by the government can benefit all segments of the agricultural supply chain (Srimanee & Routray, 2012). This paper comes with the introduction, methodology, result and discussion, and conclusion.

Methodology

Research time and site

The time of this research was conducted from September 2024 to January 2025 in Prek Ambel commune, S'ang district, Kandal province. People can travel from Phnom Penh capital along with Basac River by National Road 21B. This study site, which is in the southeast portion of the country, borders the Koh Khel commune to the north, Kien Svay district to the east, and shares a border with Kaoh Thom district to the south of Kandal province and Prey Kabas district of Takeo province to the west. The study area riches in a multiple-use ecosystem called "Prek" which ends in low-lying areas known as "boeng", which are potentially suitable for productive small-scale capture fishery during the flood

season and rice farming during the dry season, or what people call “chamkar” (Venot et al., 2022).

Concept of value chain

In 1985, Michael Porter introduced the term “Value Chain” in his book “Competitive Advantage: Creating and Sustaining Superior Performance”. It is the series of steps a business takes to create a product and deliver it to a customer to make money. He defined the value chain as based on the idea that an organization is made up of subsystems with inputs, processes, and outputs, which are involved with the acquisition and consumption of resources. According to Porter (1990), he defined value chain is the factor conditions related to resources such as physical, human, knowledge, technology, and infrastructure are the main resources for the nation's endowment. Later, WB and USAID announced that the “Value chain” is a full range of value-adding activities required to bring a product service through the different phases of production, including procurement of raw materials, other inputs, and all the market channels available to all firms an interaction within a value chain helps to identify the factors that influence how well or how badly the chain works, while human interaction is the linkage between people and businesses who transfer or exchange products, money, knowledge, and information, and in return receive an economic return. At each stage in the value chain, the product changes hands through chain actors, transaction costs are incurred, and generally, some form of value is added.

Charity (2022) said that in agriculture, the “Value Chain” is the integrated range of goods and services necessary for an agricultural product to move from the producer to the final consumer. It is the idea of actors connected along a chain producing and delivering goods to consumers through a sequence of activities in agricultural production. Briefly, an agricultural value chain is a system of people who work in various stages of crop production. It contains every person who works to get the crops from the farm where they were planted, to the consumer that will end up eating them and is often characterized by gendered behavior patterns in resource distribution, roles, and responsibilities on and off the farm, decision-making and control over returns from farm incomes. In addition, the sustainability of productive agricultural value chains will depend on integrating environmental and equity considerations to ensure that these value chains contribute to food security and resilient livelihoods for the farmers. Therefore, linkages between poverty, food security, and nutrition are better understood as drivers of efforts to eradicate poverty among the most vulnerable and marginalized rural sectors.

Concept of sustainable livelihood approaches

According to the sustainable livelihood framework, Scoones (1998) shows that the analysis of livelihood assets with the analysis of institution/organization, and livelihood strategies gives us to obtain livelihood sustainability outcomes by increasing job opportunities, poverty reduction, well-being, and capability improvement. There are five assets as follows: a) The Natural assets including the flows and services of resources such as land, water, and soil quality which farmers need for farm production; b) Social assets are the social resources upon which people draw in seeking their livelihood outcomes from network, social relations, associations; c) Financial asset denotes the financial resources that people use to achieve their livelihood objectives; d) Human asset represents the skills, knowledge related the production and marketing; e) Physical asset

is the basic infrastructure and producer goods needed to support production value chain. In addition, the analysis of institutions/organizations and livelihood strategies gives people better livelihood sustainability outcomes on increasing job opportunities, poverty reduction, well-being, and capability improvement.

Data collection

This research will employ a qualitative research approach through semi-structured interviews. Primary data was collected from samples of ten farmer households involved in the rice and vegetable value chain from various angles and perspectives to collect different information where people were involved in rice production and vegetable crops as their main source of household income. These households will give ideas and comments on their routine agricultural value chain in the study focus area.

Data analysis

All the above qualitative data collection methods help to understand what and how through household surveys, and personal observation. The analysis of this research aims to differentiate and capture the diversity of representative farmers in the commune, agricultural issue categories. Data will be interpreted, described, and debated based on themes of research questions and objectives for the expected findings and results. Therefore, making value judgments from representative samples is to finalize.

Results and Discussion

According to the topographical and natural resource conditions, the study site is classified into a type, which is adapted to the major area of fertilized lowland area for rice and vegetable crop production that is beyond domestic consumption. However, the limited availability of skilled labor, physical resources, and knowledge of production, distribution, and marketing is an important condition for the innovative behavior of value chain actors (Trienekens, 2011). Low agricultural productivity remains a notable challenge even though government agencies have been involved in providing much support to the farmers (Ehui & Pender, 2005; Jayne & Sanchez, 2021). First of all, most farmers have limited skills and knowledge, and shortage of specialized skills, and difficult access to technology, inputs, markets, information, credit, and external services (Giuliano et al., 2005). The lower the level of education, the low productive individuals become as they can respond positively to innovations and better methods of production. Next, high input cost and quality have been taken as another concern in promoting higher productivity.

Farmers experienced low-quality and unwell-known fertilizers from the sellers. Although the farmers use cattle manure for land preparation, chemical fertilizers, and pesticides are mostly used in production because the percentage of organic farming has not become the target of people in the area. Also, land is a major factor of production in agriculture especially in agrarian societies. Shortage of land is regarded as one limiting factor to increased production (Tshatsinde, 1990). From the official land certificate, farmers can increase their farming productivity without any land conflicts. However, farmers are not eased to expand their plot size due to the size of the land plot of each household, which can support the farmer for only basic daily consumption and enough meals. In addition, gender and age are indicators to attract farmers involved in the agricultural sector (Brickell, 2011 & Tshatsinde, 1990). Some farmers are getting old so they need to hire

labour as in the fact that their children go to work as laborers in the non-agricultural sector. So, the change in agriculture requires the mobilization of human resources through such means as education and technical training.

In this context of aging, changes in working-age households have a significant impact on agricultural output. The young generation is willing not to work in the agricultural sector anymore; they seek to work in the non-agriculture sector. They said, “I didn’t want to do farming because of the experience from my parents”, an old farmer repeats his son’s speech. Lastly, marketing activity after harvesting is a big concern for all farmers. They don’t have enough techniques or equipment to apply for the post-harvest process. To adapt to the shortage of storage, several villagers know businessmen from outside and then introduce him to the farmers in the local villages. Moreover, poor-quality storage facilities along the crop value chain can lead to high post-harvest losses (Balakrishnan & Zass, 2023). Therefore, productivity remains the key source for farmers. Increasing productivity among smallholders in developing countries is also an instrument to guarantee food security in the long run. Agriculture can also be an engine of growth and employment opportunities for the rural non-farm economy because of its linkages with small cities and rural areas. Meanwhile, the support of knowledge training and reducing production costs are other key ideals involved in enhancing farmers’ livelihood.

Conclusion

Increasing productivity in agriculture is critical for better farmer’s livelihood. It can boost farmers’ income, especially for smallholder farmers who have limited resources to leverage in growing and marketing their produce. Fertilized soil is an essential asset for the productivity and quality of products and shares in the market. However, gender equity in farm participation is a notable situation. To adapt to the high productivity, farmers challenge input production costs. The price of fertilizer and diesel is too high in comparison with the revenue from selling the commodity. Otherwise, education and training are important strategic support services for sustained socio-economic development of communities, but agricultural education and training can succeed in their objectives only when integrated into an overall development program including incentives, infrastructure, marketing, etc. Shortage of this support is an issue that lower the technical assistance, farm knowledge, and access to the market. Therefore, to solve this issue, the involvement of government agencies to improve the well-being of farmers by increasing access to agricultural knowledge, information, and technologies to improve the agricultural value chain for smallholder farmers. Providing more extension services demonstrating improved cultivation methods to farmers could help increase productivity for higher income. With the cooperation between the state government and the private sector, they need to consider Agricultural Cooperatives establishment as well because it contributes to productivity increasing and promoting market accessibility.

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References

- Ambler, B. et al. (2020). Agriculture Value Chain Finance in Vietnam. <https://www.tools4valuechains.org/node/513.html>.
- Asian Development Bank. *Cambodia: Agricultural Value Chain Competitiveness and Safety Enhancement Project*. <https://www.adb.org/projects/50264-002/main>
- Balakrishnan, U. and Zaas, D. (2023). *Challenges and Opportunities in Agricultural Value Chains*.
- Brickell, K. (2011). The 'Stubborn Stain' on Development: Gendered Meanings of Housework (Non-)Participation in Cambodia. *The Journal of Development Studies*, 47(9), 1353–1370. <https://doi.org/10.1080/00220388.2010.527955>
- Bunthan, S., & Ryuichi, Y. (2019). Comparative Study on 3 Rice Farming Systems: Conventional, Partially Organic, and Organic Farming, Case Study in Prey Kabbas District, Takeo, Cambodia. *International Journal of Environmental and Rural Development*, 10(2), 54-60. https://doi.org/10.32115/ijerd.10.2_54
- Cambodia Development Resource Institute CDRI (2012). *Credit for Rice Farmers: A Study in Takeo Province*. Cambodia Development Review, 16(3).
- Cambodia Development Resource Institute CDRI (2024). Enhancing Rural Resilience for Climate-Induced Migration Responses. Retrieved January 16, 2025, from https://cdri.org.kh/storage/pdf/PB2024E-2%20Rural%20Resilience_1727319841.pdf
- Ehui, S., & Pender, J. (2005). Resource degradation, low agricultural productivity, and poverty in sub-Saharan Africa: pathways out of the spiral, *Agricultural Economics, International Association of Agricultural Economists*, 32(s1), 225-242.
- Food and Agriculture Organization of the United Nations (2023). Retrieved January 16, 2025, from <https://www.fao.org/hand-in-hand/hih-IF-2023/cambodia/en>
- Giuliani, E., Pietrobelli, C., and Rabellotti, R. (2005). Upgrading in global value chains: Lessons from Latin American Clusters. *World Development*, 33(4), 549-574.
- Gudeman, S. (2001). *Community, Market, and Culture*. The Anthropology of Economy.
- Hernandez, J.E. and Kacprzyk, J. and Panetto, H. and Fernandez, A. and Liu, S. and Ortiz, A. and De Angelis, M. (2017) *Challenges and solutions for enhancing agriculture value chain decision-making. A short review*. In: [PRO-VE 2017 : Working Conference on Virtual Enterprises](https://doi.org/10.1007/978-3-319-65151-4_68), 2017-09-18 - 2017-09-20. https://doi.org/10.1007/978-3-319-65151-4_68
- Ho, K. L. P., Nguyen, C. N., Adhikari, R., Miles, M. P., & Bonney, L. (2018). Exploring market orientation, innovation, and financial performance in agricultural value chains in emerging economies. *Journal of Innovation & Knowledge*, 3(3), 154-163. <https://doi.org/10.1016/j.jik.2017.03.008>
- Hoang, V. (2021). Impact of contract farming on farmers' income in the food value chain: A theoretical analysis and empirical study in Vietnam. *Agriculture*, 11(8), 797. <https://doi.org/10.3390/agriculture11080797>
- Irz, X., Lin, L., Thirtle, C., & Wiggins, S. (2002). Agricultural Productivity Growth and Poverty Alleviation. *Issues in Rural Development*, 19(4), 449-466.

- Janvry, A. D., & Sadoulet, E. (2005). Achieving success in rural development: toward implementation of an integral approach. *Agricultural Economics, International Association of Agricultural Economists*, 32(s1), 75-89.
- Jayne, T., & Sanchez, P. (2021). Agricultural productivity must improve in sub-Saharan Africa. *Science*, 372. [10.1126/science.abf5413](https://doi.org/10.1126/science.abf5413)
- Patrawart, J., & Sriurai, S. (2010). Value chain management in agricultural co-operatives, Thailand: Innovation for competitiveness and fair-trade approaches. *In ICA European Research Conference*. 1-14. http://cai.ku.ac.th/article/value_chain_management.pdf
- Pierre, P. and Collion, M. (2001). Agricultural producer organizations: their contribution to rural capacity building and poverty reduction. Washington: World Bank, 81 p. International Workshop on Strengthening Producer Organizations, Washington, États-Unis, 28 June 1999/30 June 1999.
- Porter, M. (1985). *Competitive Advantages: Creating and Sustaining Superior Performance*. New York: Free Press.
- Porter, M.E., 1990. *The Competitive Advantage of Nations*. Simon & Schuster.
- Rerkasem, B. (2017). The rice value chain: a case study of Thai rice. *Chiang Mai University Journal of Social Sciences and Humanities*, 4(1), 1-26.
- Rondot, Pierre; Collion, Marie-Helene [editors]. *Agricultural producer organizations: their contribution to rural capacity building and poverty reduction (English)*. Proceedings Washington, D.C.: World Bank Group. <http://documents.worldbank.org/curated/en/111471468740104722/Agri-cultural-producer-organizations-their-contribution-to-rural-capacity-building-and-poverty-reduction>.
- S'ang. (2009). Report on agricultural production in 2009: Agriculture Office of Saang District.
- Scoones, I. (1998). Sustainable rural livelihoods: A framework for analysis. Working Paper 72. Brighton, UK: Institute for Development Studies.
- Scoones, I. (2015). Sustainable livelihoods and rural development (p. xv). Rugby: Practical Action Publishing.
- Seifu, E., & Doluschit, R. (2014). Analysis of the dairy value chain: Challenges and opportunities for dairy development in Dire Dawa, Eastern Ethiopia. *International Journal of Agricultural Policy and Research*, 2(6), 224-233. <https://journalissues.org/ibme/wp-content/uploads/2014/07/Seifu-and-Doluschitz.pdf>
- Srimanee, Y. and Routray, J.K. (2012), "The fruit and vegetable marketing chains in Thailand: policy impacts and implications", *International Journal of Retail and distribution Management*, 40(9). 656-675. <https://doi.org/10.1108/09590551211255956>
- Tray, B., Garnevska, E., & Shadbolt, N. (2021). Linking smallholder producers to high-value markets through vegetable producer cooperatives in Cambodia. *AgEcon Search*, 24(6), 905-920.
- Trienekens, J. H. (2011). Agricultural Value Chains in Developing Countries; a Framework for Analysis. *International Food and Agribusiness Management Review*, 14(2), 51-83. <https://edepot.wur.nl/189057>

- Tshatsinde, M. A. (1990). Factors Leading to Low Productivity Among Rural Women in Agricultural Production. *AgEcon Search*, 29(4), 359 - 362. 10.22004/ag.econ.267333
- Venot, J.-P., Jensen, C. B., Delay, E., & Daré, W. (2022). Mosaic Glimpses: Serious games, generous constraints, and sustainable futures in Kandal, Cambodia. *World Development*, 151, 1-11. <https://doi.org/10.1016/j.worlddev.2021.105779>
- Vo, T. T. L. (2016). Assessment of agri-product value chains in the Mekong Delta: Problems and solutions. *CTU Journal of Innovation and Sustainable Development*, (02), 100-111. <https://doi.org/10.22144/ctu.jen.2016.001>

Engaging Grade 10 Students in Agriculture Through Site Visits and Practical Activities as a Pathway to Food System Transformation

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Abstract

The global food system faces significant challenges, including climate change, population growth, and diminishing natural resources, which threaten food security and sustainability. Addressing these issues requires initiatives that engage young individuals in agriculture to ensure a steady pipeline of professionals capable of transforming the sector. This study evaluates a training program, "Skill Advancement of Grade 10 Students on Food Systems through Site Visits and Practical Activities," designed to enhance students' appreciation of agriculture through experiential learning. The program combined lectures, site visits, and hands-on activities, with students documenting their experiences through video documentaries shared on social media and reflective personal journals. Pre- and post-training surveys were conducted to assess changes in perception, and participant feedback was gathered through training evaluations. Results showed a 3.67-fold increase in students interested in agricultural careers, rising from 15% before the program to 55% afterward. Training evaluations highlighted crop cultivation and food preparation as the most enjoyable activities, while site visits to agricultural institutions received the highest evaluation ratings. A thematic analysis of student journals identified salary and working conditions as key factors influencing career choices in agriculture. These findings demonstrate the effectiveness of experiential learning in fostering youth engagement in agriculture. Key elements of this initiative can guide future programs aimed at deepening students' appreciation of the food system during a critical period of career decision-making. By doing so, such programs will not only increase interest in agricultural professions but also develop a well-informed and actively engaged generation capable of driving meaningful food system transformation.

Keywords: agricultural education, youth in agriculture, food system

JEL code: Q16, Q18, I21

SDG classification: SDG 2, SDG 4, SDG 8, SDG 12, SDG 13

Introduction

The Food System Countdown Initiative (2025), a global interdisciplinary scientific collaboration, has identified several persistent and interconnected challenges that continue to affect food systems worldwide. Chief among these are widespread malnutrition, employment instability within the food sector, and the environmental impacts of food production. These issues underscore the urgent need for a sustainable and transformative approach to reshaping how food is produced, distributed, and consumed.

Agriculture is widely recognized as one of the largest contributors to greenhouse gas (GHG) emissions, which is the primary driver of climate change. Across the various stages of food production and distribution, different levels of GHGs are emitted, depending largely on the practices and technologies employed. For example, agricultural systems that utilize organic methods, relying on natural processes and inputs, tend to have a lower environmental footprint compared to those dependent on synthetic agricultural chemicals. In particular, the use of nitrogen-based synthetic fertilizers has been linked to a dramatic increase in nitrous oxide emissions, a potent greenhouse gas (Shcherbak et al., 2014). These environmental concerns point to the need for adopting more climate-resilient and sustainable agricultural practices.

In parallel, the rapid growth of the global population, now exceeding 8 billion, intensifies pressure on food systems and natural resources. According to the Global Resources Outlook 2024, our use of materials has tripled in the last 50 years and is expected to rise by 60% by 2060 (United Nations Environment Programme, 2024). This puts more pressure on land, water, and energy resources that are already stretched thin. To keep up, food systems need to become more efficient and sustainable. Part of the solution includes cutting back on food waste, promoting healthier and less resource-heavy diets (like plant-based diets), and finding better ways to produce food with fewer inputs.

Beyond environmental and resource challenges, agriculture faces pressing labor and human capital issues. A key concern is the aging farming population, particularly in developing countries like the Philippines, where the average age of farmers is 57 years (Philippine Statistics Authority [PSA], 2021). Younger generations are not entering the sector at a sustainable rate, often deterred by perceptions of agriculture as labor-intensive, low-paying, and lacking in career advancement opportunities (Food and Agriculture Organization [FAO], 2014). This has led to a labor gap that poses risks to food production and rural economies. Agricultural labor, particularly for farm workers, is often marked by low and unstable incomes, a lack of benefits, and informal employment structures (International Labor Organization [ILO], 2020). These conditions contribute to the sector's declining appeal, especially for younger generations that normally seek stability and upward progression in their careers.

There is also a perception gap, and a lot of the youth do not realize that agriculture today goes way beyond traditional farming. Many of them are unaware of the wide range of career paths in modern agriculture, such as agribusiness, agricultural engineering, biotechnology, food policy, and environmental sustainability (Parr & Trexler, 2011). These misconceptions limit youth engagement and reinforce the idea that agriculture is a last resort career. In the Philippines, the Congressional Committee on Higher and Technical Education (CHTE) has expressed concern over declining enrollment in agriculture-related courses, citing this trend as a threat to national food, fuel, and feed security (Fernandez, 2015).

Although agriculture's share in the Philippine economy is shrinking, contributing only 8.6% to the country's GDP in 2023, it still employs around 22.4% of the national workforce (Philippine Statistics Authority, 2024). Compared to neighbors like Thailand, Vietnam, Indonesia, and Malaysia, agricultural productivity in the Philippines has been lagging. These countries have followed an agriculture-led development strategy, using agriculture as a springboard for industrial and economic growth. According to Briones and Felipe (2013), adopting a similar approach in the Philippines could foster inclusive economic progress and strengthen food security. However, realizing this vision requires a renewed and sustainable pool of agricultural professionals and skilled workers.

Changing the way young people view agriculture starts with education, especially the kind that moves beyond the classroom. When students get the chance to learn by doing, it becomes easier to challenge the outdated image of farming as dirty, difficult, and unrewarding work. Instead, they begin to see how agriculture connects to science, sustainability, and real-world issues like food security and climate change. In a study from Cambodia, Alrawashdesh et al. (2022) found that students who participated in innovative, hands-on agricultural learning became more open to the idea of a career in the field. Their interest was often tied to a stronger connection with their local environment and a better appreciation of agriculture's role in society.

Parr and Trexler (2011) also highlighted the impact of direct experience when engaging the youth in agriculture. Whether it is a visit to a farm, a laboratory, or a community project, these activities help students break away from long-standing stereotypes and showcase agriculture as a dynamic and intellectually stimulating profession. These experiences not only enrich students' understanding of agriculture but also inspire a sense of purpose and agency in contributing to food system transformation. Phipps et al. (2008) added that giving students the chance to engage in actual agriculture- and food system-related work like planting, preparing food, or visiting agricultural research institutions can spark emotional interest that lasts. These kinds of experiences help them connect agriculture to creativity, purpose, and innovation.

These findings emphasize the potential of experiential education in transforming agriculture and the food systems. These findings also served as basis in the design and implementation of the training program by integrating field visits and practical learning activities with reflective and participatory approaches which ultimately aims to improve the knowledge and awareness of high school students in agriculture and food systems, dismantle traditional perceptions, and promote the field as a possible career pathway.

This paper presents education-based interventions and recommendations for designing training programs aimed to promote food systems awareness among high school students, measure possible changes in perception, and assess the training program's impact on the career decision-making of Grade 10 students concerning agriculture-related courses.

Methodology

This study employed a descriptive-evaluative design to assess the effectiveness of a short-term experiential learning program titled "Skill Advancement of Grade 10 Students on Food Systems through Site Visits and Practical Activities." The two-day training was conducted at the University of the Philippines Rural High School (UPRHS) in Bay, Laguna, and partner agricultural institutions within Los Baños, Laguna, Philippines.

Description of the training program

The program participants were Grade 10 students enrolled in high schools in Laguna, Philippines. Grade 10 students aged 15 to 16 were selected as participants since they are at a pivotal stage in deciding their future career paths and college courses within 1 to 2 years. Participation in the program was voluntary and based on student interest, with appropriate consent secured from parents or guardians. A total of 20 students participated in the training program, coming from the following schools: University of the Philippines Rural High School, Los Baños National High School - Batong Malake, and Nicolas Galvez Memorial Integrated National High School, all located in Laguna, Philippines.

The training program was designed to enhance Grade 10 students' awareness and appreciation of the food system through immersive and practical learning experiences. It consisted of a combination of lecture-based sessions, guided site visits to agricultural institutions, and hands-on activities in areas such as crop cultivation and food preparation.

To reinforce learning and allow for personal reflection, students were tasked to document their experiences through two output requirements: (1) a short video documentary of their experience, shared on social media platforms, and (2) individual reflective journals capturing their insights, realizations, and attitudes toward agriculture. A training guide shown in Figure 1 contained the important information the students needed, such as the schedule of activities and guide questions for their reflective journals.

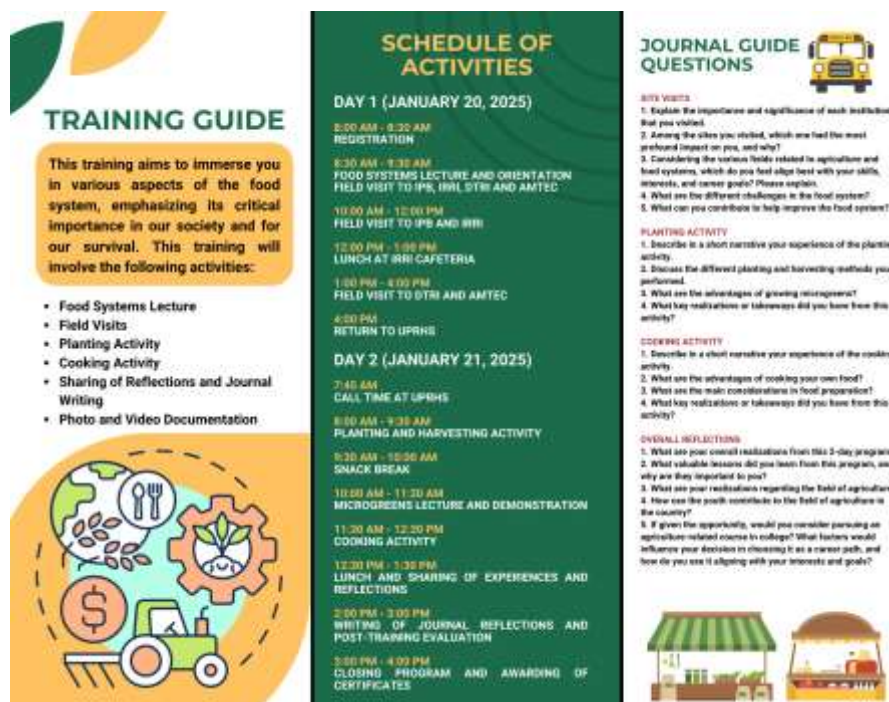




Figure 1. Training guide used by the student participants.

The two-day training-immersion program was designed to provide students with foundational knowledge and hands-on experiences related to agriculture and the food system. The first day began with a one-hour program orientation and a lecture on Food Systems, which covered its current status, fundamental components, societal relevance, key challenges, and potential solutions. This was followed by a series of educational site visits. The first visit was to the Institute of Plant Breeding (IPB) under the College of Agriculture and Food Science of the University of the Philippines Los Baños (CAFS-UPLB), wherein students toured various laboratories engaged in plant tissue culture, plant breeding research, and experimental field production. The next site visit was to the International Rice Research Institute (IRRI), home to the world's largest collection of rice genetic resources, during which the students gained insights into rice research and its global importance. The group then proceeded to the Dairy Training and Research Institute (DTRI), also under CAFS-UPLB, where they were introduced to dairy production operations and sampled locally produced dairy products. The final field visit was to the Agricultural Machinery Testing and Evaluation Center (AMTEC), the country's premier facility for agricultural machinery testing. Various farm equipment were introduced, and the students learned about their roles in agricultural mechanization.

The second day focused on experiential learning at the UPRHS farm grounds. Students engaged in core farming activities such as land preparation, fertilizer application, planting, and harvesting. This was followed by a lecture and hands-on session on microgreens propagation, a simple and cost-effective method of producing nutritious food that students can easily replicate at home. After the session, students were provided with microgreens-based recipes, which they cooked and prepared and enjoyed as part of their lunch. The program concluded with a reflection session where students shared their experiences, followed by awarding certificates of completion.

Data collection instruments and procedures

To evaluate the effectiveness of the training program, data were gathered using a combination of surveys, evaluation forms, reflective journals, and multimedia outputs. A pre-training survey was administered before the program began to establish baseline data on the students' perceptions of the food system and their interest in pursuing careers in the field. At the end of the program, a post-training survey was conducted to assess changes in these perceptions and interests.

To assess the quality and effectiveness of the training program, a structured evaluation form was administered to all 20 student participants at the conclusion of the activities. The evaluation consisted of 13 indicators covering various aspects of the training, such as organization, content relevance, speaker effectiveness, timeliness, field visits, hands-on activities, and overall quality. Each indicator was rated on a 5-point Likert scale, ranging from 5 (Outstanding) to 1 (Poor). The results were tallied and analyzed to determine which components were most valued by the students and to identify areas for potential improvement. Additionally, open-ended responses and reflections from student journals complemented the quantitative data, providing further context and deeper insights into the students' experiences.

At the end of the training program, each participant submitted a reflective journal to capture deeper insights into the students' learning journey. These journals served as personal narratives that documented their thoughts, realizations, and overall impressions of the program and agriculture as a potential career path. The students also answered guide questions that checked their level of understanding of the lectures and activities they attended, their overall perception of the food system, and factors affecting their career decision-making. Furthermore, students were tasked with producing video documentaries that highlighted their experience throughout the training. These videos were shared via social media platforms as a way to promote their learnings and experiences to a wider scope and served as creative outputs that showcased their level of engagement and understanding of the food system. Together, these instruments provided both quantitative and qualitative data to assess the impact of the experiential learning intervention.

Data analysis

Quantitative data from the pre- and post-training surveys were analyzed using descriptive statistics to determine percentage change and fold increase in interest toward agricultural careers. Training evaluation responses were summarized to highlight the program's most and least appreciated components.

Qualitative data from reflective journals were subjected to thematic analysis to identify recurring themes influencing students' career considerations and perceptions of agriculture. Video documentary outputs were reviewed for thematic consistency and levels of student engagement but were not subjected to formal content analysis.

Results and Discussion

Change in career interest and perception toward food systems

A pre-training survey was administered to all student participants to assess their motivations, baseline knowledge, and career interests prior to the program. The survey included the following key questions:

Q1. "Why do you want to participate in this program?"

Q2. "Based on your current understanding, how would you define food systems?"

Q3. "What courses are you currently considering for college?"

For Q1, the majority of students (15 out of 20) expressed that their primary motivation was to gain new knowledge about food systems. Three students indicated that their participation was linked to their capstone research projects, while two students stated that they wanted to promote improved food systems in their school and community. For Q2, responses revealed a range of understanding of food systems. Fourteen students described food systems primarily in terms of food production, while two students associated the term with food nutrients and their benefits. The remaining four students provided a more comprehensive definition, encompassing the entire food system, including food production, processing, distribution, consumption, and disposal. These varied responses highlight the diverse levels of conceptual understanding among students: while most were still in the early stages of learning, a few demonstrated a more advanced and integrated perspective on food systems. For Q3, only three out of the twenty students indicated an interest in pursuing college programs aligned with agriculture and the food system, specifically culinary arts, food technology, and agricultural and biosystems engineering. The rest expressed intentions to pursue careers in other fields, such as medicine, engineering, and business.

Following the completion of the training program, a post-training survey was conducted to assess changes in student perspectives and career interests. When asked again about their intended college courses (Q3), eleven students, which is 3.67 times more than the original number, indicated a newfound interest in agriculture- and food systems-related fields. These included culinary arts, food science, food technology, animal science, agricultural and biosystems engineering, agriculture, and agribusiness management. The remaining students still expressed interest in non-agriculture fields, such as medicine, engineering, and business.

For Q2, all twenty students were able to define food systems more accurately and comprehensively in the post-training survey. Their responses reflected a deeper understanding of the concept, encompassing the full range of food system components and emphasizing its social, economic, and environmental significance.

Student evaluation of the training program

A post-training evaluation was conducted among all the twenty (20) student participants to assess the effectiveness of the training program. The evaluation utilized a Likert-type scale ranging from 1 (Poor) to 5 (Outstanding), covering thirteen key indicators of the training program. For reporting clarity and brevity, each evaluation item is coded as E1 to E13, as shown in Figure 2. Most responses fell within the top two categories: "Outstanding" and "Very Satisfactory," with no ratings of "Fair" or "Poor" and only minimal

occurrences of "Satisfactory." These results strongly indicate the training program's effectiveness and its alignment with student expectations.

E1 (Conduct of the program by the organizer) and E2 (Effectiveness of the speakers) received 17 and 16 "Outstanding" ratings, respectively, with the remaining responses being "Very Satisfactory." Similarly, E3 (Relevance of the program content) and E4 (Timeliness of the program) received comparable results, affirming that the program was both timely and meaningful to the students.

The field visits (E5 to E8) were especially appreciated by the students. Notably, E6 (Field Visit to the International Rice Research Institute or IRRI) received a perfect score of 20 "Outstanding" ratings, making it the most highly rated activity. The other field visits to the Institute of Plant Breeding (E5), Dairy Training and Research Institute (E7), and Agricultural Machinery Testing and Evaluation Center (E8) each garnered 17 "Outstanding" and 3 "Very Satisfactory" ratings.

Practical and hands-on activities such as the planting activity (E9), microgreens lecture and demonstration (E10), and cooking activity (E11) were also positively rated. While E9 had one "Satisfactory" rating, it still earned 18 "Outstanding" and 1 "Very Satisfactory" responses, indicating a generally excellent reception.



Figure 2. Student evaluation ratings of training program components (n=20).

In terms of evaluation tools used during the training (E12), 19 students rated it as "Outstanding" and 1 as "Very Satisfactory," suggesting that the video documentation, journaling, and other reflective activities were appropriate and appreciated. Lastly, E13 (Overall Quality of the Program) received 17 "Outstanding" and 3 "Very Satisfactory" responses, reinforcing the success of the training as a holistic experience.

The open-ended questions from the training evaluation (E14 to E16) provided valuable insights into the students' experiences and suggestions for improvement. These questions asked what they liked most about the program (E14), what aspects could be improved (E15), and what additional field visit sites or activities they would like to see included (E16). The open-ended responses from the training evaluation provided valuable insights into the students' experiences and preferences throughout the program.

Responses to Question E14, "What did you like most about the program and why?", revealed that students particularly enjoyed the practical, hands-on components of the training. Crop cultivation and food preparation activities were mentioned in 13 out of the 20 responses, highlighting that learning-by-doing activities are effective in engaging students. Field visit activities, followed closely, were cited in 9 out of the 20 responses. These findings underscore the effectiveness of combining practical activities with field visits in promoting interest in agriculture and food systems among students.

For Question E15, "What aspects of the program could be improved?", most students suggested extending the program duration to accommodate more activities and additional field visits. This feedback points to the students' enthusiasm for deeper engagement and their desire for a more immersive experience.

In response to Question E16, "What other field visit sites or activities would you like to be added?", students recommended visits to more advanced food system-related sites. Suggested locations included farms, public markets, and industrial-scale food processing facilities. These responses indicate a strong student interest in gaining a broader understanding of the food system.

Themes from student outputs and journal reflections

The students' journal reflections revealed a marked improvement in their understanding and appreciation of various aspects of the food system. Following the site visits, most students were able to articulate the importance and unique contributions of each institution they visited. In connection with the hands-on activities, many students expressed the realization that growing and preparing their own food is a challenging task. The journal reflections also mentioned gaining a deeper respect for the labor and expertise involved in food production and helped them gain a greater appreciation for the diverse professions that sustain the food system.

The journal reflections also revealed increased awareness of the complex challenges facing today's food systems. Students frequently cited issues such as climate change, population growth, environmental degradation, and the shrinking availability of agricultural land. From the journal entries, the students suggested ways they could contribute to transforming the food system, including buying local products, reducing food waste, and advocating for the agricultural sector. A few responses also suggested that choosing a career in agriculture would enable them to contribute to transforming the food system. These reflections highlight a growing consciousness among the students regarding the roles they can play, both individually and collectively, in shaping a more sustainable food system.

Factors influencing the student's career decisions as extracted from the journal reflections included competitive salary, work-life balance, supportive work environments, opportunities for professional growth, and other personal considerations. Therefore, actively engaging the students in agriculture and the various aspects of the food system is a good starting point but is not enough to completely entice them to pursue a career

in the field. Labor and career challenges in agriculture and food systems should also be addressed to reinvigorate the appeal of agriculture to the youth. Regardless of whether students ultimately choose to pursue careers in agriculture and food systems, participating in hands-on training programs like this will cultivate a more informed and conscious citizenry, one that is better equipped to contribute to the collective transformation of the food system.

Conclusion

Transforming the food system requires a long-term global effort that involves addressing a range of interconnected challenges, from environmental concerns to social and economic issues. Achieving a sustainable transformation will require not only a strong pool of professionals in agriculture and food-related fields but also a generation of citizens who are informed, engaged, and empowered to make conscious decisions about food.

This training program demonstrated the value of experiential learning in helping students better understand and appreciate the food system. The increase in the number of students expressing interest in agriculture- and food system-related careers after the training highlights its potential to reshape perceptions and inspire future engagement. More than just transferring knowledge, the program helped students reflect on the realities of food production, recognize the pressing issues facing the sector, and see themselves as part of the solution. Still, generating long-term interest in agriculture goes beyond exposure and education. Broader concerns such as job security, compensation, and growth opportunities must also be addressed to make these fields truly appealing to the youth.

Given the encouraging results of this initiative, it is recommended that similar programs be integrated more systematically into the basic education curriculum. Schools should be supported in incorporating experiential learning modules that introduce students to real-world food systems, from production to consumption. To make this possible and sustainable, funding support from both government and private institutions is crucial, particularly to cover logistical needs such as transportation, meals, and training materials. Strong collaboration between schools, industry, government agencies, and research institutions will be key to creating impactful and lasting programs. With the right support and structure, experiential learning initiatives like this can play a vital role in nurturing the next generation of food system leaders.

To maximize the impact of future programs with similar goals, the following recommendations are proposed:

- Extend program duration to allow more time for meaningful exploration of food system topics, increased hands-on practice, and additional site visits to a broader range of facilities, including farms, local markets, and processing plants.
- Support and encourage student-initiated projects. Students can create projects after visits or hands-on activities. They can work in groups or individually to explore ideas they care about and apply what they've learned.
- Incorporate structured career talks and mentorship opportunities featuring professionals from agriculture, food science, agribusiness, and related sectors to help students visualize viable and fulfilling career pathways.

- Integrate entrepreneurship and innovation components to highlight diverse roles within food systems, particularly those that move beyond traditional farming, such as food technology, smart agriculture, product development, and sustainable enterprise.
- Strengthen partnerships with government, academic, and private sector stakeholders to provide access to real-world learning, internships, and scholarship opportunities for students interested in agriculture and food systems.
- Design post-program engagement strategies, such as school-based projects, alumni networks, or online platforms, to reinforce student interest and provide continued learning and peer interaction.
- Advocate for policy and curriculum support to formally integrate food systems education into the basic and secondary education curriculum, empowering students with the knowledge and civic responsibility to contribute to a more equitable and resilient food system.

Integrating these recommendations into the design of future training programs can help cultivate sustained and meaningful engagement with food systems among the youth and lay the foundation for both long-term career interest and a stronger sense of civic responsibility in contributing to the transformation of the food system.

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- Dairy Training and Research Institute (DTRI), CAFS, UPLB

References

- Alrawashdeh, G. S., Lindgren, S., Reyes, M., & Pisey, S. (2022). Engaging youth at school to advance sustainable agriculture and inspire future farming: evidence from Cambodia. *The Journal of Agricultural Education and Extension*, 29(5), 539–556. <https://doi.org/10.1080/1389224X.2022.2117213>
- Briones, R., & Felipe, J. (2013). *Agriculture and Structural Transformation in Developing Asia: Review and Outlook*. Metro Manila: Asian Development Bank.
- Fernandez, R. (2015, September 15). Declining agriculture enrollment poses threat to food security. *Philippine Star*. Retrieved from <https://www.philstar.com/business/agriculture/2015/09/05/1496506/declining-agriculture-enrollment-poses-threat-food-security>

- Food and Agriculture Organization [FAO] (2014). Youth and agriculture: Key challenges and concrete solutions. Food and Agriculture Organization of the United Nations. SBN 978-92-5-108475-5
- Food Systems Countdown Initiative (2025). The food systems countdown report 2024: Tracking progress and managing interactions. New York: Columbia University; Ithaca: Cornell University; Rome: Food and Agriculture Organization of the United Nations (FAO); Geneva: Global Alliance for Improved Nutrition (GAIN). <https://doi.org/10.36072/fsci2024>.
- International Labor Organization [ILO] (2020). Agricultural workers and their contribution to sustainable agriculture and rural development. International Labour Organization. ISBN: 978-92-2-118709-7
- Parr, D. M., & Trexler, C. J. (2011). Student perceptions of a sustainable agriculture internship experience. *Journal of Agricultural Education*, 52(1), 22–34.
- Philippine Statistics Authority [PSA] (2021). *Census of Agriculture and Fisheries*. Retrieved from <https://psa.gov.ph/statistics/caf>
- PSA (2024). Agriculture and Fisheries Indicators System: Employment and wages in agriculture and fishing 2019–2023. Retrieved from https://psa.gov.ph/system/files/main-publication/AFIS%20Employment%20and%20Wages%20in%20Agri%20and%20Fishing%202019-2023_e-signed.pdf
- Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. L. (2008). *Handbook on Agricultural Education in Public Schools* (6th ed.). Thomson Delmar Learning.
- Shcherbak, I., Millar, N. & Robertson, G.P. (2014). Global metaanalysis of the nonlinear response of soil nitrous oxide (N₂O) emissions to fertilizer nitrogen, *Proc. Natl. Acad. Sci. U.S.A.* 111 (25) 9199-9204, <https://doi.org/10.1073/pnas.1322434111>
- United Nations Environment Programme (2024). Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. <https://wedocs.unep.org/20.500.11822/44901>

Cost and Return Analysis of Sunflower Edible Oil Production in Yamethin Township, Mandalay Region, Myanmar

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Abstract

This study investigated the cost and return analysis of sunflower edible oil production in Yamethin Township, Mandalay Region, Myanmar. A total of 52 sunflower edible oil-producing farmers were selected through a purposive sampling method. Data collection was conducted using a structured questionnaire. Descriptive statistics and cost and return analysis were used for data analysis. The research examined the age, education levels, and farming experience of the sample farmers. Results showed that the average age of sample farmers was 56 years, with an average farming experience of 34 years. Education levels varied, with the majority of sample farmers having primary and middle school education. The detailed cost and return analysis revealed material costs, family labour costs, and hired labour costs, along with their respective contributions to the gross benefit. The cost and return analysis of sunflower edible oil production highlighted its profitability, with an average grain yield of 534.17 kg/ha and a combined gross benefit from edible oil and oil cake production of 2,413,744 MMK/ha. The benefit-cost ratio was 1.97, highlighting the economic viability of sunflower edible oil production. The findings concluded that sunflower edible oil production in Yamethin Township was a profitable agricultural enterprise with significant potential for income generation and economic growth.

Keywords: cost and return analysis, sunflower edible oil production, Yamethin Township

JEL code: D24, D57, D61

SDG classification: SDG 2, SDG 12

Introduction

Myanmar's agriculture sector is the backbone of the country's economy, contributed (23.70%) of Gross Domestic Product (GDP) in 2022-2023 and (28.79%) of total export earnings (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2023). The country's competitive advantages include abundant land, water, and labour resources, as well as its proximity to food markets. The agricultural potential is immense, with 12.80 million hectare of cultivated land under cultivation and potential expansion to additional fallow areas (International Trade Administration [ITA], 2024). Myanmar's agriculture depends on over 60 different crops, including cereals, pulses, oilseeds crops, industrial crops, fruits, vegetables, and culinary crops. Cereal crops are the most important crop group, covering (40.96%) of the total area sown for crops. Oilseed crops, the third most important crop (17.79%) after rice and pulses, support domestic food security and enhance the livelihoods of millions of farmers (MOALI, 2023). Myanmar aims to achieve edible oil self-sufficiency by expanding the production of oilseed crops, including groundnut, sesame, sunflower, mustard, and niger.

A basic component of eating habits, edible oil is used for frying and is frequently combined with other meals, such as rice, to enhance flavor. Oilseed crops are important because they provide cooking oil, generate export income, and create employment opportunities in the country. Only three types of domestically produced edible oils, including peanut oil, sesame oil, and sunflower oil, are found in both wet markets and supermarkets with different brand names (Hnin et al., 2021). However, the country heavily relies on imports for edible oil, which reach approximately 700,000 tons per year, with palm oil constituting (90%) of these imports due to its competitive pricing compared to other alternatives (Moh et al., 2021).

One of the three Economic Affairs of State Administration Council is to promote the cultivation of oilseed crops to meet targeted production levels, thereby achieving self-sufficiency in local edible oil supply and striving towards both local adequacy and overseas export of surplus oilseed crops. Therefore, nation must extend sown acreage of oilseed crops depending on climatic conditions and costs of inputs. Only by expanding the cultivation of oilseed crops will the country be able to reduce its import volume of palm oil from abroad, saving foreign exchange. The government established guidelines to encourage the production of oilseed crops in order to meet the country's edible oil consumption needs.

Hybrid sunflower seed was introduced in upland farming systems to double the existing average yield. In the 2022-2023 financial year, sunflower cultivation projects were introduced on 607,041.68 hectare across the country (The Global New Light of Myanmar, 2022). Thus, the Department of Agricultural Research (DAR) and the Department of Agriculture (DOA) under MOALI are working together to develop high-quality sunflower seeds. MOALI provides supports such as inputs, irrigation water, technology, agricultural loans, and seeds to sunflower growers (MOALI, 2023).

Sunflower is a potential oilseed crop due to its lower cultivation cost and high oil yield per unit area. It is now more widely cultivated worldwide due to its adaptation to various climatic and soil conditions (Forleo et al., 2018). The oil extracted from processed sunflower seeds is used in cooking and the food industry for producing margarine, butter,

bread, and snacks (Kottapalli et al., 2020). Sunflower oil is considered safe and suitable for human consumption with low cholesterol.

In Myanmar, the major top three regions of sunflower cultivation and production were Sagaing Region, Magway Region, and Mandalay Region. According to DOA data, (73.45%) of sunflower were grown in the Central Dry Zone of Myanmar, while (26.55%) were grown in other regions (DOA, 2024a). The prominent varieties of sunflower in Myanmar are Yezin hybrid-1, Sinshwekyar-2, Sinshwekyar-3, Sanpholar and local variety (MOALI, 2023). In Myanmar, sunflower is primarily used for manufacturing sunflower edible oil and oil cake for animal feed. By investing in research and development as well as providing support to local farmers, the government can enhance the productivity and sustainability of these oilseed crops.

The previous research studies predominantly concentrated on varieties and cultural practices of sunflower production with little focus on sunflower processing to promote industrial development within the country. Despite the significant enhancements in farmers' access to processing services, some farmers in Myanmar continue to sell sunflower grain in their unprocessed form. Analyzing the costs and returns of selling refined sunflower edible oil is particularly important.

Therefore, the study aimed to examine the profitability of selling processed edible oil for sunflower farmers.

Methodology

Mandalay Region is located in centre of the country. The region consists of 11 districts, which are subdivided into 28 townships. In Mandalay Region, Yamethin District is the most sunflower cultivated District. In Yamethin District, there are two townships, Yamethin and Pyawbwe. According to the sunflower acreage, Yamethin Township was chosen as a study area. Yamethin Township is situated in the southern part of Mandalay Region in the Dry Zone of Central Myanmar. Astronomically, it locates between the latitudes of 20°25' N and the longitudes of 96°08' E. It covers an area of 836.92 square miles and constituted of 11 stations or administrative units (5 wards and 63 village tracts), formed of 234 villages (General Administration Department [GAD], 2024).

In Yamethin Township, major oilseed crops were sunflower, groundnut and sesame. Among the oilseed crops, sunflower was the largest in sown acreage with (54.10%), then groundnut with (40.04%) and sesamum with (5.86%) of total area (DOA, 2024b). The survey was conducted from August to October 2024, covering 52 farmers from Kanbeit village tract and Segyi village tract in Yamethin Township who sold sunflower edible oil.

Quantitative data were first entered into the Microsoft Excel program. The analytical techniques, which included descriptive statistics such as average, minimum, maximum, frequency and percentage, etc. Economic analysis with related methods were calculated by using Microsoft excel program to fulfill the research objectives.

The study analyzed the profitability of sunflower farmers in the study area using cost and return analysis. The enterprise budget, a tool used to evaluate the economic and technical performance of an individual farm enterprise, was used to compare the profitability of existing and proposed enterprises. Budgets were calculated based on one hectare unit to simplify calculations. Variable costs were considered, including material input costs,

hired labour costs, family labour costs, and interest on cash costs. Both cash and non-cash items were used to estimate material and labour costs, including non-cash material costs, family labour, owned working animals, and farm yard manure. Average yield and average price were used to assess gross benefit for each crop. Total gross returns or benefits were calculated by total variable cash costs, excluding opportunity costs. Return above variable costs, or gross margin, and return above variable cash costs were also calculated. Expressions for estimating returns to various factors were described as follows;

- (1) Return above variable cost = Gross benefit - Total variable cost
- (2) Return above variable cash cost = Gross benefit - Total variable cash cost
- (3) Break-even yield = Total variable cost / Average price per kg
- (4) Break-even price = Total variable cost / Average yield per ha
- (5) Benefit-cost ratio = Gross benefit / Total variable cost

Source: Olson, 2003

Results and Discussion

Demographic characteristics of sample farmers

Age, education level and farming experience of sample farmers were principally considered as vital demographic characteristics of sample farmers in this study. The average age of sample farmers was 56 years ranging from 27 years to 60 years presented in Table 1.

Farming experience of farmers plays a vital role in agricultural production to make correct decision and take the risk. It is estimated that the higher the farmers' experience in farming, the better production capacity of the farmers. The average experience in farming was 34 years with minimum of 6 and maximum of 60 years showed in Table 1. As they spend almost half of their lives in farming, they had more productive experiences and potential for decision-making in sunflower production. The average household size of the sample farmers was 5 persons. The maximum number of family members was 12 persons and minimum was 2 persons. In this study area, farm size per household means only cultivable land. Among the cultivable land, average lowland was 3.19 ha and average upland was 1.17 ha respectively in the study area. As a result, the sample farmers owned more lowland than upland land.

Education of the farmers is also an important aspect of learning about modern agriculture, farm management and adoption of new technology. The education levels of sample farmers are presented in Table 2. The education levels were distributed into five categories; monastery education referred to informal schooling although they could read and write, primary level referred to formal education up to 5 schooling years, middle level referred to formal schooling years up to 9 years, high school level referred to formal schooling years up to 11 years and graduate level mentioned to those who was attending

the university and received a bachelor from university. Majority of sample farmers were primary school level (57.69%), middle school level (28.85%), graduate (5.77%), high school level (3.85%) and monastery education level (3.85%) respectively.

Table 1. Demographic characteristics of sample farmers (n=52)

Items	Unit	Avg.	Min.	Max.	SD
Age	Year	55.73	27.00	60.00	13.61
Farming experience	Year	33.60	6.00	60.00	14.41
Sunflower cultivating experience	Year	22.50	1.00	50.00	14.41
Household size	No.	5.23	2.00	12.00	2.15
Farm size (lowland)	ha	3.19	0.81	16.19	2.44
Farm size (upland)	ha	1.17	0.40	7.28	1.25

Table 2. Education level of sample farmers (n=52)

Education level	Frequency	Percent
Monastery (only read & write)	2	3.85
Primary (1-5 schooling years)	30	57.69
Middle (6-9 schooling years)	15	28.85
High (10-11 schooling years)	2	3.85
Graduate (12-14 schooling years)	3	5.77

Sunflower varieties cultivated and sources of seeds received by sample farmers

The variety of sunflower cultivated and the sources of seeds received by sample farmers in the study area are described in Table 3. In the study area, all sample farmers grew only Sinshwekyar-2 variety. Most of sample farmers received sunflower seeds from the Department of Agriculture (82.69%), from their neighbouring farmers (13.46%) and from wholesalers they connected (3.85%).

Table 3. Sunflower varieties cultivated and sources of seeds received by sample farmers (n=52)

Items	Frequency	Percent
1. Variety		
• Sinshwekyar-2	52	100.00
2. Sources of seeds		
• Department of Agriculture (DOA)	43	82.69

• Neighbouring farmers	7	13.46
• Wholesalers	2	3.85

Yield, market price and gross benefit of sunflower edible oil production

A detailed analysis of the performance of sunflower production in terms of yield, production of edible oil, and sunflower oil cake, alongside their respective prices and gross benefits are showed in Table 4. The average yield of sunflower per hectare was 534.17 kg, with a range from a minimum of 179.15 kg to a maximum of 895.74 kg. On average, 210.50 kg of edible oil was produced per hectare, with a minimum of 70.49 kg and a maximum of 352.43 kg. The average price of edible oil was 9,993 MMK/kg, ranging from 8,600 MMK/kg to 12,285 MMK/kg. The average gross benefit from edible oil production was 2,078,638 MMK/ha, with values ranging from 692,730 MMK/ha to 3,562,611 MMK/ha. The average production of sunflower oil cake per hectare was 362.60 kg, with a minimum of 112.78 kg and a maximum of 704.85 kg. The average price of sunflower oil cake was 923 MMK/kg, with a range from 920 MMK/kg to 1,043 MMK/kg. The average gross benefit from oil cake production was 335,106 MMK/ha, with values ranging from 103,782 MMK/ha to 648,638 MMK/ha. The combined gross benefit from both edible oil and oil cake production averages was 2,413,744 MMK/ha, with a minimum of 803,925 MMK/ha and a maximum of 4,093,755 MMK/ha.

Table 4. Yield, market price and gross benefit of sunflower edible oil production (n=52)

Items	Units	Average	Minimum	Maximum
Yield	kg/ha	534.17	179.15	895.74
Edible oil	kg/ha	210.50	70.49	352.43
Price of edible oil	MMK/kg	9,993	8,600	12,285
Gross benefit for edible oil	MMK/ha	2,078,638	692,730	3,562,611
Sunflower oil cake	kg/ha	362.60	112.78	704.85
Price of sunflower oil cake	MMK/kg	923	920	1,043
Gross benefit for oil cake	MMK/ha	335,106	103,782	648,638
Gross benefit	MMK/ha	2,413,744	803,925	4,093,755

Inputs utilization and material costs of sunflower edible oil production of sample farmers

The average, minimum, maximum, and standard deviation values for various inputs used by sample farmers in sunflower edible oil production are presented in Table 5. Sample farmers used an average of 10.18 kg/ha of seeds. The minimum and maximum seed rates were 4.45 kg/ha and 17.79 kg/ha, respectively. Farmers applied an average of 80.66 kg/ha of urea and 84.24 kg/ha of compound fertilizer. The average application rate of FYM was 3.77 MT/ha, ranging from 1.24 MT/ha to 7.41 MT/ha. The average application

of foliar, pesticide, and herbicide was 1.85 liter/ha, 2.50 liter/ha, and 1.05 liter/ha, respectively.

The material costs of sunflower edible oil production in the study area, where farmers applied seed, FYM, urea, compound fertilizer, herbicide, pesticides, foliar, and petrol, are described in Table 6. All sample farmers spent about 53,198 MMK/ha for seeds in sunflower production. For crop protection, most farmers spent approximately 102,161 MMK/ha on urea and 42,435 MMK/ha for compound fertilizer. They spent about 99,553 MMK/ha for FYM. Additionally, sample farmers spent around 20,224 MMK/ha on foliar application and 29,272 MMK/ha on pesticides.

Table 5. Utilization of seed, FYM and agrochemicals of sunflower edible oil production of sample farmers (n=52)

Items	Units	Average	Minimum	Maximum	SD
Seed	kg/ha	10.18	4.45	17.79	3.48
Urea	kg/ha	80.66	20.58	123.55	34.70
Compound	kg/ha	84.24	61.78	123.55	31.17
FYM	MT/ha	3.77	1.24	7.41	1.79
Foliar	liter/ha	1.85	0.62	3.71	0.80
Pesticide	liter/ha	2.50	0.25	12.36	3.68
Herbicide	liter/ha	1.05	0.31	2.47	0.86
Petrol	liter/ha	6.02	7.41	5.56	0.93

Table 6. Material input costs of sunflower edible oil production of sample farmers (n=52)

Items	Unit	Total cost
Seed	MMK/ha	53,198
Urea	MMK/ha	102,161
Compound	MMK/ha	42,435
FYM	MMK/ha	99,553
Foliar	MMK/ha	20,224
Pesticide	MMK/ha	29,272
Herbicide	MMK/ha	2,946
Petrol	MMK/ha	1,307
Total material cost/ha	MMK/ha	351,096

Family and hired labour costs of sunflower edible oil production of sample farmers

The total labour cost of sample farmers was 830,968 MMK/ha, with family labour costs of 333,159 MMK/ha and hired labour costs of 497,809 MMK/ha, as shown in Table 7. The largest amount of hired labour costs was ploughing with machine at 92,187 MMK/ha. The total hired labour cost for planting was 56,943 MMK/ha, the hired labour cost for seed threshing was 52,039 MMK/ha, and the hired labour cost for harvesting was 42,746 MMK/ha. The milling fee was 172,649 MMK/ha. The largest amount of family labour costs for the harrowing with draft cattle was 58,686 MMK/ha. Followed by total family labour costs for line sowing with draft cattle of 41,817 MMK/ha, ploughing with draft cattle of 29,937 MMK/ha and family labour costs of seed threshing of 21,655 MMK/ha.

Table 7. Family labour costs and hired labour cost of sunflower edible oil production of sample farmers (n=52) (Unit=MMK/ha)

Items	Family labour cost	Hired labour cost
Ploughing with draft cattle	29,937	2,614
Ploughing with machine	3,326	92,187
Harrowing with draft cattle	58,686	8,553
Harrowing with machine	3,326	10,929
Line sowing (cattle)	41,817	4,118
Planting	11,565	56,943
Inter-cultivation with cattle	19,245	3,802
Hand weeding	5,295	7,959
Herbicide application	855	-
Fertilizer application	12,268	966
Pesticide application	9,454	580
Foliar application	10,093	-
Irrigation	2,697	570
Harvesting	16,416	42,746
Drying of flower	16,285	1,364
Threshing	21,655	52,039
Cleaning	14,685	3,741
Seed drying	18,036	-
Transportation from farm to home with cattle	35,236	15,254
Transportation from home to market with machinery	2,281	20,794

Items	Family labour cost	Hired labour cost
Milling fee	-	172,649
Total family and hired labour cost/ha	333,159	497,809
Total labour cost/ha		830,968

Cost and return analysis of sunflower edible oil production of sample farmers

The enterprise budget was calculated to analyze the cost and return of sunflower edible oil production in Yamethin Township. A detailed calculation of cost and return in sunflower edible oil production of sample farmers is shown in Table 8. Total material cost included seed, urea, compound, foliar, FYM, pesticides, herbicides, and diesel used in sunflower edible oil production. The opportunity cost of family labour was also calculated by mentioning the wage rate of hired labour. Interest on paid-hired labour costs and material cash costs were also included. The total variable cost or total production cost of sunflower edible oil production per hectare was then computed by combining total material costs, family labour and hired labour costs, and total interest on cash costs.

Total variable costs of sample farmers were 1,203,287 MMK/ha, while total variable cash costs were 870,128 MMK/ha. The gross benefit for edible oil was computed by multiplying the edible oil yield per hectare and price of edible oil per kilogram received by sample farmers. The gross benefit for sunflower oil cake was computed by multiplying the oil cake received after milling per hectare and price of oil cake per kilogram received by sample farmers. Total gross benefit was 2,413,744 MMK/ha while return above variable cost was 1,207,907 MMK/ha. In addition, return above variable cash cost was 1,541,065 MMK/ha for sample farmers as presented in Table 8.

Benefit cost ratio for sunflower edible oil production was 1.97. The findings indicated that sunflower edible oil production in the study area was profitable because farmers get back 0.97 MMK if they invest 1 MMK cash expense in sunflower edible oil production. The break-even yield was the edible oil yield that could cover the total variable cost at the current sunflower edible oil price, and the break-even price was the price that could cover the total variable cost at the current sunflower edible oil production. Actual yield and market price of sunflower edible oil production by sample farmers were 210.50 kg/ha and 9,993 MMK/kg. The break-even yield and break-even price of sunflower edible oil production by sample farmers were 122.04 kg/ha and 6,687 MMK/kg, respectively. The finding indicated that even if the sample farmers' actual yield covers the total variable cost at the current sunflower edible oil price. Therefore, the sample farmers in the study area were in a profitable position.

Table 8. Enterprise budget of sunflower edible oil production of sample farmers (n=52)

Items	Unit	Edible oil
Grain yield	kg/ha	534.17
Edible oil yield	kg/ha	210.50
Price of edible oil	MMK/kg	9,993

Gross benefit for edible oil	MMK/ha	2,078,638
Sunflower oil cake	kg/ha	362.60
Price of oil cake	MMK/kg	923
Gross benefit for oil cake	MMK/ha	335,106
Gross benefit	MMK/ha	2,413,744
(a) Total material cost	MMK/ha	351,096
(b) Total family labour cost	MMK/ha	333,159
(c) Total hired labour cost	MMK/ha	497,809
(d) Interest on cash cost	MMK/ha	21,223
Total variable cost (a+b+c+d)	MMK/ha	1,203,287
Total variable cash cost (a+c+d)	MMK/ha	870,128
Return above variable cost (Gross benefit-TVC)	MMK/ha	1,207,907
Return above variable cash cost (Gross benefit-TVCC)	MMK/ha	1,541,065
Benefit-cost ratio (BCR)		1.97
Break-even yield (edible oil)	kg/ha	122.04
Break-even price (edible oil)	MMK/kg	6,687

Conclusion

The study analyzed the socio-economic characteristics, input utilization, and cost and return of sunflower edible oil production in Yamethin Township. The average age of sample farmers was 56 years, with an average farming experience of 34 years, emphasizing their ability to make informed decisions and manage risks in agriculture.

The cost and return analysis revealed that sunflower farming is a profitable enterprise in the study area. The average yield of sunflower per hectare was 534.17 kg, producing 210.50 kg of edible oil and 362.60 kg of oil cake, by-product. With an average gross benefit of 2,413,744 MMK/ha, sunflower edible oil production was a viable income source for farmers. The benefit-cost ratio of 1.97 indicated that farmers could expect a significant return on their investment. The break-even analysis further supported the profitability of sunflower edible oil production, with actual yield and market prices covering the total variable costs. This result underlined the financial viability and potential for growth in sunflower edible oil production in the study area.

Based on the results, sunflower edible oil production in Yamethin Township is one of the profitable agricultural enterprises with significant potential for income generation and economic growth. Therefore, encouraging value addition activities, such as producing sunflower edible oil, and diversifying into other sunflower-based products will open new

income sources for farmers. By implementing these recommendations, sunflower edible oil production in Yamethin Township can be significantly enhanced, benefiting the farmers and contributing to the regional economic growth.

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References

- Department of Agriculture (2024a). 2023-2024 Annual Report of Extension Division, Department of Agriculture (DOA), Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.
- Department of Agriculture (2024b). Data records of Department of Agriculture (DOA), Yamethin Township, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.
- Forleo, M. B., Palmieri, N., Suardi, A., Coaloa, D., & Pari, L. (2018). The eco-efficiency of rapeseed and sunflower cultivation in Italy. Joining environmental and economic assessment. *Journal of Cleaner Production*, 172, 3138-3153.
- General Administrative Department (2024). Regional information. Retrieved from <http://www.gad.gov.mm/sites/default/files/eaangln.pdf>
- Hnin, C. H., Theingi, M., Thi, T. S., Moh, M., & Cho, Z. W. (2021). Edible oil in the market, Nay Pyi Taw, Myanmar: Types, brands, market prices and consumer preferences. FFTC Agricultural Policy Platform,
- International Trade Administration (2024) Retrieved from <https://www.trade.gov/country-commercial-guides/burma-agriculture>
- Kottapalli, B., Nguyen, S. P., Dawson, K., Casulli, K., Knockenhauer, C., & Schaffner, D. W. (2020). Evaluating the risk of Salmonellosis from dry roasted sunflower Seeds. *Journal Of Food Protection*, 83(1), 17-27.
- Ministry of Agriculture, Livestock and Irrigation (2023). Myanmar Agriculture in Brief, Department of Planning.
- Moh, M., Myint, T., Win, C. Z., Soe, T. T., Hnin, C. H., & Thandar, K., (2021). Does Myanmar Have Sufficient Edible Oil Production? FFTC Agricultural Policy Platform, <https://ap.fttc.org.tw/article/2936>.
- Olson, K. (2003). *Farm management principles and strategies. The Textbook of Farm Management: Principles and Strategies*. Department of Applied Economics at the University of Minnesota. Retrieved from <https://www.wiley.com/en-us/Farm+Management%3A+Principles+and+S>.

The Global New Light of Myanmar. (2022, July 15). Expand sown acreage of oil crops for local oil sufficiency. *Global New Light of Myanmar*. Retrieved from <https://www.gnlnm.com.mm/expand-sown-acreage-of-oil-crops-for-local-oil-sufficiency/>

Cost and Return Analysis of Cotton Production Compared to DOA Released OPV and Imported Hybrid Varieties Grown by Sample Farmers in Yamethin Township

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Abstract

Cotton is one of the most essential fiber crops and plays a significant role in textile industries. The study was conducted to analyze the cost and return of cotton production compared between Department of Agriculture (DOA) released Open Pollinated Variety (OPV) and imported hybrid varieties in Yamethin Township, Myanmar. The study was conducted with 72 cotton growers (30 farmers who grew DOA released OPV and 42 farmers who grew imported hybrid varieties) by using purposive and random sampling methods in August and October 2024. Descriptive analysis, cost and return analysis and SWOT analysis were used. The results indicated that DOA released OPV (Shwe Daung-10, Shwe Daung-8) and the imported hybrid varieties (B-31, RAKA 666) were the most common cultivated varieties. Imported hybrid varieties had significantly higher yields, variable costs, gross benefit, return above variable costs and benefit cost ratio compared to DOA released OPV. Between these two groups, imported hybrid varieties gained higher profits. The main strengths of cotton production for farmers were good appearance of seed cotton and high yielding. However, farmers faced weaknesses such as weight loss due to storage and not enough credit access. Opportunities were employment for local labor and cotton-seed oil production. The major threats were unstable market price. Therefore, to produce high-yielding and better fiber quality hybrid cotton varieties, to support good quality seeds, to transfer effective cultivation technology and input use management systems for cotton farmers in all cotton growing areas through strengthened extension activities are needed to improve the cotton production.

Keywords: cotton, cost and return analysis, DOA released OPV, imported hybrid varieties, SWOT analysis

JEL code: D61, E23

SDG classification: SDG 2, SDG 8, SDG 12

Introduction

Myanmar is primarily an agricultural country and the sector continue to play a significant role in the national economy. In 2022-2023, the agriculture sector was contributed to 23.7% of the nation's Gross Domestic Product (GDP). The agriculture sector remained critical for food production, and it would continue to account for an important part of export earnings. Myanmar is an agriculture-based country, the main growing crop groups are cereal, pulses, oilseed, industrial, culinary and others. Industrial crops are coffee, rubber, kenaf, sugarcane, cotton and oil palm (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2023).

Cotton makes a significant portion of the industrial crops. In Myanmar, cotton is the most important crop and is well suited to the climate, particularly in the dry zone where cotton plantations (Smart Myanmar, 2023). Both long-staple and short-staple cotton are widely grown in Myanmar's central dry zone. Local varieties, Mahlaing-5 and Wagyi, are being planted in the entire short-staple cotton growing area. Long-staple cotton, Ngwe Chi-6, Shwe Daung-8, Ngwe Chi-9, Shwe Daung-10, Ngwe Chi-11, RAKA 666, B-31 and Lonemalay are grown in the Sagaing, Mandalay, Magwe, and Bago Regions, Nay Pyi Taw council area, and Shan State (South) (MOALI, 2023).

Because the imported hybrid seed generated around 20% more high-quality lint than the local seed produced by MOALI, cotton growers preferred the imported hybrid seed. Imported hybrid cotton seeds were also resistant to pests and diseases compared to local cotton seeds. Since imported hybrid seeds were expensive due to imported from other countries, most farmers could not afford to purchase them (Smart Myanmar, 2023). In the 2023-2024 growing season, Magway Region and Mandalay Region had the highest cotton sown area, while the lowest was found in Shan State and Chin State (Department of Agriculture [DOA], 2024).

Sown area, yield, production and export of cotton in Myanmar during the period of 2013-2014 to 2023-2024 were presented in Table 1. The cotton sown area began to decline from 2015-2016 to 2022-2023, even though the cotton production increased steadily throughout the year. Between 2013-2014 and 2019-2020, the average cotton yield rose from 1.70 MT/ha to 1.75 MT/ha, and between 2020-2021, it fell by 1.69 MT/ha. Between 2021-2022 (Mini) and 2023-2024, the average cotton yield rose from 1.76 MT/ha to 1.92 MT/ha. In 2022-2023, 0.33 million metric tons were produced on 0.19 million hectares of cultivated area. Although the official cotton trade account for approximately 15,497.74 tons in 2022-2023, cotton is primarily shipped to China through border trade. About 400 metric tons were produced in 2023-2024, with 208 million hectares of cotton planted and yielding 1.92 MT/ha. In Myanmar, the total production amount of long-staple cotton was 393,364.29 MT (98.30%) and short-staple cotton was 6,768.28 MT (1.70%) in 2023-2024 (MOALI, 2023; DOA, 2024 and MOC, 2024).

The "Cotton Development Project," a four-year initiative from 2022-2023 to 2025-2026, was implemented by the MOALI to support domestic cotton demand, increase exports and decrease yarn imports. The annual cultivation targets are as follows: 202,347 ha in 2022-2023, 232,699 ha in 2023-2024, 252,934 ha in 2024-2025, and 283,286 ha in 2025-2026 including short staple cotton. In the initial year 2022-2023, the actual sown area reached 185,001 hectares, achieving 91.69% of the targeted area.

Additionally, field days, training and demonstration plots provide farmers with access to technology for cotton growing methods (MOALI, 2023).

In 2023, under the regional government's plan, special zones were established to achieve a national target yield of 2.83 MT/ha for cotton crops. These zones were selected as pilot areas where most farmers could participate and learn improved cultivation methods, incorporating quality seed, proper land management, efficient water use and advanced techniques. Local cotton varieties used by farmers struggle to reach the national target yield (2.83 MT/ha). According to the regional government's plan, farmers are provided imported hybrid cotton seed (1.24 kg/ha) within the special zones to get higher yields.

Even for the local market, cotton production in the country is unable to achieve the quality and price standards needed to create garments and other products competitively (Smart Myanmar, 2023). To meet domestic demand, reduce cotton yarn imports, and increase exports, Myanmar's cotton production must be further developed. However, Myanmar's cotton farmers faced higher input costs, unstable market price, labour shortages, high transportation costs, insufficient high-quality seed, etc. (Soe Khaing et al., 2023). Cotton farmers also consider agronomic, environmental and market-related factors that influence the sustainability of cotton production. Although both DOA released Open Pollinated Variety (OPV) and imported hybrid cotton varieties are grown in Myanmar, there is limited study has been done to compare their economic viability in terms of costs, returns and production sustainability. It is essential to assess the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of DOA released OPV and imported hybrid cotton varieties in Yamethin Township. Therefore, this study aimed to compare the cost and return analysis of cotton production based on DOA released OPV and imported hybrid varieties and to examine the Strengths, Weaknesses, Opportunities and Threats (SWOT) of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers in Yamethin Township.

Table 1. Sown area, yield, production and export of cotton in Myanmar from 2013-2014 to 2023-2024

Year	Sown area (['] 000 ha)	Yield (MT/ha)	Production (['] 000 MT)	Export (['] 000 MT)
2013-2014	299	1.70	509	1.60
2014-2015	304	1.75	533	15.65
2015-2016	291	1.79	521	2.41
2016-2017	260	1.82	473	4.29
2017-2018	225	1.76	395	4.53
2018-2019	193	1.77	342	9.17
2019-2020	168	1.75	294	5.85
2020-2021	158	1.69	266	21.74
2021-2022(mini)	159	1.76	280	4.72
2022-2023	186	1.77	328	15.49

2023-2024	208	1.92	400	28.25

Source: MOALI, 2023; DOA, 2024 and MOC, 2024

Methodology

Mandalay is the second largest cotton sown area in Myanmar. According to the DOA data, Shwe Daung-10 and Shwe Daung-8 are the most cultivated varieties, and RAKA 666, B-31, Lonemalay, Ngwe Chi-6 and Ngwe Chi-9 are the second most cultivated varieties in the Mandalay region. Yamethin District is the most cotton cultivated district in the Mandalay region. In Yamethin District, there are two townships, Yamethin and Pyawbwe. Between these townships, Yamethin township was chosen as the study area due to the major cotton production area of 17,410 ha (52.98%) in Yamethin districts. In Yamethin township, cotton was grown in pre-monsoon and post-monsoon season. Shwe Daung-8, Shwe Daung-10, B-31, RAKA 666, and Lonemalay are the most cultivated varieties in Yamethin Township. Yamethin Township was one of the cotton special zones in Mandalay region. Yamethin Township contains 11 village tracts that are classified as cotton special zones. Thirty-five cotton growing farmers from Segyi village tract (Segyi village and Nyaungei village) were interviewed among these village tracts.

The primary survey data were taken from selected cotton farmers through personal interviews. The household survey was conducted in August and October 2024, covering 72 cotton growing farmers from Katin, Kanbeit, Segyi, Htanpaukkone, Nyaungei, Zeephyukan villages in Yamethin Township. The farmers in these selected villages have grown different cotton varieties in different growing seasons. The purposive sampling method was used to identify the cotton farmers, and then random sampling was used to collect the sample cotton farmers. For this study, a sample of 30 farmers who grew DOA released OPV, Shwe Daung-10 (93.33%) and Shwe Daung-8 (6.67%), and 42 farmers who grew imported hybrid varieties, B-31 (90.48%) and RAKA 666 (9.52%), were interviewed from among all cotton farmers in pre-monsoon and post-monsoon season. Both qualitative and quantitative data were first compiled into the Microsoft Excel program. The study employed descriptive methods and t-test analysis by using statistical software packages, STATA 15. Descriptive analysis was used to describe the demographic characteristics of respondents. Cost and return analysis was used to compare the cost and return of cotton production based on DOA released OPV and imported hybrid varieties. SWOT analysis was used to examine the current situation of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers.

Descriptive statistics such as frequency, percentage, mean, minimum, maximum and standard deviation were used to explore the demographic characteristics of sample farm households, such as age, schooling year, farming experience, cotton producing experience, family size and household assets, access to extension services, crop production activities, etc. Enterprise budgeting developed by Olson (2003) was applied in economic analysis for the estimation of cost, return and profit per unit area of cotton production of sample farmers in the study area. In the analysis, the following variable costs include:

- (1) Material input cost
- (2) Family labour cost

(3) Hired labour cost

Both cash and non-cash items were included in the estimation of material cost and labour cost. Non-cash items for material costs included own reserved seed and family labour. Cash payment items included that buying directly from shops or markets using cash, hired labour and payment for land preparation (custom-hired tractor).

Expressions for estimating returns to various factors are described as follows;

Return above variable cost (Gross margin) = Total Revenue - Total Variable Cost

Return above variable cash cost = Total Revenue - Total Variable Cash Cost

Return per unit of cash expensed = Total Revenue / Total Variable Cash Cost

Benefit cost ratio = Total Revenue / Total Variable Cost

Break-even yield = Total Variable Cost / Average price per kg

Break-even price = Total Variable Cost / Average yield per hectare

Source: Olson, 2003

Results and Discussion

Demographic characteristics of sample farmers

The demographic characteristics of sample farmers in the study area showed in Table 2. The average age of farmers who grew DOA released OPV was 54 years, and that of farmers who grew imported hybrid varieties was 55 years. The average schooling year of all sample farmers was 5 years. The average farming experience of farmers who grew DOA released OPV was 33 years, while that of farmers who grew imported hybrid varieties was 32 years. The average cotton producing experience of farmers who grew DOA released OPV was 24 years, while that of farmers who grew imported hybrid varieties was 23 years. Although cotton farmers have extensive experience in cotton farming, they primarily grow local cotton varieties, and the cultivation of hybrid cotton varieties has been practiced for a few years. There was no significant difference in age, schooling year, farming experience and cotton producing experience between the farmers who grew DOA released OPV and imported hybrid varieties in the study area.

Table 2. Demographic characteristics of sample farmers

(Unit = Year)					
Items	DOA released OPV (n=30)		Imported hybrid varieties (n=42)		t-test
	Average	SD	Average	SD	
Age	54 (26-78)	13.58	55 (32-80)	12.11	0.65 ^{ns}
Schooling year	5 (2-9)	1.73	5 (0-10)	2.20	0.60 ^{ns}
Farming experience	33 (10-55)	13.29	32 (1-65)	15.21	0.91 ^{ns}

Cotton producing experience	24 (3-55)	14.24	23 (1-60)	15.29	0.82 ^{ns}

Note: The values in the parentheses represent range. ns is not significant differences.

Cultivated area, yield, total production and market price of cotton

The cultivated area, yield, total production and market price of cotton showed in Table 3. The average cultivated area of cotton was 1.13 ha for farmers who grew DOA released OPV within the range between 0.40 ha and 3.64 ha, and that of farmers who grew imported hybrid varieties was 1.25 ha, ranging from 0.40 ha to 4.05 ha. The average cotton yield of farmers who grew DOA released OPV was 1,373.53 kg/ha, ranging from 360.08 kg/ha to 2,430.49 kg/ha, while the farmers who grew imported hybrid varieties was 1,988.92 kg/ha, ranging from 405.08 kg/ha to 2,835.57 kg/ha. The average total cotton production was 1,603.83 kg for farmers who grew DOA released OPV, and that of farmers who grew imported hybrid varieties was 2,396.57 kg. Farmers who grew DOA released OPV and imported hybrid varieties had average cotton market price of 1,817.07 MMK/kg and 1,961.38 MMK/kg, respectively.

The results showed that there were significant differences between DOA released OPV and imported hybrid varieties production. The yield, total production and market price of imported hybrid varieties were higher than those of DOA released OPV. These significant yield gains result from the government sponsored cotton special zones program implemented by the DOA, particularly through its distribution of high-quality imported hybrid F₁ seed that enhanced farmer profitability. However, there was no significant difference in cultivated area between the two groups of sample farmers.

Table 3. Cultivated area, yield, total production and market price of cotton

Items	Unit	DOA released OPV (n=30)	SD	Imported hybrid varieties (n=42)		t-test
		Average		Average	SD	
Cultivated area	ha	1.13 (0.40-3.64)	0.74	1.25 (0.40-4.05)	0.74	0.51 ^{ns}
Yield	kg/ha	1,373.53 (360.08-2,430.49)	585.2 ¹	1,988.92 (405.08-2,835.57)	581.89	0.00***
Total production	kg	1,603.83 (295.08-7,377.05)	1,489.46	2,396.57 (327.87-6,721.31)	1,494.23	0.03**
Market price	MMK/kg	1,817.07 (1,219.51-2,012.20)	167.4 ⁹	1,961.38 (1,524.39-2,317.07)	196.51	0.00***

Note: The values in the parentheses represent range. ** and *** are significant at 5% and 1% level respectively, ns is not significant differences.

Cost and return analysis of cotton production compare to doa released opv and imported hybrid varieties grown by sample farmers

Cost and return analysis of cotton production compared to DOA released OPV and imported hybrid varieties were determined by enterprise budgeting. The different costs of cotton production by sample farmers in the study area, showed in Table 4. Total material cost was slightly higher for farmers who grew imported hybrid varieties, which was 666,689 MMK/ha, as compared to that of farmers who grew DOA released OPV, which was 538,979 MMK/ha. There was a significant difference in total material cost at 1% level ($p < 0.01$). The total family labour cost for farmers who grew DOA released OPV was 554,495 MMK/ha, while farmers who grew imported hybrid varieties spent 511,041 MMK/ha for family labour as opportunity cost. The hired labour cost for farmers who grew DOA released OPV and imported hybrid varieties were 659,232 MMK/ha and 973,339 MMK/ha, respectively. The total family labour cost was not significantly different and there was a significant difference in total hired labour cost at a 5% level ($p < 0.05$).

The total variable cost per hectare of cotton was 1,782,662 MMK/ha for farmers who grew DOA released OPV and 2,192,070 MMK/ha for farmers who grew imported hybrid varieties respectively. There was a significant difference in total variable cost at a 5% level ($p < 0.05$). Thus, the total variable cost was higher for imported hybrid varieties than for DOA released OPV. It was due to higher costs of some inputs and hired labour spent by farmers who grew imported hybrid varieties. Imported hybrid cotton is a high-yielding variety. However, higher productivity can result in more frequent harvesting, increasing labour costs as more workers need to be hired for harvesting. Total interest on cash cost for farmers who grew DOA released OPV and imported hybrid varieties were 29,955 MMK/ha and 41,001 MMK/ha, respectively. There was a significantly different in total interest on cash cost at 1% level ($p < 0.01$). All sample farmers get credit from the government (State Economic Promotion Fund) with a 0.025 interest rate for six months. The total variable cash cost per hectare of cotton was 1,228,167 MMK/ha for farmers who grew DOA released OPV and 1,681,029 MMK/ha for farmers who grew imported hybrid varieties in the study area. There was a significant difference in total variable cash cost at 1% level ($p < 0.01$).

The total gross benefit was calculated by multiplying the effective cotton yield and effective price received by sample farmers. The total gross benefit was about 2,495,800 MMK/ha for farmers who grew DOA released OPV, while that for imported hybrid varieties was 3,901,038 MMK/ha. Return above variable cost for farmers who grew DOA released OPV and imported hybrid varieties was 713,138 MMK/ha and 1,708,968 MMK/ha, respectively. In addition, the return above variable cash cost was 1,267,634 MMK/ha for farmers who grew DOA released OPV and 2,220,009 MMK/ha for farmers who grew imported hybrid varieties. There were significant differences in gross benefit, return above variable cost and return above variable cash cost at a 1% level ($p < 0.01$). Not only the yield and but also the price of hybrid varieties, gross benefit, return above variable costs and benefit cost ratio of cotton production by farmers who grew imported hybrid varieties were significantly higher than that of farmers who grew DOA released OPV.

The benefit cost ratio indicates how much the gross returns from a given crop by investing one kyat in growing that crop. The amount of benefit cost ratio of greater than one is profitable. Farmers who grew imported hybrid varieties achieved higher returns per unit of cash expensed and a benefit cost ratio compared to those farmers who grew DOA

released OPV. That means farmers can earn a profit from more than one unit from a given crop by investing in cotton production if they invest a unit cash expense. Return per unit of cash expenses was 2.03 for farmers who grew DOA released OPV, while that of imported hybrid varieties was 2.32. Benefit cost ratio was 1.40 for farmers who grew DOA released OPV, while that of imported hybrid varieties was 1.78. There was a significant difference in benefit cost ratio at 1% level ($p < 0.01$) and return per unit cash cost was not significantly different in both groups of farmers.

The break-even yield was the yield that can cover the total variable cost at the current cotton price, and the break-even price was the price that can cover the total variable cost at the current yield of cotton production. The break-even yield of farmers who grew DOA released OPV and imported hybrid varieties was 981 kg/ha and 1,118 kg/ha, respectively. It indicated that farmers who grew DOA released OPV and imported hybrid varieties can cover their total cotton production costs when they start to achieve above yield at the current cotton price. Similarly, farmers who grew DOA released OPV and imported hybrid varieties benefit from their total production cost when they start to get cotton prices of 1,298 MMK/kg and 1,102 MMK/kg at the current yield. There was a significant difference in break-even yield at the 10% level ($p < 0.1$) and break-even price was not significantly different in both groups. The results revealed that the break-even yield of farmers who grew imported hybrid varieties was slightly higher than that of farmers who grew DOA released OPV in order to cover their production cost for cotton per hectare in the study area.

Table 4. Enterprise budget of cotton production compared to DOA released OPV and imported hybrid varieties

Items	Unit	DOA released OPV (n=30)	Imported hybrid varieties (n=42)	t-test
Gross benefit	MMK/ha	2,495,800	3,901,038	0.00***
Total material cost	MMK/ha	538,979	666,689	0.00***
Total family labour cost	MMK/ha	554,495	511,041	0.76 ^{ns}
Total hired labour cost	MMK/ha	659,232	973,339	0.04**
Total interest on cash cost	MMK/ha	29,955	41,001	0.00***
Total variable cost	MMK/ha	1,782,662	2,192,070	0.02**
Total variable cash cost	MMK/ha	1,228,167	1,681,029	0.00***
Return above variable cost	MMK/ha	713,138	1,708,968	0.00***
Return above variable cash cost	MMK/ha	1,267,634	2,220,009	0.00***
Benefit cost ratio		1.40	1.78	0.00***
Return per unit of cash cost		2.03	2.32	0.12 ^{ns}

Break-even yield	kg/ha	981	1,118	0.08*
Break-even price	MMK/kg	1,298	1,102	0.30 ^{ns}

Note: *, ** and *** are significant at 10%, 5% and 1% level respectively, ns is not significant differences.

Strengths of cotton production compare to DOA released OPV and imported hybrid varieties grown by sample farmers

Based on the current cotton production in the study areas, the sample farmers showed the following six strengths, which were named S₁ to S₆ in Table 5. They are S₁ (easy to access good variety), S₂ (high yielding), S₃ (low water requirements), S₄ (good appearance of seed cotton), S₅ (tolerance to drought compared to other crops) and S₆ (resistance to pests and diseases). Farmers who grew DOA released OPV and imported hybrid varieties responded that their cotton farms had strengths, S₁ (93.33% and 90.48%), S₂ (83.33% and 97.62%), S₃ (83.33% and 92.86%), S₄ (96.66% and 97.62%), S₅ (83.33% and 88.10%), and S₆ (70.00% and 90.48%). The main strengths of cotton production by farmers who have grown DOA released OPV and imported hybrid varieties were good appearance of seed cotton, high yielding and easy to access good variety.

Table 5. Strengths of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers

(Unit = percentage)

No.	Descriptions of Strengths	DOA released OPV (n=30)	Imported varieties (n=42)	hybrid
S ₁	Easy to access good variety	93.33	90.48	
S ₂	High yielding	83.33	97.62	
S ₃	Low water requirement	83.33	92.86	
S ₄	Good appearance of seed cotton	96.66	97.62	
S ₅	Tolerance to drought compared to other crops	83.33	88.10	
S ₆	Resistance to pests and diseases	70.00	90.48	

Weaknesses of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers

Farmers who grew DOA released OPV and imported hybrid varieties experienced 5 statements of weaknesses, which were named W₁ to W₅ in Table 6. They are W₁ (weight loss due to storage), W₂ (not enough credit access), W₃ (inadequate technical support to distinguish cotton quality), W₄ (insufficient scientific sowing methods), W₅ (incomplete market information). Farmers who grew DOA released OPV and imported hybrid varieties responded that their cotton farms had faced weaknesses of W₁ (90.00% and 92.86%), W₂ (60.00% and 52.38%), W₃ (53.33% and 45.24%), W₄ (46.47% and 35.71%), and W₅ (43.33% and 14.29%). The main weaknesses of cotton production by farmers who

have grown DOA released OPV and imported hybrid varieties were weight loss due to storage, not enough credit access and inadequate technical support to distinguish cotton quality.

Table 6. Weaknesses of cotton production compare to DOA released OPV and imported hybrid varieties grown by sample farmers

(Unit = percentage)

No.	Descriptions Weaknesses	of DOA released OPV (n=30)	Imported hybrid varieties (n=42)
W ₁	Weight loss due to storage	90.00	92.86
W ₂	Not enough credit access	60.00	52.38
W ₃	Inadequate technical support to distinguish cotton quality	53.33	45.24
W ₄	Insufficient scientific sowing methods	46.47	35.71
W ₅	Incomplete market information	43.33	14.29

Opportunities of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers

Farmers who grew DOA released OPV and imported hybrid varieties had many opportunities in cotton production. A total of 4 statements from O₁ to O₄, showed the opportunities of cotton production by sample farmers, were listed in Table 7. Among the listed statements concerning the external opportunities of cotton production, all sample farmers had opportunities: O₁ (encouragement to develop the cotton crop sector), O₂ (employment opportunities for local labour), O₃ (production of cotton seed oil and animal feed), O₄ (easy to find the buyer). Farmers who grew DOA released OPV and imported hybrid varieties responded that their cotton farms had opportunities, O₁ (86.87% and 88.10%), O₂ (80.00% and 90.48%), O₃ (63.33% and 61.90%), and O₄ (56.67% and 38.10%). According to the results about the opportunities of cotton production by both sample farmers, there was encouragement to develop the cotton crop sector and employment opportunities for local labour.

Table 7. Opportunities of cotton production compared to DOA released OPV and imported hybrid varieties grown sample farmers

(Unit = percentage)

No.	Descriptions of Opportunities	DOA released OPV (n=30)	Imported hybrid varieties (n=42)
O ₁	Encouragement to develop the cotton crop sector	86.87	88.10
O ₂	Employment opportunities for local labour	80.00	90.48
O ₃	Production of cotton seed oil and animal feed	63.33	61.90
O ₄	Easy to find the buyer	56.67	38.10

Threats of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers

The number and description of threats that were asked to know the external opportunities of cotton production by sample farmers were described in Table 8. Farmers who grew DOA released OPV and imported hybrid varieties had many threats in cotton production. Farmers who grew DOA released OPV and imported hybrid varieties experienced 4 statements of threats, which were named T₁ to T₄, respectively. Among the listed statements concerning the external threats of cotton production, all sample farmers had the following threats: T₁ (unstable market price), T₂ (high agrochemical price), T₃ (high incidence of pests and diseases), and T₄ (low resistance to heavy rainfall). Farmers who grew DOA released OPV and imported hybrid varieties replied that their cotton farms had faced threats, T₁ (80.00% and 97.62%), T₂ (80.00% and 78.57%), T₃ (46.67% and 26.19%), and T₄ (23.33% and 28.57%). The main threats of cotton production by both sample farmers were unstable market price and high agrochemical price.

Table 8. Threats of cotton production compared to DOA released OPV and imported hybrid varieties grown by sample farmers

(Unit = percentage)

No.	Descriptions of Threats	DOA released OPV (n=30)	Imported hybrid varieties (n=42)
T ₁	Unstable market price	80.00	97.62
T ₂	High agrochemical price	80.00	78.57
T ₃	High incidence of pests and diseases	46.67	26.19
T ₄	Low resistance to heavy rainfall	23.33	28.57

Conclusion

Even though the demographic characteristics of sample farmers were not significantly different, yields were significantly different. The potential yield of imported hybrid varieties was 4.05 MT/ha, but in this research, the average cotton yield of farmers who grew imported hybrid varieties was 1.98 MT/ha. Therefore, imported hybrid cotton varieties need to apply the required amount of inputs to reach potential yield. On the other hand, farmers who properly grew DOA released OPV, applied inputs, and followed recommended cultivation practices achieved high yield despite not reaching the hybrid potential yield. Furthermore, OPV seeds are more affordable, making them accessible to smallholder farmers who cannot afford the costs of imported hybrid cultivation. Ginning factories, farmers and seed multipliers should collaborate to get purified seed for Open Pollinated Varieties (OPVs). Higher cotton yield may require more frequent harvesting, increasing labor costs. To reduce these costs, labour saving technologies should be used.

The overall findings of SWOT analysis also figured out that the cotton sector has many internal and external contexts. On the other hand, to overcome the weaknesses and threats of cotton farmers, the government should set up a floor price for cotton to stable market price. Moreover, both the public and private sectors should be able to adjust agricultural input price. In addition, farmers' capacity strengthening programs like technical support concerning cotton cultivation, pests and diseases protection with effective training should also be facilitated by the public and private sectors to develop the cotton sector.

High-quality cotton varieties are important to get more profit for cotton production and better fiber quality for the garments and textile industry. In this study, it was found that imported hybrid varieties received more yield and profit than DOA released OPV. Although imported hybrid varieties get more profit, farmers need to understand their associated risks. To maximize benefits, cultivation must use F_1 seed exclusively, as F_2 generations cannot produce the same quality and quantity of F_1 . Therefore, farmers should purchase hybrid cotton seeds from trusted sources that sell F_1 seed rather than buying from unreliable middlemen. Extension workers need to train farmers to understand that only F_1 hybrid seeds can give higher yields when cultivating hybrid cotton varieties.

Hybrids, high-yielding varieties, should be produced domestically at affordable prices while improving the quality of local varieties through purification and breeding programs. In addition, foundation seed (F.S) from cotton research and technology development farms should be systematically multiplied into registered seed (R.S) and certified seed (C.S) generations and distributed to the farmers. To enable smallholder farmers to afford and cultivate crops at lower costs, it is essential to promote seed multiplication programs.

Besides, both public and private cotton seed production enterprises should be cooperated and coordinated to produce high-yield, high-quality hybrid cotton varieties that are adaptable for local conditions and make them available at affordable prices domestically. To achieve this, installing good quality cotton parental lines and investing in cotton varietal improvement research should be implemented. Furthermore, improved policies to support private and public funds for cotton breeding line development for good-quality cotton seeds, to transfer effective cultivation technology and input use management systems for all cotton farmers through strengthened extension activities.

Good-quality seed can provide better cotton quality, which is the main raw source for the textile industry. Currently, cotton yarn is imported from neighboring countries for Myanmar's textile industry. Therefore, the development of cotton seed variety in breeding research can fulfil the requirement of domestic demand for the textile industry and reduce cotton yarn imports. It is needed to improve not only the cotton production but also the textile industry.

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References

- Department of Agriculture. (2024). Data records of Cotton and Allied Fiber Crops Division, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.
- Khaing, S., Myint, T., Soe, T. T., Moh, M., Aye, Y. N. Aye, M. H., & Hnin, C. H., (2023). Myanmar cotton value chain: case study in Meiktila District, Mandalay Region. Food and Fertilizer Technology Centre for the Asian and Pacific Region. FFTC Agricultural Policy Platform. Retrieved From <https://ap.ffc.org.tw/> article/ 3300.
- Ministry of Agriculture, Livestock and Irrigation. (2023). Myanmar Agriculture in Brief, Department of Planning.
- Ministry of Commerce. (2024). Nay Pyi Taw, The Republic of the Union of Myanmar.
- Olson, K. (2003). *Farm management principles and strategies. The textbook of Farm Management: Principles and Strategies*. Department of Applied Economics at the University of Minnesota. Retrieved from <https://www.wiley.com/en-us/Farm+Management%3A+Principles+and+S>
- Smart Myanmar (2023). A value chain analysis: sustainability, more consumer awareness, responsibility and transparency in textile sector of Myanmar. Retrieved from https://smartmyanmar.org/sites/smartmyanmar.org/files/publicationdocs/23_jan_tvc_update.pdf.

Cost and Return Analysis of Sesame End Products by Farmers in Lewe Township, Nay Pyi Taw Union Territory

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Abstract

Sesame is an important oilseed crop and has the largest sown area among oilseed crops in Myanmar. Value-added sesame products are economically more profitable than raw sesame grain due to the value additions. The cost and return of sesame farmers vary depending on their sesame end products. This research aimed to observe the reasons for selling sesame end products and to find out the cost and return of sesame end products by sampled farmers in Lewe Township. A total of 65 sesame farmers from three villages in Lewe Township were selected using purposive sampling. Descriptive analysis was used to estimate the mean, frequency, and percentage. Cost and return analysis were analysed to estimate return above variable cost, return above variable cash cost, benefit-cost ratio, break-even yield and break-even price. About 29 sampled farmers sold only sesame grain because crushing sesame grain for edible oil makes them higher in labour cost and time-consuming. However, about 36 sampled farmers crushed sesame grain for edible oil for home consumption because of their health benefits. According to the cost and return analysis, the total variable cost and return of producing edible oil was higher than that of producing sesame grain. The benefit-cost ratios were 1.56 in sesame grain production and 1.84 in edible oil production. As a result, selling oil that crushed sesame grain was more profitable than selling the sesame grain from farmers in Lewe Township, Nay Pyi Taw.

Keywords: benefit-cost ratio, edible oil, reasons, sesame grain

JEL code: D61, E23

SDG classification: SDG 2, SDG8, SDG 12

Introduction

Crops, livestock, and fisheries are subsectors of the agriculture sector, which accounted for 28.79% of total export revenue and 23.71% of GDP in Myanmar (Ministry of Agriculture, Livestock, and Irrigation [MOALI], 2023a). Major crops in Myanmar are cereal crops, oilseed crops, industrial crops, and culinary crops within the crop subsectors, described in Figure 1. Oilseed crops took Myanmar's third largest sown area after cereal and pulse crop groups (MOALI, 2023b).

Most of the world's sesame production came from Africa (54.8%) and Asia (37.2%), accounting for 93.2% of global output, with the remaining 6.8% coming from America and Europe in 2025. The top ten sesame-producing countries include Sudan, India, Myanmar, China, Nigeria, Pakistan, Brazil, Tanzania, Burkina Faso, and Chad. Myanmar ranked third as the largest sown area, 1.50 million hectares in Myanmar, as shown in Figure 2 (Food and Agriculture Organization [FAOSTAT], 2025). However, Myanmar's sesame yield was 0.50 MT/ha and low compared to the other top ten sesame-producing countries except Sudan, as described in Figure 3 (FAOSTAT, 2025).

Myanmar is one of the largest global producers and exporters of sesame, benefiting from a favourable geographical location for its cultivation. However, the country faces a challenge in achieving self-sufficiency in edible oil production, as it remains heavily reliant on palm oil, with about 800 thousand metric tons imported in 2023 to meet domestic demand (MOALI, 2023a). To address this, Myanmar has prioritized agricultural development, focusing on oilseed crops to improve self-sufficiency and promote exports. The government has also supported Micro-, Small-, and Medium-Sized Enterprises (MSMEs) to enhance this sector. Twelve special zones for oilseed crops have been established by MOALI in 2024, Nay Pyi Taw Union Territory, Sagaing, Bago, Magway, Mandalay, Ayeyawaddy regions and Shan State of Myanmar to support domestic oil production.

While sesame is primarily grown for oil, much of it is exported as raw grain due to higher international prices, limiting its contribution to the domestic oil supply. Some farmers crush sesame for household consumption and local markets using traditional methods, but many sell raw grain. Strengthening MSMEs is a key to bridging the gap between sesame production and value-added processing, which can enhance oil milling, improve technology access, and create a competitive sesame oil industry. Value-added products like processed sesame oil are more profitable due to their high international market value. It is important to assess the benefits and costs of producing different sesame end products. Therefore, this research aimed to observe the reasons for selling sesame end products and to find out the cost and return of sesame end products by sampled farmers in Lewe Township.

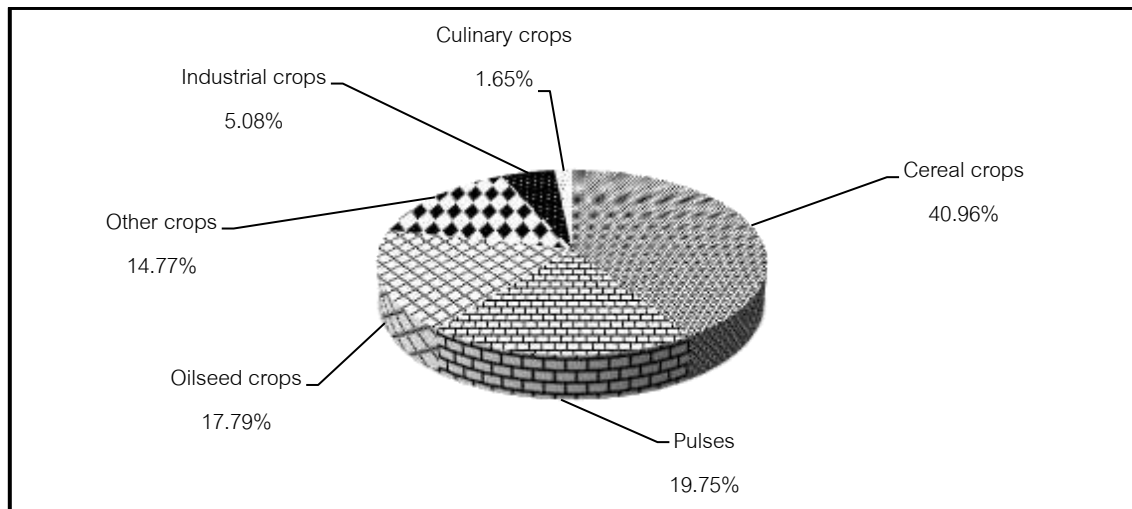


Figure 1. Proportion of total sown areas according to crop groups in Myanmar, 2022-2023

Source: MOALI, 2023b

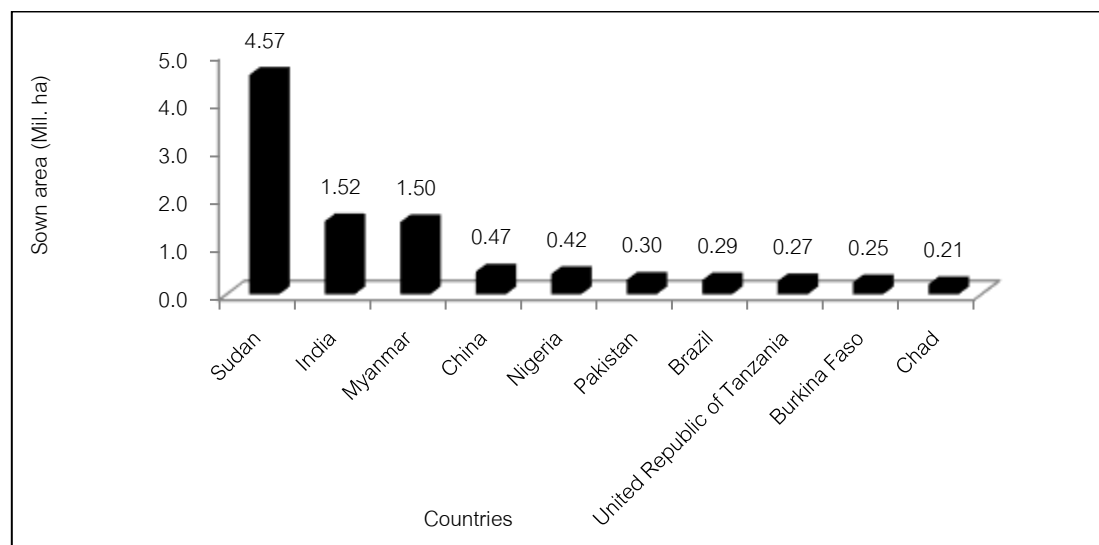


Figure 2. Sown area of sesame in the top ten sesame-producing countries in the world, 2023

Source: FAOSTAT, 2025

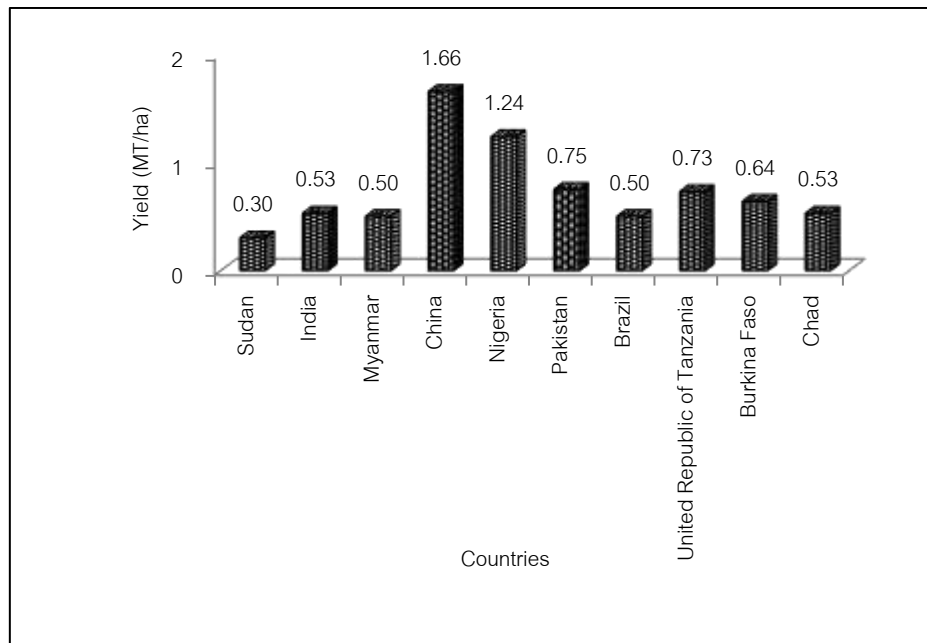


Figure 3. Yield of sesame in the top ten sesame-producing countries in the world, 2023

Source: FAOSTAT, 2025

Methodology

Lewe Township was chosen as the study area due to the largest sesame sown area in Nay Pyi Taw Union Territory during 2023-2024 (DOA, 2024). The survey was conducted from August to September 2024. The purposive sampling method was used to identify the sampled sesame farmers with 65 sampled sesame farmers from Ye Oh Zin, Mway Yoe Lay, and Zee Kone villages in Lewe Townships (Figure 4). The primary information was collected through a personal interview using a structured questionnaire to observe the cost and return among the selling types of sesame end products. The data included demographic and farming characteristics, farm and livestock assets of sesame farmers, reasons for selling different sesame end products, and sesame production data such as family labour, hired labour, yield, resources used, amount and prices of input and output, transportation costs, and crushing costs, etc. Secondary data sources were publications and official records from Ministry of Agriculture, Livestock and Irrigation (MOALI), General Administration Department (GAD), Department of Agriculture (DOA), and other related publications.

In achieving the objectives of the study, the following analytical methods were employed: (1) descriptive statistics and (2) cost and return analysis. Enterprise budgeting developed by Olson (2003) was used in cost and return analysis to estimate cost, return, and profit per unit area of sesame production of farmers in the study area; the following equations were used.

$$\begin{aligned}
 \text{Return above variable cost} &= \text{Total revenue} - \text{Total variable cost} \\
 \text{Return above variable cost} &= \text{Total revenue} - \text{Total variable cash cost} \\
 \text{Return per unit of cash cost} &= \frac{\text{Total revenue}}{\text{Total variable cash cost}} \\
 \text{Benefit cost ratio} &= \frac{\text{Total revenue}}{\text{Total variable cost}} \\
 \text{Break – even yield} &= \frac{\text{Total variable cost}}{\text{Average market price per kg}} \\
 \text{Break – even price} &= \frac{\text{Total variable cost}}{\text{Average yield per ha}}
 \end{aligned}$$

Total variable costs were taken into account: material input cost, hired labor cost, family labor cost, and interest on cash cost. Both cash and non-cash items were included in the estimation of material and labor costs. Family labor is a non-cash labor cost item. Non-cash items for material cost were own reserved seeds, working animals, and farmyard manure (FYM) owned by the sampled farmers. Cash payments for labor included expenses for the hired labor, the use of farm machinery, and payments for hired draught cattle used in farming activities.

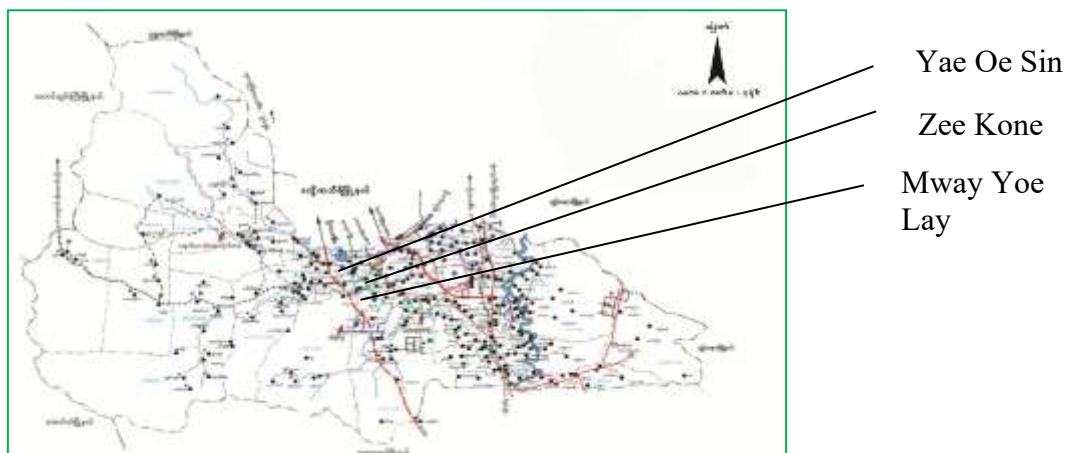


Figure.4 Map and study area of Lewe Township

Source: GAD,2022

Results and Discussion

Demographic and socioeconomic characteristics of the sampled farmers

The age and farming experience of sampled farmers in sesame production play a crucial role in enhancing productivity and decision-making among farmers (Table.1). The average age of sampled farm household heads was 54 years, ranging from 34 to 91 years, indicating they have many working experiences. The sesame farming

experience of the sampled farm household heads was 13 years, ranging from 3 to 60 years, and it implies that production and management decisions in terms of pests and disease management, pre-and post-harvest management, and market decisions could be enhanced based on their past experiences. This finding concurs with the findings of Ajabade, Adejo, Eti-Uku & Maiye (2021) who found that women sesame farmers in Kogi State, Nigeria had the average farming experience of 13 years.

The average land holding size by sampled farmers was 2.06 ha ranging from 0.40-6.68 ha (Table.1). The sampled farmers owned more lowland than upland, with an average lowland ownership area of 1.98 ha. The average sesame sown area was 1.70 ha. Approximately 61 farmers cultivated sesame in lowland areas, while two cultivated in upland areas and another two cultivated in lowland and upland areas, indicating more reliance on lowland than upland farming for sesame cultivation.

Table 1. Demographic and farming characteristics of sampled farmers (n=65)

Item	Unit	Mean	Range	SD
Age	Year	54	34-91	11.01
Sesame farming experience	Year	13	3-60	14.09
Land holding size	ha	2.06	0.40-6.68	1.37
Lowland	ha	1.98	0.40-6.07	1.31
Upland	ha	0.08	0-2.02	0.30
Sesame sown area	ha	1.70	0.40-5.26	1.12

The gender, education levels, and housing status of sampled farm households are presented in Table 2. Regarding the gender status of sampled farm household heads, about 72.31% of households were male-headed and about 27.69% were female-headed, respectively. The education levels of the sampled household heads were aggregated into four categories. The primary level referred to formal education for up to 5 years, the middle level referred to formal schooling for up to 9 years, the high school level referred to formal education for up to 11 years and the graduate level mentioned to those who were attending the university and received a bachelor's degree from a university. Most sampled farm household heads were middle school level (47.69%). About 53.85% of the sampled households lived in brick houses, indicating the highest proportion among the sampled households.

Table 2. Gender, education level and types of houses of sampled farmers (n=65)

Variable	Frequency	Percent
Gender status of household heads		
Male	47	72.31
Female	18	27.69
Education level of household heads		
Primary	13	20.00

Middle	31	47.69
High	17	26.15
Graduate	4	6.15
Types of houses		
Brick	35	53.85
Wooden	28	43.08
Bamboo	2	3.08

Ownership of farm assets by sampled farmers is shown in Table 3. The highest proportion of sampled farmers owned battery sprayers (93.48%). Thus, it was a popular farm asset in the study area. Around 40% of sampled farmers possessed warehouse (44.61%), plough (41.53%), harrow (41.53%), bullock cart (40.00%), and pump (23.07%), respectively. Only a small proportion of sampled farmers, less than 5%, owned combine harvester (4.61%), tractor/ hand tractor (3.07%) and rotary weeder (3.07%) because these assets were expensive, and most of the sampled farmers could not afford to buy them.

Table 3. Farm assets of sampled farmers (n=65)

Item	Frequency	Percent
Sprayer (Battery)	61	93.48
Warehouse	29	44.61
Plough	27	41.53
Harrow	27	41.53
Bullock Cart	26	40.00
Pump	15	23.07
Power tiller	12	18.46
Sprayer (Manual)	7	10.76
Seeder	6	9.23
Combine harvester	3	4.61
Tractor/ Hand tractor	2	3.07
Rotary weeder	2	3.07

Table 4 describes the livestock assets of the sampled farmers. The sampled farmers possessed cattle (35.38%), chicken (32.30%), buffalo (6.15%), pig (6.15%), and goat (1.53%). The most widely owned livestock were chicken and cattle, demonstrating their importance in the agricultural system for manure, draft power, and revenue creation. A smaller ownership proportion of buffalo, pigs, and goats indicated their lesser significance in the study area.

Table 4. Livestock assets of sampled farmers (n=65)

Item	Unit	Frequency	Percent
Cattle	No.	23	35.38
Chicken	No.	21	32.30
Buffalo	No.	4	6.15
Pig	No.	4	6.15
Goat	No.	1	1.53

Reasons for selling sesame as grain by sampled farmers in Lewe Township

The reasons for selling sesame as grain by sampled farmers are presented in Table 5. About 29 sampled farmers sold sesame grain without oil crushing for home consumption. The reasons to sell only sesame grain were high labour cost and consuming time for oil crushing (41.38%), higher profit in selling sesame grain (34.48%), capital for the next season crop (24.13%) and low level of consumption for the oil obtained from crushing the black sesame (24.13%). Among 29 sampled farmers, 79.31% cultivated Samonenet, and 20.69% cultivated Sinyadanar-14 sesame variety.

Table 5. Reasons for selling sesame as grain by sampled farmers (n=29)

No.	Reason	Frequency	Percent
1.	High labor cost and time consuming in oil crushing	12	41.38
2.	Higher profit in selling sesame as grain	10	34.48
3.	Capital for the next season crop	7	24.13
4.	Limited demand for black sesame oil	7	24.13

Reasons for crushing sesame oil for home consumption by sampled farmers in Lewe Township

The reasons for crushing sesame oil for home consumption by sampled farmers are presented in Table 6. About 36 sampled farmers sold sesame as grain and crushed it for home consumption of edible oil. The reasons for home consumption of sesame oil were its benefit for health concerns (66.67%), self-sufficiency of edible oil (50.00%), and the high price of edible oil (38.89%). Among 36 sampled farmers, 63.89% cultivated Samonenet, 22.22% cultivated Sinyadanar-14 and 13.89% cultivated red sesame variety. Although Red sesame is mainly grown for edible sesame oil and Samonenet is for selling as grain in Myanmar, the sampled farmers crushed also black sesame varieties (Samonenet and Sinyadanar-14) for home consumption for its health concerns.

Table 6. Reason for crushing sesame for edible oil home consumption by sampled farmers (n=36)

No.	Reason	Frequency	Percent
1.	Sesame oil is beneficial for health	24	66.67
2.	Self-sufficiency of edible oil	18	50.00
3.	High price of cooking oil	14	38.89

Yield and market prices of sesame end products by sampled farmers

In this study, there were 65 sampled farmers who sold sesame as grain and 36 sampled farmers who crushed it for home consumption of edible oil in the study area. In the following parts of the results and discussion, the 65 sampled farmers who sold sesame as grain were termed as sampled sesame grain producers and 36 sampled farmers who crushed it for edible oil for home consumption as sampled sesame edible oil producers.

Yield and market prices of sesame end products by sampled farmers are followed as, the average yield of sesame from sampled sesame grain producers was 598.63 kg/ha with a range of 181.54-1,331.33 kg/ha. The average yield of grain from sampled sesame edible oil producers was 597.58 kg/ha with a range of 181.54-1,331.33 kg/ha. The average yield of edible oil was 292.57 kg/ha with a range of 84.58-664.58 kg/ha. The average yield of oil cake was 297.77 kg/ha with a range of 84.58-708.88 kg/ha.

The average grain price of the sampled sesame grain producers was 6,022.55 MMK/kg with a range of 3,674.97-7,349.94 MMK/kg. The average sesame grain price of sampled sesame edible oil producers was 6,085.25 MMK/kg with the range of 3,879.13-7,349.94 MMK/kg. The average edible oil price was 12,678.94 MMK/kg with a range of 11,042.94-13,496.93 MMK/kg. The average oil cake price was 1,806.41 MMK/kg, with a range of 1,595.09-2,024.54 MMK/kg.

Cost and return analysis of sesame production

The enterprise budget was calculated using cost and return analysis of sesame end products by sampled farmers in Lewe Township (Table 7). Total revenue was computed by multiplying the yield and price received by sampled farmers. Total revenue was 3,605,279 MMK/ha for sampled sesame grain producers and 4,247,372 MMK/ha for sampled edible oil producers. Total variable costs of sampled grain and sesame edible oil producers were 2,287,960 MMK/ha and 2,310,892 MMK/ha, respectively. Total variable cash costs were 1,997,617 MMK/ha for sampled sesame grain producers and 2,039,450 MMK/ha for sampled edible oil producers. The returns above variable costs were 1,278,456 MMK/ha for sampled sesame grain producers and 1,936,479 MMK/ha for sampled edible oil producers. The returns above variable cash costs were 1,568,799 MMK/ha for sampled sesame grain producers and 2,207,922 MMK/ha for sampled edible oil producers.

Returns per unit of cash expended were 1.79 for sampled sesame grain producers and 2.08 for sampled edible oil producers. This indicates that for every 100 MMK spent on production, the sampled sesame farmer earned 179 MMK in revenue for sampled grain

producers and 208 MMK in revenue for sampled edible oil producers. Returns per unit of capital expensed were 1.56 and 1.84 for sampled grain and sesame edible oil producers, respectively. It considered the opportunity costs and total variable cash costs as the costs of production. So, the returns per unit of capital expensed mean that for every 100 MMK of cost of production, 156 MMK in revenue for sampled grain producers and the sampled sesame farmer earned 182 MMK in revenue for sampled edible oil producers.

Table 7. Enterprise budget in sesame production of sampled farmers

Item	Unit	Grain producers (n=65)	Edible oil producers (n=36)
Total variable cost	MMK/ha	2,287,960	2,310,892
Total variable cash cost	MMK/ha	1,997,617	2,039,450
Return above variable cost	MMK/ha	1,278,456	1,936,479
Return above variable cash cost	MMK/ha	1,568,799	2,207,922
Return per unit of cash expensed		1.79	2.08
Return per unit of capital invested		1.56	1.84
Break-even price	MMK/kg	3,813	7,899
Break-even yield	kg/ha	385	182

According to the break-even analysis, the minimum price per kilogram of sesame grain (break-even price) was 3,813 MMK needed to cover the variable costs associated with sesame grain production. The break-even price of sesame edible oil was 7,899 MMK, indicating the minimum price per kilogram of sesame edible oil to cover the variable costs associated with sesame edible oil production. A break-even yield of sesame grain was 385 kg/ha. This means that the sampled farmers in the study area must produce at least 385 kg/ha to cover the variable costs of sesame grain production. A break-even yield of sesame edible oil was 182 kg/ha, and thus, the sampled farmers must produce at least 182 kg/ha to cover the variable costs of sesame edible oil production. At those yield and price levels, the total revenue from selling sesame as grain or edible oil equals the total production costs, indicating no profit or loss.

As a consequence of better returns by edible oil producers, return per unit of cash expensed and capital invested for edible oil producers were higher than those of sampled sesame grain producers, as shown in Figure 4. The returns of sampled edible oil producers were higher than those of sampled sesame grain producers. However, they had more total variable production costs and additional milling costs for edible oil. As a result, sampled edible oil producers were more profitable than sampled sesame grain producers in sesame production in the study area.

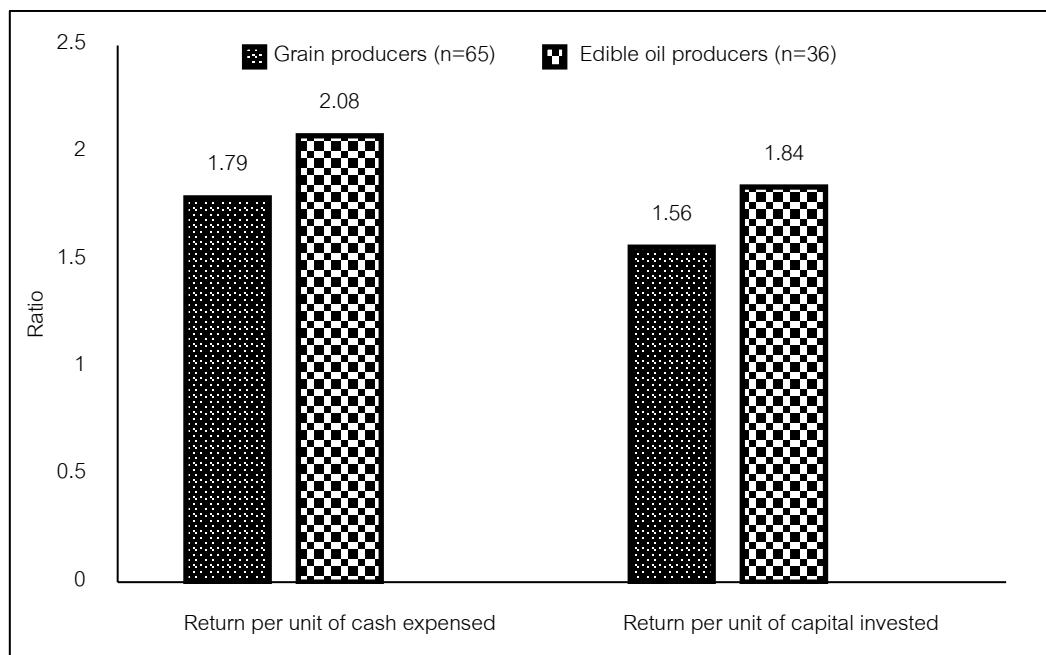


Figure 5. Return per unit of cash expense and capital invested (benefit-cost ratio) of sesame production per hectare by sampled farmers

Conclusion

According to the findings, the majority of sampled farmers were middle-aged with approximately 13 years of farming experience and had a middle school education. High labor costs and time-consuming crushing were the main reasons for farmers focused on producing sesame grain rather than sesame oil. However, the health benefits of sesame oil motivated many farmers to produce it for home consumption, contributing to household self-sufficiency. Overall, sesame oil is more economically viable than sesame grain, making it a preferred option for home consumption and value addition.

The benefit-cost ratio for sesame edible oil production was higher than that of sesame grain, making oil production a more profitable option for farmers. Therefore, producing edible oil was economically more attractive. Sesame farmers should consider producing value-added products, such as sesame oil, instead of selling raw sesame grain to increase their profits. The cost and return of sesame production vary depending on the type of sesame end products. MSME businesses can also help sesame farmers earn more profit by producing value-added products from sesame crops. Therefore, the government should collaborate with farmers, MSME entrepreneurs, and relevant stakeholders to enable the production of value-added products from sesame crops, rather than selling raw sesame seeds alone. Government and development organizations should support small- and medium-scale milling by providing affordable milling equipment or services, increasing accessibility and profitability. Widespread production of sesame oil at small- and medium-scale mills will enhance self-sufficiency in domestic oil consumption and reduce the need for palm oil imports.

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References

- Ajibade, Y. E., Adejo, P. E., Eti-Ukwu, A. I., & Maiye, M.O. (2021). Profitability analysis if sesame production among women farmers in Ofu Local Government Area, Kogi State, Nigeria. *International Journal Agricultural Economics, Management and Development*, 9(1), 110-124.
- Department of Agriculture. (2024a). Data records of Department of Agriculture (DOA), Lewe Township, Nay Pyi Taw, Ministry of Agriculture, Livestock and Irrigation, Myanmar.
- Department of Agriculture. (2024b). Annual Report of Department of Agriculture (DOA), Nay Pyi Taw, Ministry of Agriculture, Livestock and Irrigation. The Republic of the Union of Myanmar.
- Food and Agricultural Organization of the United Nation Statistics. (2025). *Crops and Livestock Products*. Retrieved from <http://www.fao.org/faostat/en/#data/QCL> (Accessed on 5 February 2025).
- Food and Agriculture Organization. (2023). List of countries by sesame production. Retrieved from https://en.wikipedia.org/wiki/List_of_countries_by_sesame_production#cite_note_FAOSTAT2022-1.
- General Administrative Department. (2022). Lewe Township Report, General Administrative Department (GAD), Nay Pyi Taw, The Republic of Union of Myanmar.
- Ministry of Agriculture, Livestock and Irrigation. (2023a). Myanmar Agriculture in Brief, Department of Planning.
- Ministry of Agriculture, Livestock and Irrigation. (2023b). Myanmar Agriculture in Glance, Department of Planning.
- Olson, K. (2003). Farm management principles and Strategies. The textbook of Farm Management: Principles and Strategies. Department of Applied Economics at the University of Minnesota.

Strategy Analysis of Business Development to Improve Sales of Healthy Drink: Case Study of Lime Juice Drink

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Abstract

Competition in the lime-based beverage industry is increasing with the emergence of similar products from local and international brands. However, most packaged beverages contain added sweeteners and preservatives, presenting challenges and opportunities for natural lime juice producers to establish a competitive advantage through health-focused marketing. This study aims to analyze business development strategies to enhance the sales of healthy lime-based beverages, with a focus on the unique selling point of natural lime juice producers. This research is a robust combination of qualitative and quantitative approaches. We gathered data through in-depth interviews with a wide range of stakeholders, including business advisors, strategy experts, consumers, and competitors. To ensure the most effective strategy, we conducted data analysis using a variety of methods, including IFE analysis, EFE analysis, SWOT analysis, SPACE analysis, IE matrix, and QSPM. The results, which include an IFE score of 2.58 indicating a strong internal position and an EFE score of 2.38 suggesting challenges in leveraging external opportunities, were used to generate strategies. The IE matrix places the formulated strategy in quadrant 5, indicating a 'hold and maintain' approach, while the SPACE matrix classifies the business as competitive. The QSPM analysis of 5.25 suggests that market penetration is the most suitable strategy for developing the lime juice business.

Keywords: business strategy, development, healthy beverages, digital marketing, market penetration

JEL code: B55, D12, L26

SDG classification: SDG 3, SDG 8, SDG 12

Introduction

The burgeoning population of Indonesia, projected to reach 282 million people in 2024 (BPS, 2024), presents a vast potential for producers and marketers in business development. The Indonesian economy in 2024 saw a robust growth of 5.03%. Notably, the business field that experienced the highest growth was Other Services at 9.80%, while the processing industry saw a respectable growth of 4.43% (BPS, 2024). While the growth value in this processing industry may not be staggering, it certainly signals promising prospects for the future.

Lime has been known to the Indonesian people in general as a complementary ingredient in cooking, chili sauce, and drinks. This orange is believed to have good nutritional content and has also been used by most Indonesians as a herbal medicine. Yanti (2021) showed that lime juice contains secondary metabolites in the form of alkaloids, flavonoids, saponins, tannins, and phenols. According to Haerani et al. (2018), plants containing polyphenols are widely used as cosmetic ingredients.

The existence of market potential and the advantages of the lime content do not necessarily make this commodity readily accepted by the public, especially in processed beverage products. The main problems that producers often face are the lack of effective marketing strategies, limited product innovation, and difficulties in building brand awareness amidst the dominance of big brands. For this reason, an appropriate business development strategy is needed so that lime juice drink producers can increase sales and make their businesses grow more stable. Therefore, this study focuses on the analysis of business development strategies to increase sales using IFE, EFE, TOWS, SPACE, IE, and QSPM analysis. This study focuses on several hypotheses, including:

- H1: Internal factor analysis (IFE) has a significant influence on the market penetration strategy for lime juice drinks
- H2: External factor analysis (EFE) plays a role in determining the market penetration strategy for lime juice drinks
- H3: Strategies obtained through TOWS Matrix analysis can increase the competitiveness and sales of lime juice drinks
- H4: SPACE Matrix can help determine the most appropriate business strategy for lime juice drinks
- H5: The results of the IE Matrix indicate that market penetration strategy is the most appropriate choice for lime juice drinks
- H6: QSPM indicates that market penetration has a significant positive impact on the growth of the lime juice drink business

Methodology

Data types and sources

This study adopts a qualitative and quantitative approach. According to Sugiono (2018), qualitative methods are often called artistic methods because they are flexible and interpretive, so the results depend on data analysis in the field. Quantitative methods are

used to analyze macro and micro environmental factors in order to formulate business strategies that are based on market needs (Wantayakul, 2025).

According to Hair et al. (2020), qualitative data includes data in textual or visual form rather than numerical descriptions. The data collected is in textual form, resulting from interviews in which the researcher records the respondents' words. The sampling technique used is purposive sampling, namely selecting samples based on specific characteristics relevant to the research objectives (Oluwakoya, 2025). The quantitative data were analyzed using qualitative methods to develop a business strategy for selling lime juice drinks. Qualitative analysis focuses on an in-depth understanding of the lime juice drink business, including internal and external factors influencing its sustainability.

Meanwhile, quantitative data is used to analyze the macro and micro environments to formulate strategies relevant to business needs. This research was conducted in Jabodetabek, a location chosen because of its relevance to the business background and the primary target market in Jabodetabek. This research's primary and secondary data sources were obtained through in-depth interviews and questionnaires. According to Cuyvers et al. (2025), an in-depth interview is a discussion session with an unstructured flow, allowing the interviewer to explore the respondent's perspective more broadly. In this study, the respondents selected were business experts and consumers who had insight into the lime juice beverage market and the factors that influenced its business sustainability (Mwale & Mwange, 2025). Primary data was collected from interviews with experts and consumers, while secondary data included information related to internal and external factors of the company.

Data analysis

Several analysis techniques are used in this study, including the TOWS (Strengths, Weaknesses, Opportunities, and Threats) analysis, the IE (Internal-External Matrix), the IFE (Internal Factor Evaluation) matrix, the EFE (External Factor Evaluation) matrix, and the QSPM (Quantitative Strategic Planning Matrix). The IE matrix is created using the findings of the IFE and EFE investigations, and the QSPM assists in identifying the most appealing course of action. Their positions within the organization and prior experiences as lime juice beverage product users were considered when choosing the respondents.

Internal Factors Evaluation (IFE) and External Factors Evaluation (EFE)

According to Puspita and Rustiadi (2025), the IFE matrix shown in Table 1 provides a basis for identifying the strengths and weaknesses of a company. The IFE matrix shows the strengths and weaknesses of the company, which are calculated based on weights and ratings. The weight and rating values are obtained from the company's internal parties. There are five steps in developing the IFE Matrix, namely, identification of internal company factors, weighting, rating, weighted values, and total IFE values to interpret the overall internal conditions of the company (Astutik et al., 2025).

Table 1. Matrix IFE (Internal Factor Evaluation)

Internal Factors	Weight	Rating	Weighted Values
Strengths	0,54	3	1,62
Weaknesses	0,46	2	0,92
Total	1,00		2,54

Source: David et al. (2023)

According to Machmud et al. (2025), the EFE matrix shown in Table 2 helps know how well a company is in dealing with external factors from the company such as minimizing threats and taking advantage of opportunities. The EFE matrix is intended to identify the extent of influence of external factors on the company, such as the environment, economy, society, culture, government, technology, law, politics, and competition.

The EFE matrix shows the company's threat and opportunity conditions, which are calculated based on ratings and weights. There are five steps in developing the EFE Matrix: identifying internal company factors, weighting, rating, weighted value, and total value. Adding up the total EFE value to understand the strengths and weaknesses in responding to the external environment (Febrina et al., 2025).

Table 2. Matrix EFE (External Factor Evaluation)

External Factors	Weight	Rating	Weighted Values
Opportunities	0,46	3	1,38
Threats	0,54	3	1,62
Total	1,00		3,00

Source: David et.al (2023)

Competitive Profile Matrix (CPM)

Competitive Profile Matrix can show how a company's condition compares to its main competitors based on strengths and weaknesses (David et al., 2023). CPM shown in Table 3 uses weights to measure the importance of strategic factors and calculates a total weighted score to compare the company's performance with its competitors (Gunawan, 2024). The total weight in CPM must be 1.0. Meanwhile, the rating is given to show how effective the company's strategy is in dealing with strengths and weaknesses. The rating in CPM is given to show how effective the company's strategy is in dealing with strengths and weaknesses on a scale between 1 (poor) and 4 (very good) (Irianto et al., 2024). This rating is based on company performance, not industry.

Table 3. CPM (Competitive Profile Matrix)

Success Factors	Weight	Products under study		Competitors 1		Competitors 2	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
1.							
2.							
etc							
Total							

TOWS matrix

The TOWS matrix is often used in strategic planning to develop strategies based on internal and external factors (Illiyina et al., 2025). According to Taktak (2025), the TOWS Matrix effectively creates SWOT-based corporate strategies because it allows companies to identify more specific and actionable strategies. This matrix shown in Figure 1 is a TOWS analysis scheme consisting of nine cells grouped into three parts, namely:

1. The first cell on the top left is a description to separate internal and external factors.
2. The four central factor cells are S, W, O, and T.
3. The four strategy cells of the main factor intersection are S-O, W-O, S-T, and W-T.

Internal		Strength - S	Weakness - W
External		Company's internal strengths	Company's internal weaknesses
	Opportunities - O	S-O Strategy leveraging the company's strengths to seize opportunities	W-O Strategy minimizing weaknesses by applying opportunities
	Threats - T	S-T Strategy leveraging the company's strengths to mitigate threats	W-T Strategy minimizing weaknesses and avoiding threats

Figure 1. TOWS Matrix

Source :(Youcef, 2025)

SPACE matrix

The Strategic Position and Action Evaluation (SPACE) Matrix shown in Figure 2 is a tool that uses two axes and four quadrants to determine the most appropriate strategy for an organization to prove whether it is aggressive, conservative, defensive, or competitive (David et al., 2023). The SPACE matrix evaluates two internal dimensions (financial position [FP] and competitive position [CP]) and two external dimensions (stability position [SP] and industry position [IP]) to understand the company's capabilities in responding to the business environment (Guo et al., 2025). The following are the steps to create a SPACE matrix :

1. Select a set of variables to determine financial position (FP), competitive position (CP), stability position (SP), and industry position (IP) (Rahman, 2025).
2. Determine the value on each axis; the IP axis (+7) is stated as high growth, and (+1) is stated as low growth. On the FP axis, (+7) is stated as really strong, and (+1) is stated as really weak. On the SP axis, (-7) is unstable, and (-1) is stable. On the CP axis, (-7) is stated as weak, and (-1) as very strong. On the FP and CP axes, comparisons are made with competitors (Espinoza & Bohorquez, 2025). While on the IP and SP axes, comparisons are made with other industries.
3. Add up the values of each variable in each dimension (FP, CP, IP, and SP), then divide by the number of variables in each dimension.
4. Enter the average score on each axis FP, IP, SP, and CP.
5. Enter two scores on the x-axis and determine the resultant point on X. Enter two scores on the y-axis and determine the resultant point on Y. Plot the intersection of the new coordinates (x, y).
6. Draw a directed vector using the coordinates (x, y); the location of the resulting quadrant will determine the company's strategy.
7. Analyze the results and formulate appropriate strategies, considering the positions shown in the graph (Xue et al., 2025).

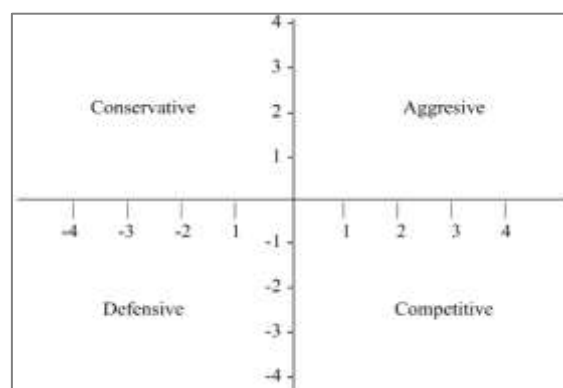


Figure 2. SPACE Matrix

Source: David et al. (2023)

IE matrix

The Internal-External (IE) Matrix is used to position a company's Strategic Business Unit (SBU) in a nine-quadrant matrix shown in Figure 3, which helps in determining the most appropriate strategy for business growth (Laksono, 2025). The IE Matrix consists of two dimensions: the total score of the IFE matrix on the X axis and the total score and EFE Matrix on the Y axis, where the results of the intersection of the X and Y axes will determine the position of a company in a particular quadrant, which will then be used to choose the appropriate business development strategy (Febrina et al., 2025).

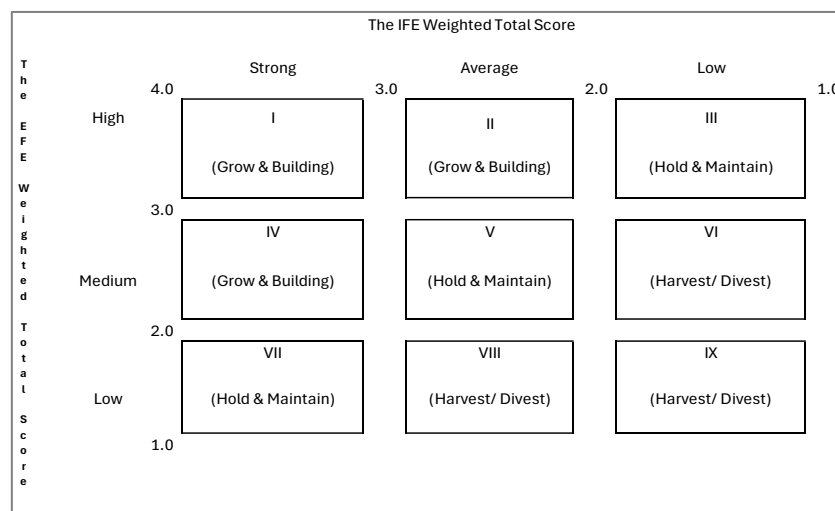


Figure 3. IE Matrix

Source: David et al. (2023)

The QSPM matrix, a crucial tool in strategic decision-making, is the cornerstone of this analysis. It objectively evaluates internal and external factors, as Machmud et al. (2025) highlighted. The steps for compiling the QSPM matrix are as follows in Table 4:

1. The first stage involves creating a list of the company's external opportunities/threats and internal strengths/weaknesses. This information is crucial and can be obtained from the EFE and IFE matrices.
2. In the second stage, the weights given to internal and external factors are the same as those in the EFE and IFE matrices.
3. The third stage is evaluating the matrix and identifying alternative strategies that must be considered for implementation.
4. The fourth stage is determining the Attractiveness Scores (AS), which indicate the attractiveness of each strategy in a particular alternative.

Value 1 = not attractive

Value 2 = somewhat attractive

Value 3 = quite attractive

Value 4 = very attractive

5. In the fifth stage, we calculate the Total Attractiveness Scores (TAS) by multiplying the Attractiveness Scores by the weight of the key factors. This step is crucial in determining the overall attractiveness of each strategy.
6. In The sixth stage, calculate the Total Attractiveness Scores (TAS) in each strategy column; the most significant TAS number will be the strategy used.

Table 4. Matrix QSPM

Key Factors	Weight	Strategy 1		Strategy 2		Strategy 3	
		AS	TAS	AS	TAS	AS	TAS
Internal Factors							
External Factors							
Total							

Source: David et al. (2023)

According to Ardhiarisca et al. (2024) using the IE Matrix and QSPM effectively determines business strategies based on quantitative data because it allows companies to choose the most profitable options objectively.

Business analysis stages

The techniques used in strategic analysis can be integrated into a decision-making framework in three stages (David et al., 2023). The results of this strategic analysis help organizations determine the best strategy to improve their competitiveness and operational efficiency (Mais et al., 2025). The following Figure 4 is a graph of the research stages.

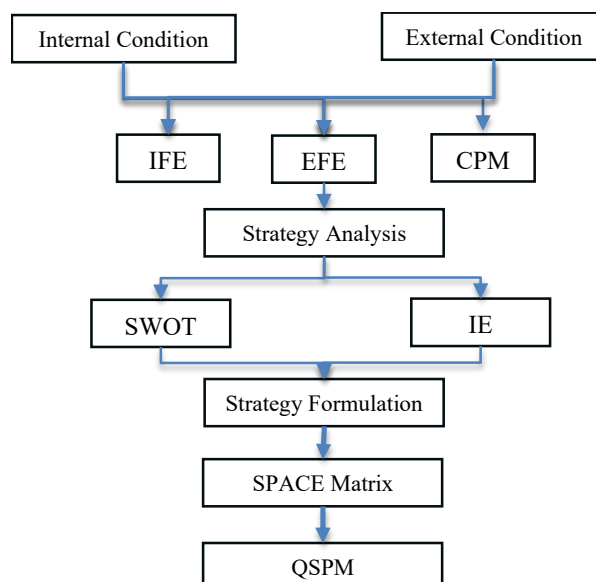


Figure 4. Business Analysis Stages

Source: Researcher (2025)

Results and Discussion

Respondents and identification of internal factors

In this study, researchers engaged in the Focus Group Discussion (FGD) method, a powerful tool for gathering collective perspectives from various stakeholders in business, as endorsed by Amam & Ramadhan (2025). The FGD resource persons, including CEOs, COOs, CMOs, and R&D personnel from a lime juice beverage company, were selected to identify internal business factors, such as the company's strengths and weaknesses detailed in Table 5 facing industry competition (Taufik et al., 2025). As Puspita et al. (2025) suggest, the results of the FGD are not just findings but strategic inputs that can significantly influence the preparation of business development plans, especially for companies in the expansion stage.

Table 5. Identification of Internal Factors

Strengths (S)	Weaknesses (W)
The raw materials used are natural ingredients without flavorings, colorings, and preservatives (S1)	The packaging size option is only available in one size (W1)
Unique and more diverse flavor variants compared to competitors (S2)	Products are easily imitated and damaged (W2)
The quality of the raw materials used for limes is premium limes which are selected directly from the garden in fresh condition (S3)	The brand is still not well known to the general public (W3)
It has the form of a legal entity, namely CV (S4)	Minimal capital (W4)
Has Halal certificate (for all variants) and PIRT (for syrup products) (S5)	Sales are still only done through bazaars and online (WhatsApp, Instagram, Tokopedia, and GrabFood) (W5)
The prices offered are affordable and competitive compared to competitors (S6)	
Have established consignment cooperation with one restaurant and one cafe (S7)	

Source: Researcher (2025)

Respondents and identification of external factors

In this study, the sources used as respondents act as competitors of similar products, customers, experts in the field of food technology, and business consultants. The data obtained from these sources are defined as opportunities and threats, as described in Table 6.

Table 6. Identification of External Factors

Opportunities (O)	Threats (T)
Awareness of healthy living increases the market share of lime sales (O1)	Weather changes can result in a decrease in the quality of raw lime materials (T1)

Opportunities (O)	Threats (T)
Increasing use of online buying and selling platforms (O2)	Many competitors offer other citrus-based drinks (T2)
The large number of restaurants, cafes and sports venues such as yoga or pilates studios opens up opportunities to expand market share (O3)	Consumers with acid reflux disease or GERD and citrus allergies cannot consume citrus-based products (T3)
The use of social media and digital marketing can increase brand awareness and expand market reach (O4)	The number of raw material suppliers is still limited, only one vendor in Tangerang (T4)
The dry season in Indonesia increases demand for fresh drinks (O5)	Rising fuel prices could increase production and logistics costs (T5)
	Flavored beverage trends change rapidly (T6)
	New competitors easily enter the ready-to-drink beverage market (T7)

Source: Researcher (2025)

Internal Factor Evaluation (IFE)

Based on the data processing results regarding the evaluation of internal factors shown in Table 7, the business conditions of the lime juice beverage products studied in the study are pretty good. This refers to the total weighted score for internal factors, which is calculated at 2.58 and is higher than the average value of 2.50, indicating that the strength factors are more dominant than the weakness factors (Ben-Abdallah & Shamout, 2022). These business conditions illustrate that the strength factors of the lime juice beverage products studied in this study are positioned more dominantly and superior to the weak factors. The business conditions studied in this study are deemed necessary to evaluate these strengths and weaknesses so that the identified strength factors can be strengthened and developed. In addition, the identified weakness factors can be improved to be more, or their impact can be minimized.

Table 7. IFE Matrix of Lime Juice Drink

Internal Factors	Weight	Rating	Weighted Values
Strengths			
S1	0.07	2	0.13
S2	0.09	4	0.34
S3	0.07	2	0.14
S4	0.06	4	0.22
S5	0.06	2	0.11
S6	0.08	4	0.30
S7	0.07	4	0.27

Internal Factors	Weight	Rating	Weighted Values
Weaknesses			
W1	0.11	2	0.22
W2	0.11	2	0.22
W3	0.11	1	0.11
W4	0.09	1	0.09
W5	0.10	4	0.40
Total	1.00		2.58

Source: Researcher (2025)

External Factor Evaluation (EFE)

Based on the data processing results regarding the evaluation of external factors shown in Table 8, the business conditions of the lime juice beverage products studied in this study can be justified as being able to survive and compete in the market. This refers to the total weighted score for external factors, which is calculated at 2.63 on a scale of 4.00, which indicates that this business has a good responseability to the opportunities and threats it faces (Minh & Rangaraju, 2024). These business conditions illustrate that the lime juice beverage products studied in this study can respond reasonably well to the opportunities and threats they face. Based on the analysis and data processing results, the business conditions of the lime juice beverage products studied in this study can take advantage of opportunities to avoid threats. One example of this strategy is utilizing healthy lifestyle trends to increase product appeal and prepare alternative strategies to face potential challenges in the future (Setiawan & Waeno, 2025).

Table 8. EFE Matrix of Lime Juice Drink

External Factors	Weight	Rating	Weighted Values
Opportunities			
W1	0.07	3	0.21
W2	0.09	2	0.19
W3	0.07	3	0.21
W4	0.08	4	0.28
W5	0.08	3	0.26
Threats			
T1	0.09	3	0.26
T2	0.07	3	0.23
T3	0.12	1	0.17
T4	0.09	3	0.24
T5	0.10	2	0.20

External Factors	Weight	Rating	Weighted Values
T6	0.08	2	0.19
T7	0.07	3	0.20
Total	1.00		2.63

Source : Researcher (2025)

Competitive Profile Matrix (CPM)

Based on data analysis and processing, the interpretation of CPM is described and presented in Table 9. The total weight score for the lime juice beverage product studied in this study is still lower than the two competitors with similar products, namely, 2.80. Meanwhile, it is known that the total weight score for Competitor 1 reached 3.30, and the total weight score for Competitor 2 reached 2.81. This illustrates that the business conditions of the lime juice product studied in this study can be said not to be able to lead the market or, in other words, can be said to be not superior to its competitors.

Table 9. CPM of Lime Juice Drink

Success Factors	Weight	Products under study		Competitors 1		Competitors 2	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Advertising	0.10	3	0.30	4	0.4	3	0.3
Competitive Price	0.11	3	0.33	3	0.33	3	0.33
Product Quality	0.07	4	0.28	4	0.28	4	0.28
Financial Position	0.12	3	0.36	3	0.36	3	0.36
Product Variants	0.10	3	0.30	3	0.3	3	0.3
Branding	0.07	3	0.21	4	0.28	3	0.21
Desain & Packaging	0.10	2	0.20	3	0.3	3	0.3
Customer Loyalty	0.09	3	0.27	3	0.27	2	0.18
Locations	0.14	2	0.28	3	0.42	2	0.28
Service	0.09	3	0.27	4	0.36	3	0.27
Total			2.8		3.3		2.81

Source: Researcher (2025)

TWOS matrix

TOWS can be used to determine strategies based on the intersection of internal and external factors. There are four strategies: SO (Strengths-Opportunity) strategy, ST (Strengths-Threats) strategy, WO (Weakness-Opportunity) strategy, and WT (Weakness-Threats) strategy, as presented in Appendix 1.

SPACE matrix

The data processing results found that the X-axis value for the business conditions of the lime juice beverage product studied in this study was 2.64. Meanwhile, the Y-axis value for the business conditions of the lime juice beverage product studied in this study was -0.17. Susanto et al. (2025) show that this business can compete in the market but with relatively low growth. So, the position of the business conditions for the lime juice beverage product studied is mapped in the competitive quadrant in the SPACE Matrix shown in Figure 5, reaffirming its competitive position.

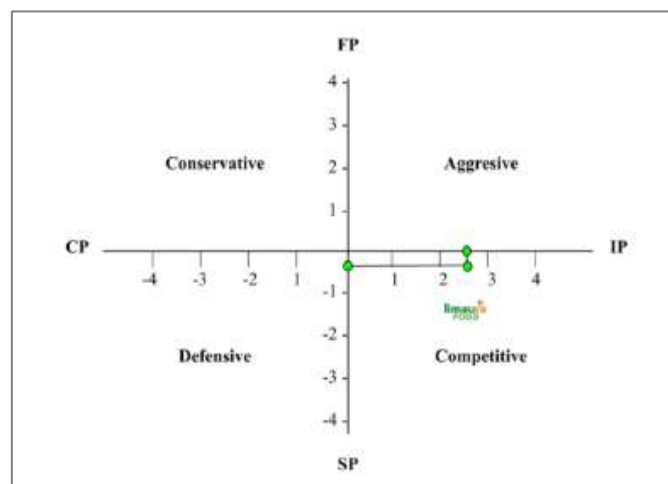


Figure 5. SPACE Matrix Results for Lime Juice Drink

Source: Researcher (2025)

The business conditions in this quadrant illustrate that this lime juice beverage business can compete stably in the related industry, but its growth is relatively low (David et al., 2023). According to Putri (2024), the SPACE Matrix is a method used in business strategy planning to determine the position of a company in industrial competition. Position in the competitive quadrant indicates that businesses should focus their strategies on strengthening existing markets and expanding and innovating products to increase their competitiveness (Wuner et al., 2024).

IE matrix

Based on the results of the previous data analysis and processing in Figure 6, it is known that the EFE value for the lime juice beverage product studied in this study was recorded at 2.63, and the IFE value was 2.58. Thus, this business condition can be mapped to the

Cell V position in the IE Matrix, which indicates that the business needs to survive and make strategic improvements through market penetration and product development (Novena & Murhadi, 2024). The mapping at this position illustrates that the lime juice beverage business conditions studied in this study still need to survive and be improved by implementing market penetration and product development strategies (David et al., 2023); these findings are in line with the research results of Utari et al. (2024).

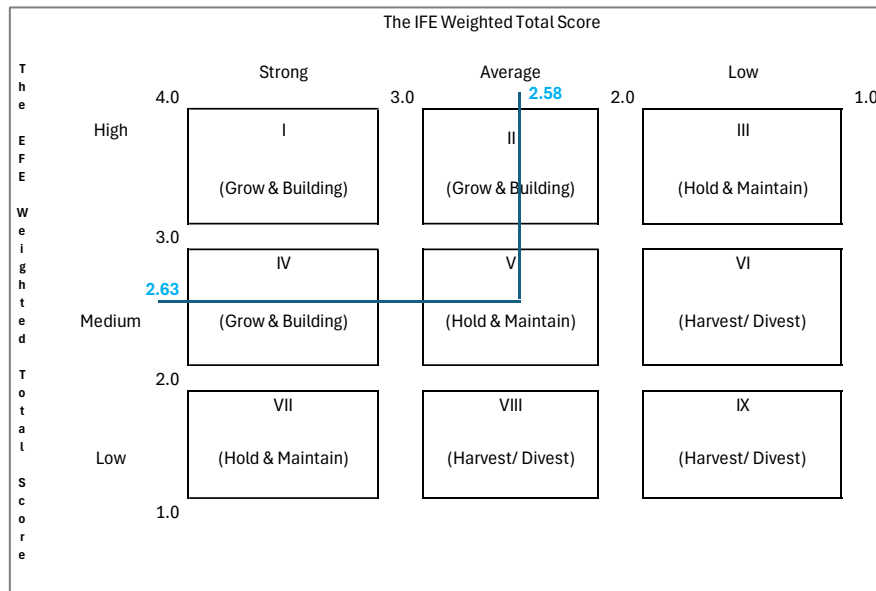


Figure 6. Results of the IE Matrix for Lime Juice Drinksf

Source: Researcher (2025)

The adjustment stage managed using SWOT, SPACE, and IE Matrix, produces several strategy formulations detailed in Table 10. These include market penetration, market development, product development, forward integration, backward integration, and horizontal integration. Market penetration and product development are the most alternative strategy choices formulated in the adjustment stage.

Table 10. Results of Alternative Strategy Calculations

Alternative Strategy	Matrix	Amount
Market Penetration	TOWS, SPACE, IE	3
Market Development	TOWS, SPACE	2
Product Development	TOWS, SPACE, IE	3
Forward Integration	SPACE	1
Backward Integration	SPACE	1
Horizontal Integration	SPACE	1

Source: Researcher (2025)

QSPM matrix

Based on the calculation results in the QSPM Matrix, several objectively best alternative strategies can be formulated (Tricahyono & Pramudhito, 2025). The results of the analysis of previous data can be used as a reference to formulate nine alternative strategies adjusted to the business conditions of the lime juice beverage product studied in this study and presented in Appendix 2. The type of strategy considered most appropriate to be implemented and applied to the business conditions studied is the market penetration strategy. This refers to the highest total attractiveness value, at 5.16. Prioritizing the market penetration strategy is expected to be able to increase sales and develop and expand the market from the business conditions studied in this study. Some examples of alternative market penetration strategies that can be applied to the market conditions studied include:

1. Carrying out promotions or campaigns that focus on health benefits for consumer segments who care about healthy living by highlighting the use of natural, premium raw materials and already have Halal and PIRT certificates in order to attract consumer segments who care about a healthy lifestyle (Tricahyono & Pramudhito, 2025).
2. Maximizing demand growth with aggressive marketing strategies through digital campaigns, attractive visual advertisements, and partnerships with influencers to highlight product freshness (Rao et al., 2025). Promotion of fresh drinks during the dry season by promoting them aggressively with attractive advertisements and highlighting the freshness of the product so that it can increase sales
3. Highlighting Halal certification as a competitive advantage, assuring product quality and safety to increase consumer confidence compared to competitors who do not have similar certification (Ardhiariska et al., 2024).
4. Seasonal promotions in bazaars, e-commerce, and social media, especially during the dry season, because the demand for fresh drinks tends to increase significantly (Wibowo & Sukesu, 2024).

Discussion

The strength score obtained was 0.89; the score came from weighing the strength factors of the studied lime juice drink product. While the weakness score obtained was 1.46, the score came from the weighting of the weakness factors of the lime juice drink product studied. The IFE score has a value scale from 1.00 to 4.00 with an average scale of 2.50 so an IFE score above 2.50 indicates that the internal position is strong, while if the IFE score is below 2.50 indicates a weak internal position (David et al., 2023). If the IFE score exceeds 2.50, the company can utilize strengths and minimize weaknesses (Novianti et al., 2024). The results obtained from the IFE of the lime juice drink product studied were 2.36, below average. Based on the description of the internal factors obtained, it can be concluded that the lime juice beverage product studied has not succeeded in maximizing its strengths because the total score of the strength factors is smaller than the score of the weakness factors. The internal position is not strong enough. This shows that the internal position of the business is still relatively weak, so a strategy is needed to increase its competitiveness (Alam et al., 2018).

The opportunity score obtained was 1.16, which comes from the weighting of the opportunity factors owned by the lime juice beverage product studied. While the threat score obtained was 1.22. The EFE score has a scale of 1.00 to 4.00, with an average value of 2.50. The greater the EFE score produced, the more the company can respond to opportunities and avoid threats in an extraordinary way (David et al., 2023). As stated by (Utari et al., 2024), companies with an EFE score of more than 2.5 indicate that the company can take advantage of opportunities well in facing threats. The results obtained from the EFE are 2.38, which is below 2.50. Based on the description of the external factors that have been obtained, it can be concluded that the lime juice drink product studied has not maximized the use of opportunities to avoid threats.

Based on the results of the IFE of 2.36 and EFE of 2.38, the results of the IE matrix obtained are in quadrant V, namely surviving and improving. This quadrant indicates that the appropriate strategy is a survival and improvement strategy through market penetration and product development (Amirshenava, 2022). The methods that can be used by the lime juice drink product studied are market penetration and product development (David et al., 2023). Based on the Focus Group Discussion results with strategy experts and business advisors, the lime juice drink product studied needs a market penetration strategy.

Of the nine strategies that have been made, they are recalculated using the QSPM matrix. Based on the results of the QSPM calculation in Table 10, the right strategy to apply is strategy 1 (creating a campaign or educational content related to the benefits of lime drinks with a target consumer who is aware of healthy living) with a total of 5.61. This strategy is included in the market penetration strategy. This educational campaign strategy is adequate because it combines a communication approach, an important added value in Indonesian consumer behavior (Wibowo, 2024). The following is a list of strategies from data processing results from the strategy with the highest rating to the lowest rating.

Table 10. QSPM Value Ranking

No.	Strategy	QSPM Matrix Value	Rating
1.	Market Penetration	5.25	1
2.	Market Development	5.22	2
3.	Product Development	5.16	3

Source: Researcher (2025)

Conclusion

Based on the results of the data processing analysis, it can be concluded as follows:

- The IFE matrix shows a calculation result of 2.58, which shows that lime juice drinks have quite strong internal factors.
- The EFE matrix shows a calculation result of 2.38, which shows that lime juice drinks are necessary to overcome threats using several opportunities.
- Based on the results of the TOWS matrix, the types of strategies are formulated into four parts: SO, WO, ST, and WT strategies. Five strategies are formulated

under the SO strategy, four under the WO strategy, six under the ST strategy, and six under the WT strategy.

- The mapping on the SPACE matrix shows that lime juice drinks are in the competitive quadrant, which illustrates that the product is able to compete.
- Based on the mapping on the IE matrix, it shows that lime juice drinks are in quadrant 5 (hold and maintain), which indicates that the product needs to survive, but there must be improvements to develop in the future.
- Based on the results of data processing on the quantitative strategy planning matrix (QSPM), it shows that the most appropriate strategy to be applied for the development of lime juice drink product business is to formulate a market penetration strategy supported by the highest score on the QSPM Matrix, namely, 5.25. The following strategy that can be formulated is a market development strategy, with a total score of 5.22, followed by a product development strategy, with a total score of 5.16.

References

- Abidin, Z., Rahmad, V. F., & Hamid, S. N. A. (2024). Digital Marketing Strategy Development for Recovery Ecotourism Visit After COVID-19 Pandemic. *AGRIS On-Line Papers in Economics and Informatics*.
- Alam, K., Erdiaw-Kwasie, M. O., & Shahiduzzaman, M. (2018). Assessing regional digital competence: Digital futures and strategic planning implications. *Journal of Rural Studies*.
- Amam, A., & Ramadhan, A. M. (2025). Analisis Kelayakan Finansial dan Strategi Pengembangan Usaha Peternakan Itik Mojosari. *Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis*.
- Amirshenava, S., & Osanloo, M. (2022). Strategic planning of post-mining land uses: A semi-quantitative approach based on the SWOT analysis and IE matrix. *Resources Policy*, 75, 102454.
- Ardhariasca, O., Faizin, N., & Putra, R. 2024. Analysis of Coffee Business Development Strategy in the Sumber Kembang Farmer Group Using the SWOT Method to Achieve Global Competitiveness. *International Journal of Studies in Social Sciences & Humanities*.
- Astutik, S. W. V., Darsan, D., & Yusri, F. 2025. Mengembangkan Produk Olahan Daun Kelor (Studi Kasus UD Herbasina Nutrindo). *Jurnal Inovasi Manajemen Desa dan Pertanian*.
- Ben-Abdallah, R., & Shamout, M. 2022. Business Development Strategy Model Using EFE, IFE, and IE Analysis in a High-Tech Company: An Empirical Study. *Academy of Strategic Management Journal*.
- Cuyvers, K., De Maeyer, S., & Donche, V. 2025. Unraveling Low-Educated Adults' Motivation for Second-Chance Education: A Multidimensional Perspective. *Learning and Instruction, Elsevier*.

- David, F. R., David, F. R., & David, M. E. (2023). *STRATEGIC MANAGEMENT A Competitive Advantage Approach Concepts and Cases* (17th Edition).
- Espinoza, J. C. T., & Bohórquez, A. A. D. (2025). Delimitación de Corredores de Conectividad Entre Áreas Urbano-Rurales Geográficamente Protegidas del Cantón Guayaquil. *Estoa Journal of Architectural Research*.
- Febrina, R., Machmud, R., & Febrian, F. 2025. Strategy For Developing the Quality of Public Services in The Sector at The Baruga Village Office, Baruga District Kendari City. *International Journal of Management, Economics, and Human Development*.
- Gunawan, W. B. 2024. Matching Stage Strategy Development of PT Alam Sutera Realty Tbk: Diversification as Key Strategy for Business Sustainability. *Review of Management, Accounting, and Business Studies*.
- Guo, J., Liu, R., & Gill, E. (2025). Motion Planning of Free-Floating Space Robots Through Multi-Layer Optimization Using the RRT* Algorithm. *Acta Astronautica*, Elsevier.
- Illiyyina, I., Fitriana, A. R. D., & Rosa, N. S. 2025. Increasing Interest to Pursue Tertiary Education among School Leavers in Indonesia: A Strategic Analysis. *Journal of Industrial Economics (JIE)*.
- Irianto, H., & Rohmah, I. N. 2024. Evaluasi Strategi Bersaing Teh Botol Sosro di Kota Surakarta (Pendekatan Competitive Profile Matrix). *JIA (Jurnal Ilmiah Agribisnis)*.
- Laksono, P. 2025. Strategi Pengembangan Bisnis Transportasi dan Logistik di PT Berkah Bina Amanat. *IPB Repository*.
- Machmud, R., Febrian, F., & Febrina, R. 2025. Strategic Planning of Dental and Oral Hospital Andalas University. *Journal La Medihealtico*.
- Mais, F., Vasiljevic, S., & Bauernhansl, T. 2025. A Multi-Criteria Decision Framework for designing sustainable business models in the context of decarbonization. *Journal of Cleaner Production*, Elsevier.
- Minh, N. K., & Rangaraju, S. (2024). Why Huawei Remains Resilient: A Business Analysis of External and Internal Factors. *ResearchGate*.
- Murhadi, W. R. (2024). PT Siantar Top Tbk's Strategy in Facing Competition in the Processed Food Industry. *Eduvest-Journal of Universal Business Research*.
- Mwale, S., & Mwange, A. 2025. An Assessment of Factors Affecting General Insurance Penetration in Lusaka District of Zambia. *African Journal of Commercial Studies*.
- Novina, E., & Murhadi, W. R. (2024). Memimpin Pasar dengan Optimalisasi Distribusi: Formulasi Strategi bagi PT. Avia Avian, Tbk. *Jurnal Ilmiah Mahasiswa Ekonomi dan Manajemen*.
- Oluwakoya, A. O. 2025. Challenges in the Management of Lagos State's Bus Rapid Transit (BRT) System: Insights into Operations and Governance. *RUN Journal of Management*.
- Puspita, N. F., Wardana, I. P., & Dermoredjo, S. K. (2024). Business Model Strategy for Utilization of Pregelatinized Cassava Flour (PCF) by Micro-Small-Medium Enterprise (MSME). *Atlantis Press*.

- Puspita, N. P., & Rustiadi, E. 2025. Evaluation and Development Strategy of The Minapolitan Area in Pasir Sakti Sub-District, Lampung Timur Regency. *Journal of Regional and Urban Development*.
- Putri, A. B. A. (2024). Analisis Perusahaan PT Garuda Food Putra Putri Jaya Tbk Menggunakan SPACE, BCG, dan Grand Strategy Matrix. *Jurnal Syntax Admiration*.
- Rahman, R. A. (2025). Strategi Pengembangan Usaha Madu KUPS Kelulut Pomuan di Hutan Adat Ghimbo Pomuan, Kabupaten Kampar, Provinsi Riau. *IPB Repository*.
- Rao, R. H., Syahbudi, M., & Muhaisin, A. (2025). Strategy of Competitiveness of Mandailing Natal Dodol Culinary UMKM Using QSPM. *Jurnal Apresiasi Ekonomi*.
- Setiawan, R. F., & Waeno, M. (2025). Strategy for Developing Milkfish Commodity in Wadak Lor Village, Duduk Sampean District, Gresik Regency. *Agriverse Journal*.
- Susanto, D., Fuadi, F., & Novitasari, S. (2025). Marketing Strategy Analysis to Increase Sales of Delivery Services at Gerai Multi ekspres. *International Journal of Marketing Research and Analysis*.
- Taktak, F. 2025. Structural Urban Transformation Analysis and Sustainability Strategies for Usak Province. *ResearchGate*.
- Taufik, T. A., Puspita, N. F., & Sidiq, S. (2025). Risk Analysis of The Electric Tactical Vehicle Procurement Project at A State-Owned Defense Industry Company. *ResearchGate*.
- Tricahyono, D., & Pramudhito, A. (2025). Business Strategy Formulation for Internet Service Provider (ISP): A Case Study of Iconnet by PT PLN Icon Plus. *International Journal of Science, Technology, and Management*.
- Wantayakul, N. 2025. Perspectives and Attitudes Towards Strategic Management of E-Sports in Thailand. *Journal of Lifestyle and SDGs Review*.
- Wibowo, S. A. P., & Sukesu, S. (2024). Strategic Management Using SWOT and QSPM Analysis in Increasing Crude Palm Oil (CPO) Sales at PT Windu Nabatindo Lestari. *Management, Entrepreneurship, and Business Journal*.
- Wuner, J., Mangantar, M., & Rogi, M. (2024). Strategy Formulation for Extruck Coffee Tomohon Using SPACE Matrix and SWOT Analysis. *Jurnal EMBA*.
- Xue, M., Zheng, J., Wang, Y., Xue, X., & Tsai, P. W. (2025). A Reinforcement Learning-Based Intelligent Segment Routing Algorithm Considering the Swap Node Selection Strategy. *SSRN Papers*.
- Youcef, J. T. 2025. Strategic Planning Framework for Universities: A Comprehensive Approach. *ResearchGate*.

Appendix

Appendix 1. TWOS Matrix

	Strengths The raw materials used are natural ingredients without flavorings, colorings, and preservatives (S1) Unique and more diverse flavor variants compared to competitors (S2) The quality of the raw materials used for limes is premium limes which are selected directly from the garden in fresh condition (S3) It has the form of a legal entity, namely CV (S4) Has Halal certificate (for all variants) and PIRT (for syrup products) (S5) The prices offered are affordable and competitive compared to competitors (S6) Have established consignment cooperation with one restaurant and one cafe (S7)	Weakness The packaging size option is only available in one size (W1) Products are easily imitated and damaged (W2) The brand is still not well known to the general public (W3) Minimal capital (W4) Sales are still only done through bazaars and online (WhatsApp, Instagram, Tokopedia, and GrabFood) (W5)
Opportunities Awareness of healthy living increases the market share of lime sales (O1) Increasing use of online buying and selling platforms (O2) The large number of restaurants, cafes and sports venues such as yoga or pilates studios opens up opportunities to expand market share (O3)	SO Strategy 1. Maximizing social media, e-commerce, and companies formed as legal entities (CV) can increase consumer trust. (S2, S4, O2, O4) 2. Promotes that focus on health benefits by highlighting the use of natural, premium raw materials and that Halal and PIRT certificates are already available. (S1, S3, O1, O5)	WO Strategy 1. Adding flexible packaging size options to be offered through e-commerce and consignment in several places. (W1, O2, O3) 2. Create product innovations and variations by combining unique natural ingredients with lime to attract consumer interest promoted through social media (online) or offered through restaurants, cafes, and sports venues. (W2, W3, O1, O3)

The use of social media and digital marketing can increase brand awareness and expand market reach (O4) The dry season in Indonesia increases demand for fresh drinks (O5)	3. Expanding consignment cooperation in various places to facilitate consumer access to product purchases and provide special prices. (S6, S7, O3) 4. Maximizing the demand for fresh drinks during the dry season with attractive promotions and highlighting the freshness of the product so that it can increase sales. (S3, O5) 5. Creating new unique flavor variants with a combination of lime and other natural ingredients with several choices of sugar content. (S2, O1)	3. Hold seasonal promotions at bazaars, e-commerce, and social media during the dry season, considering the demand for fresh drinks during the dry season increases. (W4, W5, O4, O5) 4. Create content planners on Instagram and TikTok more often and use ads to promote and increase brand awareness so the wider community can know it. (W3, O5)
Threats Weather changes can result in a decrease in the quality of raw lime materials (T1) Many competitors offer other citrus-based drinks (T2) Consumers with acid reflux disease or GERD and citrus allergies cannot consume citrus-based products (T3) The number of raw material suppliers is still limited, only one vendor in Tangerang (T4) Rising fuel prices could increase production and logistics costs (T5) Flavored beverage trends change rapidly (T6) New competitors easily enter the ready-to-drink beverage market (T7)	ST Strategy 1. Optimize consignment cooperation in various places by promoting light flavor variants that adjust to consumer health restrictions and provide transparent product information directly. (S7, T3) 2. Collaborate with several orange farmers in the long term to maintain the quality of natural and premium raw materials and not change in quality due to weather changes. (S1, S3, T1, T4) 3. Create advertisements or promotions by highlighting Halal certificates and having a legal entity (CV) as a guarantee of quality and safe products for consumers. (S4, S5, T2, T7) 4. Create unique flavor variants without added sugar and be more diverse (seasonal) than competitors. (S2, T2, T6)	WT Strategy 1. Improve product quality by creating innovations that are more difficult to imitate, such as premium raw materials, unique beverage concoctions, the use of technology for packaging, and increasing packaging sizes. (W1, W2, T2, T7) 2. Add fruit raw materials that are friendlier to consumers with stomach acid/GERD and reduce dependence on one type of raw material. (W3, T3) 3. Develop offline sales in collaboration with retail stores or supermarkets to reduce dependence on online sales. (W5, T6) 4. Change sales in niche segments or special segments that are rarely entered by competitors, such as offering products to consumers who pay attention to their diet or organic food lovers. (W4, T2)

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	5. Maintain competitive prices to overcome rising production and logistics costs (fuel) by streamlining the supply chain and increasing sales to reduce costs per product without sacrificing product quality. (S6, T5) 6. Plan and design product development in terms of taste according to current beverage trends and in accordance	5. Look for investors to increase cooperation with several suppliers so that the supply of limes remains stable, the use of raw materials is efficient, and the rearrangement of distribution channels is more cost-effective. (W4, T1, T4, T5) 6. Collaborate or bundle with other brands to add various flavors and product sizes and increase brand awareness. (W3 T2)

Appendix 2. QSPM matrix

Strategy Factors	Weight	Market Penetration		Market Development		Product Development	
		Attractive Score	Total Attractive Score	Attractive Score	Total Attractive Score	Attractive Score	Total Attractive Score
Strengths							
The raw materials used are natural ingredients without flavorings, colorings, and preservatives (S1)	0.07	3	0.21	2	0.14	4	0.28
Unique and more diverse flavor variants compared to competitors (S2)	0.09	4	0.36	3	0.27	4	0.36
The quality of the raw materials	0.07	3	0.21	3	0.21	4	0.28

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used for limes is premium limes which are selected directly from the garden in fresh condition (S3)							
It has the form of a legal entity, namely CV (S4)	0.06	4	0.24	4	0.24	3	0.18
Has Halal certificate (for all variants) and PIRT (for syrup products) (S5)	0.06	4	0.24	4	0.24	3	0.18
The prices offered are affordable and	0.08	4	0.32	4	0.32	2	0.16

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competitive compared to competitors (S6)							
Have established consignment cooperation with one restaurant and one cafe (S7)	0.07	3	0.21	4	0.28	1	0.07
Weakness							
The packaging size option is only available in one size (W1)	0.11	1	0.11	1	0.11	4	0.44
Products are easily imitated and damaged (W2)	0.11	3	0.33	3	0.33	4	0.44
The brand is still not well known to the	0.11	3	0.33	4	0.44	1	0.11

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general public (W3)							
Minimal capital (W4)	0.09	3	0.27	3	0.27	3	0.27
Sales are still only done through bazaars and online (WhatsApp, Instagram, Tokopedia, and GrabFood) (W5)	0.1	2	0.2	3	0.3	1	0.1
Opportunities							
Awareness of healthy living increases the market share of lime sales (O1)	0.07	4	0.28	4	0.28	3	0.21
Increasing use of online	0.09	3	0.27	4	0.37	1	0.09

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buying and selling platforms (O2)							
The large number of restaurants, cafes and sports venues such as yoga or pilates studios opens up opportunities to expand market share (O3)	0.07	3	0.21	4	0.28	1	0.07
The use of social media and digital marketing can increase brand awareness	0.08	4	0.32	3	0.24	2	0.16

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and expand market reach (O4)							
The dry season in Indonesia increases demand for fresh drinks (O5)	0.08	1	0.08	1	0.08	2	0.16
Threats							
Weather changes can result in a decrease in the quality of raw lime materials (T1)	0.09	1	0.09	1	0.09	4	0.36
Many competitors offer other citrus-based drinks (T2)	0.07	3	0.21	2	0.14	4	0.28
Consumers with acid reflux disease or	0.12	1	0.12	1	0.12	1	0.12

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GERD and citrus allergies cannot consume citrus-based products (T3)							
The number of raw material suppliers is still limited, only one vendor in Tangerang (T4)	0.09	1	0.09	1	0.09	1	0.09
Rising fuel prices could increase production and logistics costs (T5)	0.1	1	0.1	1	0.1	3	0.3
Flavored beverage trends	0.08	3	0.24	1	0.08	3	0.24

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change rapidly (T6)							
New competitors easily enter the ready-to-drink beverage market (T7)	0.07	3	0.21	3	0.11	3	0.21
Total	5.25		5.22		5.16		

Analysis of the Influence of Halal Friendly Attributes and Halal Tourism Experience on Tourist Loyalty with Perceived Value, Satisfaction, and Trust as Mediating Variables

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Abstract

The rapid growth of halal tourism highlights the need to understand the factors influencing tourist loyalty in halal destinations. This study investigates the impact of Halal Friendly Attributes (HFA) and Halal Tourism Experience (HTE) on Tourist Loyalty (TL), mediated by Perceived Value (PV), Tourist Satisfaction (TS), and Trust (TT). A quantitative approach utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to analyze survey data from 600 tourists visiting halal destinations in Lombok, Indonesia. The findings reveal that HFA significantly enhances PV, TS, and TT, reinforcing the role of halal-friendly services and facilities in shaping positive tourist experiences. HTE also positively influences PV and TT, indicating that an enriching tourism experience strengthens tourist perceptions and trust. Moreover, PV and TS emerge as critical drivers of TL, suggesting that tourists' perceived value and satisfaction significantly contribute to their intention to revisit and recommend halal destinations. TT plays a crucial mediating role, bridging the relationships between HFA, HTE, and TL. These results highlight the importance of developing halal tourism strategies that emphasize service quality, trust-building, and value creation. Destination managers should focus on enhancing halal-friendly facilities and ensuring a meaningful tourism experience to foster long-term loyalty among tourists. This study contributes to the growing literature on halal tourism and provides practical insights for tourism stakeholders aiming to strengthen competitiveness in the global halal tourism market.

Keywords: halal tourism, tourist loyalty, perceived value, tourist satisfaction, trust

JEL code: L83, Z32, M31

SDG classification: SDG 8, SDG 11, SDG 12

Introduction

Halal tourism has emerged as one of the fastest-growing sectors in the global travel industry. As the Muslim population continues to expand, so does the demand for travel services and destinations that adhere to Islamic principles (Muharis, Saidi, Alfatwari, & Ahmad, 2023). Destinations such as Lombok, Indonesia, have positioned themselves as key players in this market by offering a wide range of halal-friendly facilities, including halal-certified restaurants, prayer facilities, and gender-segregated amenities (Rahmatullah, 2023). This trend reflects the increasing importance of meeting the specific needs of Muslim tourists while fostering inclusivity and cultural understanding in the tourism industry (Zulhilmi, Terpiadi, & Hafizh, 2024). Meeting these expectations is not merely about providing halal-compliant facilities. It also involves creating a memorable and satisfying experience that fosters trust and loyalty among visitors (Aji & Muslichah, 2021). Loyal tourists are more likely to revisit destinations, recommend them to others, and contribute positively to the local economy. Despite the growing interest in halal tourism, there is still limited empirical research that systematically explores the factors influencing tourist loyalty in halal destinations, particularly in Indonesia (Aisya, Syamsu, & Muthmainnah, 2023).

While previous studies have examined individual aspects of halal tourism, such as service quality, trust, and satisfaction, many fail to provide a comprehensive model linking these factors to tourist loyalty (Akhsanty, Setyowati, Musyafa, & Destyana, 2023). Most existing research focuses on general tourism without fully addressing the unique cultural and religious dimensions of halal tourism (Prawira, et al., 2023). Furthermore, few studies explore the mediating roles of perceived value, satisfaction, and trust in shaping tourist loyalty, leaving significant gaps in understanding how these variables interact within the context of halal destinations (Syarifuddin, Mandey, Tumbuan, & Maramis, 2022). Another critical gap lies in understanding the combined effects of Halal Friendly Attributes (HFA) and Halal Tourism Experience (HTE). While both factors are acknowledged as important, their individual and combined contributions to tourist loyalty, mediated by other psychological and behavioral constructs, remain underexplored. This lack of comprehensive research limits the ability of destination managers and policymakers to design effective strategies for fostering loyalty among Muslim tourists (Hasan, 2023).

This study aims to address these gaps by developing and testing a conceptual model that links HFA and HTE to tourist loyalty. Specifically, it investigates the mediating roles of perceived value, satisfaction, and trust in these relationships (Akter & Hasan, 2022). By focusing on Lombok, a globally recognized halal tourism destination, this research provides valuable insights into the drivers of loyalty in halal tourism (Arintyas & Budiman, 2023). The study also seeks to quantify the extent to which HFA and HTE influence perceived value, trust, and satisfaction, and how these constructs collectively impact loyalty. This approach not only contributes to the academic understanding of halal tourism but also provides actionable recommendations for improving destination competitiveness in a highly dynamic market (Maskuroh, 2023).

By addressing the interrelationships among these key constructs, this research contributes to the broader literature on tourism management and consumer behavior. It highlights the unique characteristics of halal tourism and underscores the importance of tailoring tourism products and services to meet the expectations of Muslim travelers (Jalil & Akbar, 2024). Additionally, the findings of this study offer practical implications for

destination managers, particularly in optimizing resources to enhance visitor experiences and loyalty. The study is particularly relevant in the context of Lombok, Indonesia, which has been recognized as one of the world's leading halal destinations (Cahyono, Wijaya, & Widjaja, 2021). Despite its growing popularity, Lombok faces stiff competition from other halal destinations in Malaysia, Turkey, and the Middle East. Understanding the drivers of loyalty can help Lombok sustain its competitive advantage by aligning its offerings with the needs and preferences of its target market (Lestari & Yusra, 2022).

Based on the identified gaps and objectives, this study addresses the following research questions: (1) How do Halal Friendly Attributes and Halal Tourism Experience influence tourist loyalty? (2) What roles do perceived value, satisfaction, and trust play in mediating these relationships? The hypotheses are formulated to test both direct and indirect effects among the variables, providing a holistic understanding of their interactions. By bridging theoretical gaps and offering practical insights, this study positions itself at the intersection of halal tourism research and strategic destination management. The findings are expected to serve as a reference for future studies while offering actionable guidance for policymakers and stakeholders in the halal tourism sector.

Methodology

This study adopts a quantitative research design to analyze the relationships between Halal Friendly Attributes (HFA), Halal Tourism Experience (HTE), and Tourist Loyalty (TL), with Perceived Value (PV), Satisfaction (TS), and Trust (TT) as mediating variables. The quantitative approach enables the use of statistical methods to test hypotheses and validate the conceptual framework (Priadana & Sunarsi, 2021). The population of this study consists of tourists who have visited halal destinations in Lombok, Indonesia. The sample size includes 600 respondents selected using purposive sampling to ensure they meet the criteria of having experienced halal tourism services. The respondents are diverse in terms of age, gender, marital status, educational background, and income levels, providing a comprehensive representation of the target population. Data was collected using a structured questionnaire distributed to respondents both online and offline. The questionnaire was designed to measure the constructs in the proposed model, including HFA, HTE, PV, TS, TT, and TL. A 5-point Likert scale was employed, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), to capture respondents' perceptions and experiences.

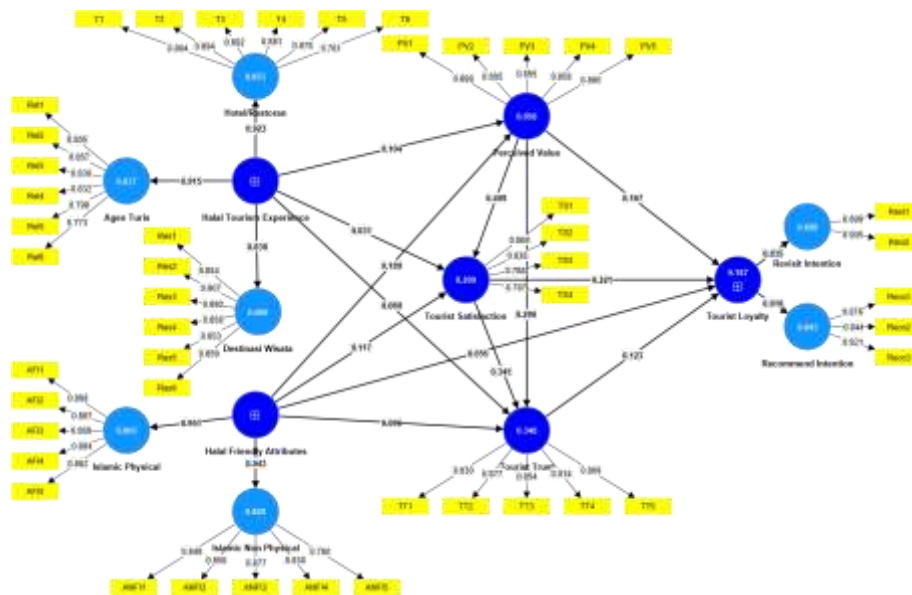


Figure 1. Flowchart

Partial Least Squares Structural Equation Modeling (PLS-SEM) was used for data analysis. PLS-SEM is suitable for predictive modeling and analyzing complex relationships among latent variables. The analysis was conducted in two stages:

- Outer Model Evaluation: Assessed the validity (convergent and discriminant) and reliability (Cronbach's Alpha and Composite Reliability) of the constructs.
- Inner Model Evaluation: Examined the structural relationships among variables, including path coefficients, R-squared values, and hypothesis testing.

The following hypotheses were tested in this study:

- H1: Halal Friendly Attributes (HFA) enhance the perception of value (PV) among tourists in halal destinations.
- H2: Halal Friendly Attributes (HFA) significantly improve Tourist Satisfaction (TS).
- H3: Halal Friendly Attributes (HFA) contribute positively to building Tourist Trust (TT).
- H4: Halal Friendly Attributes (HFA) indirectly influence Tourist Loyalty (TL) through mediating variables.
- H5: Halal Tourism Experience (HTE) positively shapes tourists' perceptions of value (PV).
- H6: Halal Tourism Experience (HTE) fosters satisfaction (TS) among tourists.
- H7: Halal Tourism Experience (HTE) plays a significant role in enhancing Tourist Trust (TT).
- H8: Higher Perceived Value (PV) strengthens Tourist Loyalty (TL) in halal destinations.

- H9: Perceived Value (PV) serves as a critical determinant of Tourist Satisfaction (TS).
- H10: Perceived Value (PV) positively affects Tourist Trust (TT).
- H11: Tourist Satisfaction (TS) acts as a driver of trust (TT) in halal tourism settings.
- H12: Greater Tourist Satisfaction (TS) increases Tourist Loyalty (TL).
- H13: Trust (TT) mediates the relationship between Tourist Satisfaction (TS) and Tourist Loyalty (TL).

Results and Discussion

The demographic profile indicates a balanced representation of gender among respondents, with the majority falling into the 18-30 age group. Most respondents are married and possess an educational background ranging from high school to undergraduate degrees. In terms of income, a significant portion earns below Rp 3,000,000, reflecting diverse socio-economic characteristics. Meanwhile, the descriptive statistics for key variables show high mean scores, indicating that respondents generally hold favorable perceptions toward halal-friendly attributes, tourism experiences, and the related constructs of perceived value, satisfaction, trust, and loyalty. These findings highlight the positive reception of halal tourism services in Lombok.

Table 1. Demographic profile of respondents

Category	Frequency	Percentage
Gender		
Male	302	50.3%
Female	298	49.7%
Age Group		
18-30 years	209	34.8%
31-40 years	184	30.7%
41-50 years	165	27.5%
51-60 years	39	6.5%
≥ 60 years	3	0.5%
Marital Status		
Unmarried	194	32.3%
Married	374	62.3%
Divorced/Widowed	32	5.3%
Education		
High School or below	245	40.9%
Undergraduate degree	186	31.0%

Category	Frequency	Percentage
Postgraduate degree	82	13.7%
Monthly Income		
Below Rp 3,000,000	190	31.7%
Rp 3,000,001 - Rp 6,000,000	141	23.5%
Rp 6,000,001 - Rp 10,000,000	128	21.3%
Rp 10,000,001 - Rp 15,000,000	130	21.7%
Above Rp 15,000,000	11	1.8%

Table 2. Descriptive statistics for key variables

Variable	Mean	Standard Deviation
Halal Friendly Attributes (HFA)	4.22	0.45
Halal Tourism Experience (HTE)	4.07	0.43
Perceived Value (PV)	4.13	0.41
Tourist Satisfaction (TS)	4.28	0.38
Tourist Trust (TT)	4.22	0.40
Tourist Loyalty (TL)	4.34	0.37

Table 3 shows that all indicators have loading factors greater than 0.7, confirming convergent validity for all constructs. The AVE values for each variable exceed 0.5, indicating that the indicators are sufficiently correlated to measure their respective constructs.

Table 3. Convergent validity

Variable	Indicator	Loading Factor	AVE
Halal Friendly Attributes	HFA1	0.888	0.770
	HFA2	0.887	
	HFA3	0.868	
	HFA4	0.884	
	HFA5	0.862	
Halal Tourism Experience	HTE1	0.854	0.758
	HTE2	0.907	
	HTE3	0.890	
	HTE4	0.858	
	HTE5	0.853	

Table 4. Discriminant validity (HTMT)

Variable 1	Variable 2	HTMT Value	Threshold
Halal Friendly Attributes	Halal Tourism Experience	0.297	< 0.90
Halal Friendly Attributes	Perceived Value	0.235	< 0.90
Halal Tourism Experience	Perceived Value	0.164	< 0.90

The HTMT values between all variables are below the threshold of 0.90, demonstrating good discriminant validity. This confirms that each variable is distinct and measures unique aspects of the constructs within the model.

Table 5. Reliability analysis

Variable	Cronbach's Alpha	Composite Reliability	Threshold
Halal Friendly Attributes	0.925	0.944	> 0.7
Halal Tourism Experience	0.936	0.949	> 0.7
Perceived Value	0.919	0.939	> 0.7
Tourist Satisfaction	0.844	0.894	> 0.7
Tourist Trust	0.893	0.921	> 0.7
Tourist Loyalty	0.826	0.878	> 0.7

All Cronbach's Alpha and Composite Reliability values exceed the threshold of 0.7, indicating that the constructs are reliable and have high internal consistency. These findings validate the stability of the indicators and their suitability for measuring the associated variables.

Table 6. Path coefficients and t-values

Hypothesis	Path	Path Coefficient	T-Value	P-Value	Conclusion
H1: HFA → PV	Halal Friendly Attributes → Perceived Value	0.189	4.550	0.000	Supported
H2: HFA → TS	Halal Friendly Attributes → Tourist Satisfaction	0.117	3.061	0.002	Supported
H3: HFA → TT	Halal Friendly Attributes → Tourist Trust	0.096	2.621	0.009	Supported
H4: HFA → TL	Halal Friendly Attributes → Tourist Loyalty	0.055	1.663	0.096	Not Supported
H5: HTE → PV	Halal Tourism Experience → Perceived Value	0.104	2.354	0.019	Supported
H6: HTE → TS	Halal Tourism Experience → Tourist Satisfaction	0.031	0.881	0.378	Not Supported

Hypothesis	Path	Path Coefficient	T-Value	P-Value	Conclusion
H7: HTE → TT	Halal Tourism Experience → Tourist Trust	0.069	1.971	0.049	Supported
H8: PV → TL	Perceived Value → Tourist Loyalty	0.167	3.492	0.000	Supported
H9: PV → TS	Perceived Value → Tourist Satisfaction	0.409	10.551	0.000	Supported
H10: PV → TT	Perceived Value → Tourist Trust	0.290	6.362	0.000	Supported
H11: TS → TT	Tourist Satisfaction → Tourist Trust	0.345	8.180	0.000	Supported
H12: TS → TL	Tourist Satisfaction → Tourist Loyalty	0.221	4.160	0.000	Supported
H13: TT → TL	Tourist Trust → Tourist Loyalty	0.123	2.452	0.014	Supported

The path coefficients indicate the strength and direction of relationships among the variables. A positive coefficient signifies a positive relationship. Hypotheses with T-values ≥ 1.96 and P-values ≤ 0.05 are considered statistically significant. As shown, most hypotheses are supported, confirming the significance of relationships such as HFA → PV, PV → TS, and TS → TT. However, some paths, such as HFA → TL and HTE → TS, are not significant.

Table 7. R-square values

Endogenous Variable	R-Square (R^2)	Interpretation
Perceived Value (PV)	0.058	5.8% of variance explained by HFA and HTE.
Tourist Trust (TT)	0.348	34.8% of variance explained by PV, TS, HFA, and HTE.
Tourist Satisfaction (TS)	0.209	20.9% of variance explained by PV, HFA, and HTE.
Tourist Loyalty (TL)	0.187	18.7% of variance explained by PV, TT, TS, and HFA.

The R-square values measure the proportion of variance in the endogenous variables explained by the predictors. Higher values indicate a stronger explanatory power of the model. For example, 34.8% of the variance in Tourist Trust is explained by the predictors, indicating a moderate fit. Meanwhile, Tourist Loyalty has an R-square value of 18.7%, showing that other unmeasured factors may contribute to loyalty.

Table 8. Hypothesis testing

Hypothesis	Path	Path Coefficient	T-Value	P-Value	Significance	Conclusion
H1: HFA → PV	Halal Friendly Attributes → Perceived Value	0.189	4.550	0.000	Significant	Supported
H2: HFA → TS	Halal Friendly Attributes → Tourist Satisfaction	0.117	3.061	0.002	Significant	Supported
H3: HFA → TT	Halal Friendly Attributes → Tourist Trust	0.096	2.621	0.009	Significant	Supported
H4: HFA → TL	Halal Friendly Attributes → Tourist Loyalty	0.055	1.663	0.096	Not Significant	Not Supported
H5: HTE → PV	Halal Tourism Experience → Perceived Value	0.104	2.354	0.019	Significant	Supported
H6: HTE → TS	Halal Tourism Experience → Tourist Satisfaction	0.031	0.881	0.378	Not Significant	Not Supported
H7: HTE → TT	Halal Tourism Experience → Tourist Trust	0.069	1.971	0.049	Significant	Supported
H8: PV → TL	Perceived Value → Tourist Loyalty	0.167	3.492	0.000	Significant	Supported
H9: PV → TS	Perceived Value → Tourist Satisfaction	0.409	10.551	0.000	Significant	Supported
H10: PV → TT	Perceived Value → Tourist Trust	0.290	6.362	0.000	Significant	Supported
H11: TS → TT	Tourist Satisfaction → Tourist Trust	0.345	8.180	0.000	Significant	Supported
H12: TS → TL	Tourist Satisfaction → Tourist Loyalty	0.221	4.160	0.000	Significant	Supported
H13: TT → TL	Tourist Trust → Tourist Loyalty	0.123	2.452	0.014	Significant	Supported

Out of the 13 hypotheses tested, 11 were found to be significant, as indicated by T-values greater than 1.96 and P-values less than 0.05. The results highlight the importance of Perceived Value (PV), Tourist Satisfaction (TS), and Tourist Trust (TT) in explaining Tourist Loyalty (TL). Specifically:

- H1, H2, and H3: Halal Friendly Attributes (HFA) positively influence Perceived Value (PV), Tourist Satisfaction (TS), and Tourist Trust (TT).
- H5 and H7: Halal Tourism Experience (HTE) significantly impacts Perceived Value (PV) and Tourist Trust (TT), but its effect on Tourist Satisfaction (TS) (H6) is not significant.
- H8, H9, and H10: Perceived Value (PV) positively impacts Tourist Loyalty (TL), Tourist Satisfaction (TS), and Tourist Trust (TT).
- H12 and H13: Tourist Satisfaction (TS) and Tourist Trust (TT) significantly contribute to Tourist Loyalty (TL).
- H4: The direct influence of HFA on Tourist Loyalty (TL) is not significant, suggesting the importance of mediating variables like Perceived Value, Satisfaction, and Trust.

These results underline the pivotal role of mediators in driving loyalty and emphasize the need for destinations to focus on enhancing tourist experiences and trust.

The results of this study confirm the theoretical framework underpinning the relationships among Halal Friendly Attributes (HFA), Halal Tourism Experience (HTE), Perceived Value (PV), Tourist Satisfaction (TS), Tourist Trust (TT), and Tourist Loyalty (TL). Consistent with previous research, HFA significantly influence PV, TS, and TT, underscoring the importance of halal-compliant facilities in shaping positive tourist perceptions and emotional responses. The study reveals that HTE significantly impacts PV and TT but has no direct effect on TS. This finding partially supports studies which highlighted the importance of tourism experiences in enhancing perceived value and trust. The insignificant impact on TS suggests that other factors, such as service quality or destination infrastructure, may play a stronger role in shaping satisfaction, especially in halal tourism contexts (Lestari, Saidah, & Putri, 2021).

The mediating roles of PV, TS, and TT are evident in the relationships between HFA, HTE, and TL. For example, while the direct effect of HFA on TL is insignificant, the indirect effects mediated by PV, TS, and TT are significant. This highlights the importance of a holistic approach where perceived value and emotional satisfaction act as bridges between initial tourist perceptions and their loyalty. This study advances the literature on halal tourism by providing an integrated model that connects HFA, HTE, and key mediating variables to tourist loyalty. Unlike prior studies that focus on isolated constructs, this research demonstrates how multiple psychological and experiential factors interact to shape loyalty in halal tourism (Virana & Pradani, 2023). The study also validates the applicability of the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach in analyzing complex relationships within this domain.

The novelty of this study lies in its contextual focus on Lombok as a leading halal tourism destination and its examination of the nuanced roles of mediators like PV and TT. Practically, the findings suggest that destination managers should prioritize enhancing perceived value by offering affordable, high-quality halal services. Fostering trust through transparent halal certifications and culturally sensitive customer service can significantly impact tourist loyalty (Sulfardin, et al., 2024). One notable unexpected result is the

insignificant direct effect of HFA on TL. While HFA are crucial in establishing initial perceptions, they appear insufficient in driving loyalty without the mediating influence of PV, TS, and TT. The non-significant impact of HTE on TS suggests that experiential factors alone do not guarantee satisfaction unless complemented by other attributes, such as reliability and service excellence. These findings provide critical insights into the nuanced dynamics of halal tourism.

The findings suggest that theoretical models of halal tourism should incorporate mediators like PV and TT to better explain loyalty dynamics. From a practical perspective, tourism providers should adopt a comprehensive strategy that integrates facility enhancements, memorable experiences, and trust-building measures. For example, promoting Islamic cultural events or ensuring consistent halal certifications can reinforce trust and satisfaction among tourists. This study is not without limitations. The focus on Lombok limits the generalizability of findings to other halal tourism destinations with different cultural and infrastructural characteristics. The cross-sectional design may not capture the evolving nature of tourist perceptions over time. Future research could explore longitudinal data and include variables like service quality and cultural authenticity to provide a more holistic understanding of halal tourism.

Conclusion

This study highlights the critical roles of Halal Friendly Attributes (HFA) and Halal Tourism Experience (HTE) in shaping tourist loyalty through the mediating effects of Perceived Value (PV), Tourist Satisfaction (TS), and Tourist Trust (TT). The findings confirm that while HFA and HTE significantly influence PV, TS, and TT, their direct impact on loyalty is limited without the mediating variables. This underscores the importance of enhancing the overall tourist experience by not only providing halal-compliant services but also building trust and satisfaction. These insights contribute to the growing body of halal tourism literature and offer a robust framework for understanding tourist behavior in this niche market. To sustain and improve tourist loyalty, destination managers should focus on creating high-value and memorable experiences that align with Islamic principles. Practical strategies include ensuring consistent halal certifications, offering diverse halal-friendly amenities, and organizing culturally enriching activities. Trust-building initiatives such as transparent communication and personalized customer service should be prioritized. Future research could explore longitudinal approaches and consider broader cultural and demographic contexts to deepen the understanding of tourist behavior in halal destinations.

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References

- Aisya, S., Syamsu, N., & Muthmainnah. (2023). Evaluating the Growth Potential of Halal Tourism in Palu. *Iqtishodia: Jurnal Ekonomi Syariah*, 8(2), 40–55.
- Aji, H. M., & Muslichah, I. (2021). The determinants of Muslim travellers' intention to visit non-Islamic countries: a halal tourism implication. *Journal of Islamic Marketing*, 12(8), 1553-1576.
- Akhsanty, A. S., Setyowati, R., Musyafa, A. A., & Destyana, M. E. (2023). Halal certification mechanism for Sharia hotels in the development of Muslim-friendly tourism under Job Creation Law. *Borobudur Law Review*, 5(1).
- Akter, N., & Hasan, S. (2022). The moderating role of perceived behavioral control in predicting Muslim tourists' halal tourism intention: a developing country perspective. *Journal of Islamic Marketing*.
- Arintyas, A. R., & Budiman, R. C. (2023). Halal Tourism Towards Equity Representation of Multicultural Identity and Human Development: A Case of Lombok Indonesia. *Jurnal Kepariwisata: Destinasi, Hospitalitas dan Perjalanan*, 7(2), 154-166.
- Cahyono, N. A., Wijaya, S., & Widjaja, D. C. (2021). Is Lombok Really Perceived as Halal Tourism Destination? A Study of Tourist Satisfaction and Loyalty. *Advances in Economics, Business and Management Research*, volume 175.
- Hasan, A. A.-T. (2023). Factors influencing halal tourism destinations revisit intentions among Muslim travelers of Bangladesh: the mediating role of emotional attachments. *Journal of Islamic Marketing*.
- Jalil, N. K., & Akbar, N. (2024). Analyzing Consumer Preferences in Selecting Halal Tourism Destination. *Al-Falah: Journal of Islamic Economics*, 9(1).
- Lestari, Y. B., & Yusra, K. (2022). Identifying Tourism Potentials of Ethno-Cultural Attractions in Lombok. *Sustainability*, 14(23).
- Lestari, Y. D., Saidah, F., & Putri, A. N. (2021). Effect of destination competitiveness attributes on tourists' intention to visit halal tourism destination in Indonesia. *Journal of Islamic Marketing*.
- Maskuroh, N. (2023). Development Model in Economic Growth: Dynamic Cycle on Halal Tourism. *General Management*, 24(193).
- Muharis, Saidi, M., Alfatwari, D., & Ahmad. (2023). Halal Tourism: Trend, Opportunities, Challenges and Impact of Halal Tourism on Conventional Tourism. *JMET: Journal of Management Entrepreneurship and Tourism*, 1(1), 21-28.
- Prawira, M. F., Pamungkas, Y., Agustin, D. L., Tanisa, F. S., Alviana, A. D., Anisa, D. N., & Syam, R. (2023). Halal Tourism Destination from Tourist Perspectives: A Review. *Journal of Tourism Sustainability*, 3(1).
- Priadana, S., & Sunarsi, D. (2021). *Metode Penelitian Kuantitatif*. Tangerang Selatan: Pascal Books.
- Rahmatullah. (2023). Implementation of Halal Tourism in Lombok Island (Study on the Compliance of Tourism Actors with the Halal Tourism Regulation). *Ijtima' Iyya Journal of Muslim Society Research*, 8(1), 95-116.

- Sulfardin, Fatmawati, Suheldi, R., Juniati, Zitri, I., Ali, M., & Jaelani, M. A. (2024). Enhancing Senggigi As A Lombok Tourism Destination: A Development Strategy. *Komunitas: Jurnal Pengembangan Masyarakat Islam*, 15(1), 51-78.
- Syarifuddin, Mandey, S., Tumbuan, W., & Maramis, J. (2022). The Effect Of Halal Certificate Trust, Brand Love, Food Quality, On Consumer Loyalty Through Customer Satisfaction At Halal Restaurants In North Sulawesi, Indonesia. *Journal of Positive School Psychology*, 6(10), 3155-3173.
- Virana, T. A., & Pradani, G. D. (2023). The Impact of Halal Tourism on The Economic and Social Development of The Local Community of Santen Island. *Proceedings 6th ACIEL Annual Conference on Islamic Economic and Law*.
- Zulhilmi, Terpiadi, S., & Hafizh, M. (2024). Exploring The Role of Halal Certification for Tourism Industry in Aceh. *el-Amwal*, 7(1).

Enhancing Halal Traceability in The ASEAN Beef Supply Chain: Challenges and Opportunities for Sustainable Food Systems

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Abstract

The global expansion of Islam has increased the demand for halal products, particularly in the Asia-Pacific region. As a widely consumed food, halal beef requires a robust traceability system implemented through regulations and certification standards. Despite efforts by governments and certification bodies, gaps still exist in the implementation of halal standards and traceability technologies across ASEAN countries. This research aims to provide recommendations for improving transparency and sustainability in the halal supply chain. It also explores opportunities to enhance halal traceability in the meat supply chain to ensure compliance with halal standards. This study adopts a literature review and a descriptive-qualitative approach by analyzing data from academic journals, reports from international organizations, and regulatory documents related to food, halal standards, and traceability policies in ASEAN countries. Halal traceability is crucial for monitoring each step of the beef supply chain to ensure compliance with halal requirements, such as proper sourcing, slaughtering methods, processing, storage, and transportation for distribution. By leveraging technologies such as Blockchain, the Internet of Things (IoT), data analytics, and Artificial Intelligence (AI), we can develop more reliable systems to enhance consumer trust. A robust halal traceability system ensures that Muslim consumers can safely consume beef without concerns about contamination, fraud, or non-compliance with halal standards. However, improving halal traceability not only guarantees religious compliance but also strengthens food safety systems, enhances supply chain efficiency, promotes sustainability, and boosts consumer confidence. Ultimately, this contributes to economic growth and trade efficiency in ASEAN.

Keywords: Halal traceability, halal beef, ASEAN supply chain

JEL code: D18, L66, Q18

SDG classification: SDG 2, SDG 3, SDG 12

Introduction

The concept of halal is fundamental to the food consumption of millions of Muslims in ASEAN countries. Ensuring the integrity of halal beef from farm to fork is crucial in maintaining consumer trust and fulfilling religious obligations. However, the complexity of the beef supply chain, which often involves multiple stakeholders across different countries, presents challenges in ensuring full halal traceability.

Halal traceability refers to the ability to track and verify the halal status of beef products throughout the supply chain. This process encompasses various stages, including sourcing, slaughtering, processing, packaging, and distribution. With increasing consumer awareness and demand for transparency, effective traceability systems are necessary to uphold halal integrity and ensure compliance with halal certification standards. By this research, we can enhance and develop halal traceability amidst ASEAN countries in the beef halal supply chain.

Despite efforts by governments and certification bodies, gaps still exist in implementing standardized halal traceability across ASEAN countries. These challenges include regulatory differences, technological limitations, and issues of trust among stakeholders. At the same time, advancements in digital technologies, such as blockchain, Internet of Things (IoT), and data analytics, provide opportunities to enhance transparency and efficiency in halal traceability.

This study seeks to explore halal traceability in the beef supply chain, technologies used in halal traceability, challenges in implementing halal traceability, opportunities and best practices, and gaps and proposed solutions. As many actors are related in the beef supply chain, this can be used by suppliers, producers, logistics, and consumers. Students also can gain more knowledge related to traceability by this work.

So far, training programs have been conducted to improve awareness and compliance with halal practices in food processing across ASEAN countries by a project entitled “Safeguarding and Sustaining the Integrity of Halal Food” held by SEARCA (Southeast Asian Regional Center for Graduate Study and Research in Agriculture) and University Consortium (SEARCA, 2020).

This paper aims to provide recommendations for strategies that can be implemented to increase transparency, technologies in the halal supply chain, and examine existing opportunities to improve halal traceability in the meat supply chain to ensure halal products in the ASEAN beef supply chain. By analyzing previous studies and emerging technologies, this study seeks to contribute to the development of a more resilient and transparent halal food system in the region. This paper conducts introduction, methodology, discussion, acknowledgement, and references.

Methodology

This study adopts a literature review approach by collecting data from academic journals, reports from international organizations (such as FAO, ASEAN, and halal certification bodies), and regulatory documents related to halal standards and traceability policies in ASEAN countries. The gathered literature is analyzed using a descriptive-qualitative approach, where findings are synthesized to identify key trends, challenges, and opportunities in implementing halal traceability in the ASEAN beef supply chain. The

selection of literature follows specific criteria, including relevance (focusing on halal traceability, food sustainability, or beef supply chains in ASEAN), publication year (prioritizing studies from the last 5-10 years), and credibility (ensuring that sources come from peer-reviewed journals, reputable organizations, or official government regulations).

Results and Discussion

Concept and definition of halal traceability

The attention to Islamic halal regulations and laws keeps going up due to the opportunities with the global Muslim rate population increasing by 6.4%. This number also shows the growing demand for halal items. Interestingly, the halal food market is experiencing rapid development, especially in the Asia-Pacific region (Harati & Farzaneh, 2024).

Halal is an Arabic term associated with the Islamic faith. From the Islamic Perspective, the ideas of halal (allowed) and haram (disallowed) are based on the declaration of God as right and good (Aung T et al., 2025). Several foods are considered harmful for humans to consume and are forbidden, especially meat with the most strictly regulated food (Al-Teinaz & Al-Mazzadi, 2020). Halal food and beverage criteria are often defined by the absence of pork, blood, alcohol, carrion, encompassing the prohibition of carnivorous animals such as cats and dogs, amphibians like frogs, and most insects except grasshoppers. Poultry and cattle are allowed as long as they are slaughtered according to Islamic laws.

To reassure the halalness of a product, halal traceability should be provided. Alqudsi (2014, as cited in Khan, 2018) stated transparency is the primary aspect of enhancing halal integrity, and it is related to traceability, which recreates a crucial position in the Halal Supply Chain. This also strengthens the reasons to establish a reliable traceability procedure of safe and halal products. The progress of ICTs has enabled the product of new approaches to outcome traceability (Sayogo, 2018 pp. 99-116). Several digital technologies are being integrated into halal traceability systems are blockchain, IoT, and data analysis. These systems will give consumers transparency, and make it easier to recall products in the event of contamination or other problems.

Halal traceability refers to the systematic tracking of halal beef products from their origin to the end consumer. Consumers must know what is in the food they eat; however, some manufacturers intentionally mislead consumers about the source or quality of food products for their financial gains (Ng et al., 2021). This includes monitoring each step of the supply chain to ensure compliance with halal requirements, such as proper sourcing, slaughtering methods, processing, storage, and transportation. A robust halal traceability system helps prevent contamination, fraud, and non-compliance with halal standards. The traceability approach is an effort to ensure the halalness of a product that is knowledge-oriented.

Halal regulations and standards in ASEAN

The demand for halal food, especially meat, is projected to grow significantly in Southeast-East Asia. This prediction based on the report by Pew Research Center in The Future of Global Muslim Population (2011) shows that the number of Muslims in the region is expected to increase from approximately 257,7 million in 2010 to 307.3 million by 2030. This demographic trend will likely lead to increased awareness and demand for halal compliant food products, especially in the beef supply chain.

From farm to consumer table, the halal status of beef products must be maintained throughout the supply chain, which can span multiple companies or even countries, including slaughtering, handling, processing, manufacturing, distribution and storage. Ensuring halal integrity throughout these stages requires not only religious compliance, but also requires proper traceability systems and mechanisms.

ASEAN countries have different halal certification regulations and standards. While Malaysia, Indonesia and Brunei have well-established and strong halal certification bodies, other ASEAN countries such as Vietnam and Cambodia are still developing their halal regulatory frameworks. Harmonization of halal standards across ASEAN is essential to facilitate trade and ensure consistent halal compliance across the region. Research conducted by Rizaldy and Syifana found that currently halal regulations between ASEAN countries are still very varied and inconsistent, both in terms of definition and authority institutions (Santosa & Rizaldy, 2022). Halal standards that differ in each country and based on the interests of policy makers create difficulties for business people and even for the future of the halal certification body itself (Islam et al., 2023).

In response to these growing concerns, ASEAN introduced the ASEAN General Guidelines on the Preparation and Handling of Halal Food, endorsed by the ASEAN Ministers on Agriculture and Forestry (AMAF) in 2019. This guideline provides practical guidance for the food industry on the preparation and handling of halal food, as well as basic requirements for accreditation of food processing companies for intra-ASEAN halal food trade (ASEAN, 2019) with Islamic law while respecting national differences in religious interpretation and institutional framework. It covers various aspects such as the conditions of animals prior to slaughter, which must align with Islamic requirements, and the method of slaughtering itself. They also emphasize the importance of segregating halal and non-halal products during processing, handling, storage, display, and serving. All equipment and facilities must be free from filth (*najis*), including pork, blood, carrion, and other impure substances. Additionally, hygiene and sanitation are critical components, ensuring that food is not only religiously compliant but also safe for consumption. Companies that implement these guidelines will be allowed to use the ASEAN Halal Logo on their product labels as an identifier that the product comes from an ASEAN-accredited food processing plant.

While important, these guidelines are not legally binding. Rather, they are intended to be applied in conjunction with other recognized national and international guidelines on the preparation of foods such as good manufacturing practice, hygiene and sanitation requirements.

Technologies used in halal traceability

The traceability system using the blockchain method is an innovative approach that allows for transparent, secure, and immutable recording and tracking of information. Blockchain technology can help improve supply chain efficiency by providing a tracking system for all activities occurring in the supply chain and product quality.

Blockchain technology is based on two essential functionalities: First, follow the idea of a distributed ledger with copies of the same data being kept decentrally by different, independent parties. This makes the data more or less tamper-resistant. Second, decoding information into blocks that are accepted by all parties. These blocks are chained with all previous blocks and are then cryptographically processed to so-called “hash-values”. Thus, they build a long list of all transactions ever made (Seifermann et al., 2022, pp. 172-177).

The blockchain system has several advantages in terms of traceability. One of its main advantages is high data transparency, where every piece of information is recorded permanently and immutable in the block chain. This allows all parties in a system to track the origin and movement of information in real-time and accurately, thereby increasing trust and accountability. In addition, the decentralized nature of blockchain makes it resistant to forgery or data manipulation by certain parties. However, behind its advantages, blockchain also has disadvantages. The process of validating and recording data that requires consensus from many nodes can be time-consuming and require large computing resources. In addition, limitations in integration with conventional systems and the lack of clear understanding and regulation in some regions can be challenges in implementing blockchain for widespread traceability.

The Internet of Things (IoT) brings together a large variety of devices of different platforms, computational capacities and functionalities. The network heterogeneity and the ubiquity of IoT devices introduce increased demands on both security and privacy protection. IoT provides new services and applications that can be deployed in smart homes, transport applications, and for traceability in the food industry (Malina et al., 2016, pp. 2-37).

The Internet of Things (IoT) plays a vital role in improving traceability in the food industry. By utilizing sensors and connected devices, IoT enables real-time monitoring of the food supply chain from production, processing, distribution, to the end consumer. Data such as temperature, humidity, location, and delivery time can be recorded and analyzed to ensure the quality and safety of food products. This not only helps manufacturers maintain quality standards, but also provides transparency to consumers and facilitates the product recall process in the event of contamination or other issues. Thus, the application of IoT in traceability can improve operational efficiency, regulatory compliance, and market confidence in food products.

Last, data analytics and Artificial Intelligence (AI) play a crucial role in improving traceability in the food industry. By processing large amounts of data collected from various points in the supply chain, Data Analytics enables rapid and accurate identification of patterns, anomalies, and potential risks. Meanwhile, AI can be used to predict problems before they occur, such as product damage or distribution delays, and automate the decision-making process. The combination of the two provides complete visibility into the product journey, from raw materials to consumers. This supports

increased operational efficiency, compliance with food safety standards, and strengthens consumer trust in the transparency of the production process.

Regulatory differences among ASEAN countries

ASEAN member states exhibit significant diversity in their halal regulations and certification systems. Despite being in the same region, each country has its own culture which results in different perceptions, attitudes and values in each society. This statement is supported by research conducted by Rizaldy and Syifana which found that currently halal regulations between ASEAN countries are still very varied and inconsistent, both in terms of definition and authority institutions (Santosa & Rizaldy, 2022). For instance, the Malaysian, Indonesian, Brunei, Singaporean, and Standards and Metrology Institute for Islamic Countries (SMIIC) standards are similar but at the same time are different due to the differences in the Islamic schools of thought, especially on issues of labeling, stunning and slaughtering (Akbar et al., 2023, as cited in Rahman & Razak, 2024). Countries such as Malaysia, Indonesia, and Brunei Darussalam have well-established halal regulatory frameworks that are supported by nationally recognized certification bodies such as JAKIM, BPJPH, and MUIB.

In Indonesia, halal standards are regulated by laws including UU No. 33/2014 and Peraturan Pemerintah Nomor 39 Tahun 2021 that require halal certification for every food product to be marketed in Indonesia. Additionally, Indonesia's HAS 23201 focuses on the requirements for halal materials. Meanwhile, HAS 23103 provides guidelines for halal assurance systems in slaughterhouses (Rahman & Razak, 2024). These are further complemented by ministerial and agency-level regulations. The authority responsible for halal assurance in Indonesia is Badan Penyelenggara Jaminan Produk Halal (BPJPH), under the Ministry of Religious Affairs, in collaboration with Lembaga Pemeriksa Halal (LPH) and Majelis Ulama Indonesia (MUI), which issues fatwas.

In Malaysia, the national halal standard is established under MS 1500:2019, governed by Jabatan Kemajuan Islam Malaysia (JAKIM). These standard outlines comprehensive requirements for the production, handling, storage, and preparation of halal food, with emphasis on hygiene, safety, and compliance with Islamic law. Malaysia's halal certification is voluntary, but it is mandatory for products claiming to be halal. The Malaysian government made a regulation that all meat (beef, mutton, veal and poultry) imported to Malaysia must have halal certification and such meat should be processed only from meat plants approved by the Islamic Affairs Division of the Prime Minister's Department and the Department of Veterinary Services, Malaysia (Asa, 2019).

In Brunei Darussalam Standard for halal food has been laid down in PBD 24:2007, which emphasizes on the adherence to the Islamic law during the manufacture and certification of food (Akbar et al., 2023). Also, Brunei uses Certificate and Halal Label Order, 2005 to ensure all food and drink to be consumed by Muslim are 100% halal. The guidelines establish strict requirements covering the entire supply chain—from sourcing of ingredients to slaughtering, processing, storage, and food service. All halal-labeled products must comply with these regulations, and non-compliance is subject to legal penalties. Brunei has also established their halal certification system through Division of Halal Food Control under Islamic Religious Council of Brunei mainly to handle the problem of halal meat import and its related issues (Sa'adan & Pauzi, 2017)). The Halal

Food Control Division under the Ministry of Religious Affairs (MORA), supported by the Majlis Ugama Islam Brunei (MUIB), oversees both certification and enforcement. Importantly, the guidelines emphasize not only adherence to Islamic principles but also alignment with international food safety and hygiene practices, ensuring comprehensive halal integrity.

Diverse halal regulations across ASEAN create inconsistencies in certification requirements and compliance measures. Halal standards that differ in each country and based on the interests of policy makers create difficulties for business people and even for the future of the halal certification body itself (Islam et al. 2023). A unified halal standard could streamline the certification process and facilitate regional trade.

Technical and infrastructure barriers

The main challenge in implementing a traceability system is technical barriers and inadequate infrastructure. The technical obstacles that can be encountered are that business actors still face limitations in terms of technological devices and integrated information systems. The limitations of meat suppliers are that they do not have advanced electronic devices such as radio frequency identification (RFID) or any barcode system which are specifically for traceability purposes only and time spent by officers when checking documents is too long, because the method applied is still manual, both checking documents and physical inspection of goods (Rajie et al., 2023).

In the export and import of halal meat products, infrastructure challenges are one of the main obstacles that can disrupt the smooth supply chain. Supporting facilities such as ports, refrigerated warehouses, and logistics systems that comply with halal standards are often not available evenly, limited transportation infrastructure that does not support fast and safe delivery can lead to the risk of product quality degradation, which is very crucial for halal meat products. Halal has become the crucial thing when it comes to beef for the muslim, so that the traceability of cattle and beef is a high priority. During this period, the halal food trade is growing rapidly and unsafe factors are also increasing at the same time, for example, when this beef can be contaminated with non-halal ingredients such as pork or dog meat, ingredients that are not in accordance with Islamic law, and several other haram foods (Zhao et al., 2017). There was a lot of fraud in the export and import of halal meat products in falsifying halal certificates or supporting documents so that it could eliminate the integrity value of these activities. Therefore, it is important to have a traceable system that can be tracked and can contain important and detailed information to maintain the integrity of the product itself.

Consumer trust and transparency issues

Halal food is a major concern for consumers who prioritize halal aspects in their food choices (Maysyaroh, 2023, p. 3). The muslim community always maintains their lifestyle connected to their religious beliefs. For example, when they want to buy meat like beef, they prefer halal certified stores and they stay away from markets who sell different types of meat like pork.

Customer behaviors on decisions making in the food aspect led the market to bring halal labeled beef. This relates to a person's trust. Trust is an attitude that is clearly visible

from the quality provided by service providers or products (Islam et al., 2021, as cited in Maysyaroh, 2023). Trust describes a set of personal beliefs that a person feels about certain attributes (Maysyaroh, 2023, p. 3). Trust has a relationship with risk, and if customer attitudes and behavior get good thoughts about opportunities, it will increase customer trust (Wulandari et al., 2023).

Trust can be built by showing transparency to the customer. The implementation of technology such as blockchain, IoT and data analytics has been proposed as a solution to enhance traceability within the halal beef supply chain. This technology allows consumers to validate the beef from every stage starting from slaughter to distribution. By having a traceability system in the beef supply chain, we can significantly reduce consumers' doubt on the authenticity of halal beef. Securing halal is not only about the Muslim consumer alone; it also involves safety and quality matters, as well as the main component of the traceability system, the supply chain (Rajie et al., 2023).

However, applying a traceability system might be challenging since it would involve a number of partners, times, and countries. Consumers need to be provided with documentation and certificates to show actors in the stakeholders' integrity and responsibility to halal beef.

Enhancing consumer trust and addressing transparency issues are vital for the success of the halal beef supply chain in ASEAN countries. By applying technology such as blockchain and IoT, stakeholders can improve traceability and ensure that consumers have access to reliable information about the halal status of their food. This will not only foster greater confidence among consumers but also support sustainable practices within the food system in halal beef supply chain area.

Implementation of traceability systems in developed countries

As we can see in Table 1, the EU and Japan have their mandatory traceability. Australia and Brazil have plans for general mandatory traceability, but traceability is currently mandatory only for exported beef. Canada has a mandatory animal identification scheme for all animals before it is moved from its farm of origin. Argentina created a system that is only used for products originating from its own country. The United States arranges date traceability as voluntary (Souza-Monteiro & Caswell, 2004).

Table 1. Beef traceability system adoption in different countries

Country	System/Technology	Description	Source
EU	Voluntary Labeling System	The compulsory system requires that each beef label must include a reference number or code. Labels must also show the approval number and nationality of the slaughterhouse.	Souza-Monteiro and Caswell (2004)

Japan	Four levels of Japan's traceability : - An ear tag - DNA sample - Animal health and feeding information enciphered code - Muscle and offal derived 10 digit enciphered code	The traceability system will allow consumers to access information on animal production attributes such as date and place of birth, sex, breed, and production history.	Souza-Monteiro and Caswell (2004)
Australia	NLIS (National Livestock Identification System) traceability system	The NLIS system uses an electronic identification by ear tag or a rumen bolus, the system is precise to both the individual animal and geographical location.	Souza-Monteiro and Caswell (2004)
United States	Beef Export Verification (BEV)	Program that assures Asian buyers that products shipped overseas come from animals slaughtered in the United States	Souza-Monteiro and Caswell (2004)
Canada	Canadian Identification System (CFIA 2000)	A tag should be applied to the animals before it is moved from its farm of origin. It can be removed once from animals to be slaughtered but must notify the authorities within 30 days.	Souza-Monteiro and Caswell (2004)
Brazil	Identification technologies (Lewis)	Information on farm of origin, individual ID, month of birth or entry on farm, sex and aptitude (dairy or beef), system of production, movements, and sanitary data are recorded in the system and verified by certification entities.	Souza-Monteiro and Caswell (2004)
Argentina	Export Cattle Identification System	All animals have to bear a tag on the left ear with an individual and non-repeatable code, as well as an	Souza-Monteiro and Caswell (2004)

		identification of the farm where it was born.	

All of the countries have their own system and regulation on regulating circulation of beef to consumers, from farm to table. There are multiple ways traceability systems can be implemented in the food industry. It can be used depending on every country's needs. The system or technology must be enabled and capable to track and trace the required information efficiently at any given production point. ASEAN countries can start designing and developing their own traceability system to create a more reliable system for halal beef supply chain.

Potential ASEAN collaboration on halal traceability

Meat is one of the most sensitive products in terms of halal assurance because it has special conditions that must be carried out according to Islamic law, such as the slaughtering process. To ensure halal integrity, meat products traded in ASEAN must be fully traceable and clearly identifiable in terms of their halal status. The existence of a Halal traceability framework in ASEAN is essential to enable smooth and transparent cross-border trade, especially in halal meat. In the realm of halal supply chain management, information technology has been identified as one of the factors capable of increasing overall performance efficiency and expanding the supply chain network, such as the Traceability system-based algorithm (TS-Based Algorithm) which is used to optimize the distribution of halal products so as to provide a significant contribution to company performance by reducing transportation costs while ensuring the sustainability and authenticity of halal products (Harsanto et al., 2024). The application of modern technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain can significantly improve the traceability and efficiency of halal meat distribution across ASEAN.

Differences in halal standards, regulations, and certification authorities among ASEAN member states continue to pose challenges for businesses in the halal meat sector. Inconsistencies and differences in policies across countries often result in repetitive certification processes and multiple compliance requirements that increase costs and hinder regional trade. The implications of differences in halal standards can make Imbalance acknowledgement of halal certification (Sa'adan & Pauzi, 2017). For example, when importing halal food products into Indonesia, all halal products must be certified by a certification body by BPJPH. If only certified by foreign certification bodies, such as JAKIM and MUIB, the food product needs to be subject to further evaluation or additional halal audits in Indonesia before being accepted and allowed to include the official halal logo. Harmonizing halal standards and traceability systems is therefore a key strategy to reduce these barriers and promote intra-ASEAN halal meat trade.

One fundamental step towards this alignment is the formalization of the ASEAN Common Guidelines on Halal Food Preparation and Handling, which offers a voluntary but valuable starting point for harmonizing national systems. More importantly, potential collaboration among ASEAN halal certification bodies, such as JAKIM (Malaysia), BPJPH (Indonesia), MUIB (Brunei), MUIS (Singapore), and others, can drive real progress in standardizing

traceability mechanisms, particularly for meat products. This collaboration could include joint research, joint certification practices, and development of a unified halal traceability digital platform. This cooperation can also be expanded to include regional forums and institutions dealing with halal product assurance, livestock production, and food processing.

Cultural diversity and different interpretations of Islamic law across the region may pose obstacles to full integration. In addition, differences in regulatory capacity and halal awareness among ASEAN countries may slow progress. However, with strong political will and shared commitment, these obstacles can be overcome. By strengthening collaboration and harmonizing standards, ASEAN has the potential to become a globally competitive halal hub, especially in halal meat, supported by a trusted and transparent traceability system.

Gaps and potential halal traceability

Even though traceability systems have many benefits, applying the system itself in a disciplined way might be challenging. To consume a halal beef, a lot of actors are included in the supply chain such as supplier, producer, logistics, and consumers. Harrison and Hoek (2015, as cited in Iskandar, 2023) found the supply chain is a network that connects multiple parties who work together to transform basic commodities into finished products that add value to the product. To obtain a guaranteed halal meat progression along the supply chain is vital and by adopting the traceability system is helpful to control the supply chain from any non-halal element (Rajie et al., 2023).

Rajie et al. (2023) stated from the interviews that the challenges of the implementation mostly came from the tools and methods. Where it required a lot of time, and they didn't have any advanced electronic tools or any sort of barcode system that was specifically for traceability purposes only. In Indonesia, there is a limited amount of time to complete the country-wide certification process following the guidelines for animal slaughterhouses for both poultry and ruminants, making the gap bigger in traceability implementation.

Based on the analysis, implementation of the halal traceability system for beef feels so hard to apply, especially for some countries in the ASEAN due to their economic status. For cost, we can't deny the tools for traceability would make the related actors spend a bit more on any modern tools for traceability systems. Any lack of expertise in the information technology (IT) and digitalization fields in the company also becomes a challenge in implementing the halal traceability system in the company (Rajie et al., 2023). To ensure the beef halal traceability, producers or suppliers need to find expertise to do the work. However, this will also make the cost higher and make the company choose to implement a manual method compared to any modern method.

Briefly, there is a high chance that the company will have a better system to be implemented for halal beef. As majority ASEAN countries will prefer manual methods, there is a high probability where documents will overload and may lead to the problem. Companies need to reconsider their traceability system work because controlling documents involves more space and intervention. Making a modern system will be more reliable to apply in the ASEAN halal beef supply chain.

Conclusion

Ensuring halal integrity in the beef supply chain in the ASEAN region is critical, not only to fulfill religious obligations for Muslim consumers, but also to ensure food safety, quality, and sustainability. A robust halal traceability system enables meat to be traced from upstream to downstream, strengthening consumer confidence and facilitating cross-border trade. However, the implementation of such systems in ASEAN countries faces several challenges.

Differences in halal certification standards and regulations across ASEAN create repetitive audit and documentation requirements, increasing costs and time consuming. In addition, technical barriers such as limited technological devices, lack of integrated information systems across the supply chain, and reliance on manual inspection methods hinder the implementation of modern technology-based traceability systems. Many suppliers still do not use digital devices such as RFID or barcode systems, and the lack of IT expertise further complicates implementation.

Despite these challenges, the implementation of improved traceability systems by adopting more integrated technologies such as blockchain and IoT is critical to ensuring the safety, halalness, and quality of halal meat products in the ASEAN market and offers strong potential to improve supply chain efficiency, transparency, and control.

To move forward, ASEAN countries need to focus on harmonizing halal standards, encouraging cooperation between certification bodies, and developing a common digital platform for halal traceability and accelerating the process of integrating a more effective traceability system. If these technical barriers can be overcome with the support of technology, appropriate policies, and regional cooperation, ASEAN has the potential to become a more competitive halal trading hub at the global level, with a transparent and reliable traceability system.

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References

- Akbar, J., Gul, M., Jahangir, m., Adnan, M., Saud, S., Hassan, S., Nawaz, T., Fahad, S. (2023). Global Trends in Halal Food Standards: A Review. *Foods*, 12(23), 4200. <https://doi.org/10.3390/foods12234200>
- Aneesh A., K., & Siddiq, A. (2024). Behaviour of Muslim Consumer Towards Halal Food Products: A Review and Bibliometric Analysis. *International Journal of Halal Research*, 6(1), 36-46. <https://doi.org/10.18517/ijhr.6.1.36-46.2024>
- Al-Teinaz, Y., R., & Al-Mazeedi, H., M., M. (2020). *Halal Certification and International Halal Standards*. The Halal Food Handbook, 227–251. <https://doi.org/10.1002/9781118823026.ch15>

- Anggraini, W., Ciptono, W., S., Lusiantoro, L., Tjahjono, H., K. (2024). Lean Knowledge Management in The Adoption of Traceability Technology for Halal Perishable Food Supply Chain : A Systematic Literature Review. *Journal of Applied Engineering and Technological Science*, 5(2), 1119-1220. <https://journal.yrpioku.com/index.php/jaets/article/view/3611/2944>
- Asa, R., S. (2019). An Overview of The Developments of Halal Certification Laws in Malaysia, Singapore, Brunei and Indonesia. *Jurnal Syariah*, 27(1), 173-200. <https://malindojournal.um.edu.my/index.php/JS/article/view/19553/10374>
- ASEAN. (2019). Food Handling Publication Series No.1. ASEAN General Guidelines on The Preparation and Handling of Halal Food. <https://www.asean.org/wp-content/uploads/images/Community/AEC/AMAF/UpdateApr2014/ASEAN%20GENERAL%20GUIDELINES%20ON%20HALAL%20FOOD.pdf>
- Aung, T., S., Jasman, W., Alesandra, J., Johar, H., N., Hidayati, N., Ruslan, M., F. (2025). Halal Practices for Responsible Production and Consumption Towards Sustainable Future. *Halal Studies and Society*, 2(1), 1-3. <https://doi.org/10.29244/hass.2.1.1-3>
- Ezcaray, M., H., R., Olaizola, A., M., & Sanjuan, A., I. (2023). Exploring Consumers' Beef Preferences Using a Stated Method Approach: Disentangling Differences Throughout the Value Chain. *Mediterranean Journal of Economics, Agriculture, Environment and Food*, 3, 127-143. https://newmedit.ciheam.org/bup/wp-content/uploads/2023/09/3-451-New-Medit-3-2023_07-Exploring-consumers-1.pdf
- Harati, F., & Farzaneh, P. (2024). The Advancement in Global Halal Industry from Farm to Fork. *Journal of Halal Product and Research (JHPR)*, 7(2), 113-124. <https://dx.doi.org/10.20473/jhpr.vol.7-issue.2.113-124>
- Harsanto, B., Farras, J. I., Firmansyah, E. A., Pradana, M., & Apriliadi, A. (2024). Digital Technology 4.0 on Halal Supply Chain: A Systematic Review. *Logistics*, 8(1), 21. <https://doi.org/10.3390/logistics8010021>
- Islam, M. M., Talib, S. A., & Muhamad, N. (2023). Challenges of Halal Standards and Halal Certification for Islamic Marketing. *Muslim Business and Economic Review*, 2(1), 105-124. <https://doi.org/10.56529/mber.v2i1.156>
- Khan, S., Haleem, A., Khan, M., I., Abidi, M., A. (2018). Implementing Traceability Systems in Specific Supply Chain Management (SCM) through Critical Success Factors (CSFs). *Sustainability*, 10(2), 204. <http://dx.doi.org/10.3390/su10010204>
- Malina, L., Hajny, J., Fujdiak, R., Hosek, J. (2016). On Perspective of Security and Privacy-Preserving Solutions in the Internet of Things. *Computer Networks*, 2-37. <https://doi.org/10.1016/j.comnet.2016.03.011>
- Maysyaroh, S. (2023). General Risk on Trust, and The Intention to Recommend Halal Food: A Millennial Perspective. *Halal Tourism and Pilgrimage*, 3(1). <https://journals.smartinsight.id/index.php/HTP/article/download/265/245/820>
- Ng, P., C., Ruslan, N., A., S., A., Chin, L., X., Ahmad, M., Hanifah, S., A., Abdullah, Z.,

- Khor, S., M. (2021). Recent Advances in Halal Food Authentication: Challenges and strategies. *Journal of Food Science*, 87(1), 8-35. <https://doi.org/10.1111/1750-3841.15998>
- Pew Research Center. (2011, January 27). *The Future of the Global Muslim Population Region:Asia-Pacific*. <https://www.pewresearch.org/religion/2011/01/27/future-of-the-global-muslim-population-regional-asia/>
- Rahman, S., A., & Razak, N., I., A. (2024). Diverse Halal Standards in Malaysia, Indonesia, and Brunei: Their Effect on Regional Halal Food Trade Industry Development *International Journal of Academic Research in Business and Social Sciences*, 14(7), 2036-2043. <http://dx.doi.org/10.6007/IJARBSS/v14-i7/22141>
- Rajie, D., N., S., B., A., Sahari, N., H., & Samori, Z. (2023). Difficulties in Implementing The Halal traceability System Among Imported Halal Meat Suppliers. *International Journal of Advanced Research (IJAR)*, 11(10), 571-581. <http://dx.doi.org/10.21474/IJAR01/17743>
- Sa'adan, M., & Pauzi, N. (2017). The Implication of Differences in Halal Standard of Malaysia, Indonesia, Brunei and Singapore. *The Journal of Muamalat and Islamic Finance Research*, 14(2), 157–170. Retrieved from <https://jmifr.usim.edu.my/index.php/jmifr/article/view/24>
- Santosa, S. G., & Rizaldy, M. R. (2022). The Effect Of Halal Awareness, Religiosity, Product Ingredients Knowledge, And Halal Certification On The Purchase Decision Of Halal Fast Food. *Ar-Ribhu*, 3(1), 1-12. <https://doi.org/10.55210/arribhu.v3i1.804>
- Sayogo, D., S. (2018). Online Traceability for Halal Product Information: Perceptions of Muslim Consumers in Indonesia. *Journal of Islamic Marketing*, 9(1), 99–116. <https://doi.org/10.1108/JIMA-07-2016-0057>
- SEARCA & University Consortium. (2020). Safeguarding and Sustaining the Integrity of Halal Food. <https://www.searca.org/projects/research/safeguarding-sustaining-integrity-halal-food>
- Seifermann, S., Murti, I, H., Oberle, J. (2022). Tracking and Tracing in Manufacturing Supply Chains Using Blockchain Technology. *Procedia CIRP* 115, 172-177. <https://doi.org/10.1016/j.procir.2022.10.069>
- Wulandari, S. A., Sari, P. R., & Hadining, F. A. (2023). Analysis of Customer Behavior and Attitudes (General Risk) on Satisfaction, Trust and Halal Awareness towards Purchase Intention in Food Delivery Applications. *Journal of Management Dynamics*, 14(1), 99-110. <http://dx.doi.org/10.15294/jdm.v14i1.38386>
- Zhao, J., Chen, A., You, X., Xu, Z., Zhao, Y., He, W., Zhao, L., Yang, S. (2017). A Panel of SNPs Markers for Meat Traceability of Halal Beef in The Chinese Market. *Food Control*. 1-25. <https://doi.org/10.1016/j.foodcont.2017.11.039>

A Test for the Rockets and Feathers Effect and Double Marginalization: Market Power in the Philippine Rice Supply Chain

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Abstract

Rice is a vital agronomic, economic, and political commodity in the Philippines, which underwent major market liberalization following the enactment of the Rice Tariffication Law (RTL) in 2019. This study examines vertical price transmission in the rice supply chain, focusing on the dynamics between farmgate, wholesale, and retail prices, the influence of policy shifts, external shocks, and the distribution of market power. Using monthly data on rice prices and National Food Authority (NFA) stocks, the study employs both linear and non-linear Autoregressive Distributed Lag (ARDL) models with robustness checks. Findings reveal a significant negative seasonal effect on farmgate prices in October, aligned with peak harvest. NFA rice stocks exert downward pressure on farmgate prices, wholesale prices of well-milled rice, and retail prices of regular milled rice. Long-run price adjustments occur with varying speeds of adjustment: six months for farmgate prices, one to three months for wholesale prices, and three to five months for retail prices. External shocks, including typhoons, low rice stocks, the Russia–Ukraine conflict, India’s export ban on non-basmati rice, and the RTL, influenced domestic prices of paddy and milled rice. Evidence of double marginalization is observed, particularly in the well-milled rice market, where wholesalers exhibit increased market power and retailers display asymmetric pricing behavior consistent with the “rockets and feathers” effect. To improve price efficiency and competitiveness, the study recommends improving market information dissemination, strengthening market surveillance, expanding access to affordable rice, optimizing rice stock management, and bolstering disaster preparedness, response, and recovery efforts.

Keywords: asymmetric price transmission, double marginalization, rice tariffication law, rockets and feathers, seasonality

JEL code: Q11, Q17, Q18

SDG classification: SDG 2, SDG 12, SDG 13

Introduction

Rice is the staple food for 109 million Filipinos (Valera et al., 2022) and sustains the livelihoods of 2.4 million farmers (PSA, 2020, as cited by DA-PhilRice, 2025). From 2010 to 2024, the country produced an average of 18.60 million metric tons (mt) of paddy annually, with a growth rate of 1.46% per year (PSA, 2025). However, domestic production remains insufficient to meet demand, as rice accounts for one-third of the average caloric intake and 13.10% of household food expenditure (Valera et al., 2022). This supply gap has led to continued reliance on imports, with an import dependency ratio of 12.10% (PSA, 2025), placing the Philippines as the world's top rice importer in 2014 (UN, 2025).

The most consumed types of rice are regular milled rice (RMR) and well-milled rice (WMR). RMR contains 15% to 40% bran streaks in sample grains, while WMR contains less than 15% (DA PhilMech, 2020). According to the 2018 Family Income and Expenditure Survey, per capita consumption was 66.52 kilograms for RMR and 32.60 kilograms for WMR (PSA, 2021).

Significant policy reforms have reshaped the rice sector. The Rice Tariffication Law (RTL), or Republic Act (RA) 11203, enacted on February 14, 2019, liberalized the importation, exportation, and trading of rice (Official Gazette, 2025). It replaced quantitative restrictions with a tariff-based system aligned with WTO and ASEAN commitments, reducing tariff rates from 50% to 35%, and further to 15% under the Comprehensive Tariff Program signed on June 20, 2024 (Official Gazette, 2025). The RTL also established the Rice Competitiveness Enhancement Fund (RCEF), allocating Php 10 billion annually from 2019 to 2025 to support farmers through mechanization, seed development, credit, and extension services. Amendments of the RTL (RA 12078), signed on December 9, 2024, revised the allocation of RCEF funds, reducing support for farm machinery and seed development while increasing funding for programs such as training, credit, pest and disease management, soil health, composting, and contract farming (Official Gazette, 2025).

RA 12078 also strengthened the Department of Agriculture's (DA) regulatory role by mandating the registration and inspection of rice warehouses and storage facilities through the Bureau of Plant Industry (BPI), functions previously held by the National Food Authority (NFA), which maintains the national buffer stock sourced from local farmers (NFA, 2025). Prior to the RTL, the NFA held a monopoly over rice imports. Post-RTL, private importers may bring in rice without volume or timing restrictions, provided they obtain a Sanitary and Phytosanitary Import Clearance from the DA-BPI.

In cases of food security emergencies, the Department of Agriculture (DA), upon the recommendation of the National Price Coordinating Council (NPCC), may replenish the National Food Authority's (NFA) rice buffer stocks either through domestic procurement from local farmers or through imports. Additionally, the DA may impose a mandated price ceiling on rice under the authority of the Price Act of 1992 (RA 7581) (Official Gazette, 2025). In extreme market conditions, the President may also authorize rice importation or adjust import tariffs to stabilize supply and prices.

In response to various crises, the government implemented price controls aimed at stabilizing rice prices. For instance, a 60-day price freeze on basic necessities was declared on March 8, 2020, due to the COVID-19 pandemic. In September 2023, a one-

month mandated price ceiling was imposed on rice, setting the price of RMR at Php 41/kg and WMR at Php 45/kg. Additionally, suggested retail prices were used for imported rice, including Php 49/kg on March 1, 2025, and Php 45/kg on March 31, 2025 (DA 2025).

To enhance access to affordable rice, the Department of Agriculture (DA) implements two key initiatives: Program 29, which offers rice at Php 29/kg through government-operated Kadiwa farm-to-consumer stores, and the Rice-for-All Program, which provides well-milled rice at Php 40/kg, with a daily purchase limit of 25 kilograms (PIA, 2025).

In addition to policy shifts, external shocks—such as the occurrence of strong, destructive, or successive typhoons within a month, the onset of the Russia-Ukraine conflict in February 2022, and India's trade restrictions (including the July 2023 ban on non-basmati white rice exports and the August 2023 export tax on parboiled rice)—have the potential to disrupt domestic paddy and rice markets, affecting farmgate, wholesale, and retail prices as well as their dynamics.

This study applies the price transmission framework to examine how domestic paddy and milled rice markets are influenced by prices, seasonality, and shocks. Price transmission refers to the extent and speed at which a price shock in one market is passed on to another. It captures the magnitude and timing of these effects, the responsiveness of markets to both positive and negative shocks (i.e., symmetry or asymmetry), and the direction of the shock—from the source market to the destination market (Meyer & von Cramon-Taubadel, 2004; Rose & Paparas, 2023). Asymmetry in price transmission may take the form of the “rockets and feathers” effect, where prices rise rapidly like rockets but fall slowly like feathers, suggesting potential market inefficiencies such as the exercise of market power (Bacon, 1991).

Meyer and von Cramon-Taubadel (2004) explain that asymmetric vertical price transmission, can arise from factors such as market power, menu and adjustment costs, asymmetric information, and the stronger influence of retail demand shifts compared to farm-level supply responses. In the rice supply chain, such asymmetries may result in slower or incomplete transmission of wholesale or retail price decreases, thereby disadvantaging either farmers or consumers. Additionally, double marginalization occurs when both wholesalers and retailers, exercising market power, impose markups at different stages, leading to high retail prices or low farmgate prices.

This study aims to: (1) analyze the dynamics between domestic paddy and milled rice prices; (2) evaluate the effects of policy changes and external shocks on price transmission; and (3) assess the distribution of market power across the rice supply chain.

Previous studies on rice price transmission in the Philippines—such as Mangahas et al. (1966), Umali and Duff (1992), Silvapulle and Jayasuriya (1994), Baulch (1997), Reeder (2000), Rufino (2011), Chien et al. (2011), Ghoshray (2011), Baquedano and Liefert (2014), Chaudhary et al. (2019), Briones (2019), and Cuevas (2019)—highlight important gaps in data coverage and methodology. Most relied on datasets only up to 2018, while this study extends the analysis through December 2024 to capture the post-Rice Tariffication Law (RTL) period. Unlike earlier works that focused on either regular or well-milled rice, this study covers both. It also addresses limitations in previous models by accounting for seasonal unit roots, structural breaks from policy shifts and external

shocks, and by applying robustness checks that address concerns of serial correlation, endogeneity, and potential asymmetries across different quantiles.

This study provides an evidence-based evaluation of past policies in stabilizing domestic prices—measures with significant welfare implications for both paddy farmers and rice consumers—and offers recommendations to strengthen effective policies and mitigate the impact of major external shocks. It also presents policy recommendations for the DA, NFA, NPCC, Philippine Competition Commission (PCC), and the legislative branch, particularly in the context of implementing the Rice Tariffication Law (RTL), responding to food security emergencies, and addressing potential anti-competitive behavior in the rice supply chain.

The remainder of the paper outlines the theoretical and conceptual frameworks, data sources, and analytical procedures used, followed by the presentation of results, discussion, conclusion, and policy recommendations.

Methodology

Theoretical framework

This study is grounded in the Law of One Price (LOP), which explains how prices should behave in efficient markets. In the strong form of the LOP, the same good should sell at the same price in different places if there are no barrier to trade (Clements et al. 2023). In such markets, price differences between stages of the supply chain are removed through arbitrage, leading to uniform pricing. However, the weak form of the LPP allows for some variation in prices, provided these differences are within the limits of processing, distribution, and other marketing costs and reflect short-term market imperfections (Baulch 1997; Fackler and Goodwin 2001; Kidane 2022; von Cramon-Taubadel and Goodwin 2021).

The study also applies the Theory of Derived Demand, which suggests that the demand for an input or intermediate good depends on the demand for the final product (Yeung 1972). For example, the demand for paddy depends on how much milled rice is demanded, and the demand for farm inputs depends on the demand for paddy. Gardner (1975) formalized the mathematical relationships between primary and derived supply and demand in a competitive equilibrium. These relationships are captured by the elasticity of price transmission (EPT), which varies based on whether the price shock comes from demand for final good, supply of input or intermediate good, or marketing costs.

The EPT when there is a change in the demand for the final product (x) is:

$$E_{P_x P_a} = \frac{S_b e_a + S_a e_b + \sigma}{e_b + \sigma} \quad (1)$$

The EPT when there is a change in the supply of input or intermediate good (a) is:

$$E_{P_x P_a} = \frac{S_a (e_b + \sigma)}{e_b + S_a \sigma - S_b \eta} \quad (2)$$

The EPT when there is a change in the supply of marketing inputs (b) is:

$$E_{P_x P_a} = \frac{\sigma + e_a}{\sigma + \eta} \quad (3)$$

Economic theory explains how price transmission behaves in response to changes in supply and demand across different market levels. First, the cost shares of input or intermediate goods and marketing inputs must sum to one. Second, these inputs are either perfect complements or substitutes and typically exhibit positive own-price elasticities of supply. Lastly, demand for the final good generally decreases as its price increases (Gardner, 1975; Kinnucan, 2022).

Kinnucan and Zhang (2005) extended Gardner's framework by incorporating the effects of technological change. Under Hicks-neutral technological change, where all inputs benefit equally, the elasticity of price transmission (EPT) depends on the supply elasticities of the input and marketing inputs, their respective cost shares, the elasticity of substitution, and the price elasticity of demand for the final product. In contrast, under input-biased technological change, where some inputs are favored over others, the EPT primarily depends on the supply elasticities, the share of marketing inputs, and the demand elasticity.

Conceptual framework

Figure 1 shows how prices move through the Philippine rice supply chain, from the farm level (upstream) to the retail level (downstream). Domestic prices are influenced by domestic policies, weather disturbances, and exogenous events. These influences can change how prices are passed along the supply chain, affecting both the size and timing of price changes before and after a shock occurs.

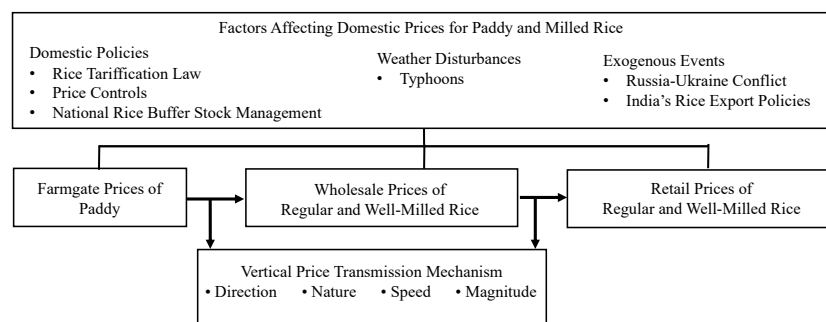


Figure 1. Vertical price transmission and determinants of domestic prices in the Philippine rice supply chain

The implementation of the RT is expected to lower farmgate prices by increasing competition from imported rice. On the other hand, external shocks such as typhoons, low NFA rice stock levels, the Russia-Ukraine conflict, and India's restrictions on rice exports may raise farmgate prices by disrupting supply and creating uncertainty. At the wholesale and retail levels, both the RTL and price control policies are expected to lower prices. However, the same external shocks may lead to higher wholesale and retail prices, especially as the Philippines becomes more dependent on imported rice.

The effect of NFA rice stock levels may also change over time. In the short run, stock levels may affect prices differently than in the long run, due to the time gap between buying paddy from farmers and releasing NFA rice for public consumption.

Data sources

This study utilized monthly time series data from January 2010 to December 2024, covering farmgate prices of paddy (other variety, 14% moisture content), as well as wholesale and retail prices of regular and well-milled rice. All prices are expressed in Philippine pesos per kilogram (Php/kg). Data on National Food Authority (NFA) rice stocks, measured in metric tons (mt), were also included. These datasets were sourced from the Philippine Statistics Authority (PSA) through its OpenSTAT platform. To validate and enrich the empirical findings, secondary data were gathered from government reports, academic literature, news articles, and expert commentaries.

Analytical procedures

Splicing technique was employed to combine the old series (January 2010 to December 2020), 2012 series (January 2012 to December 2021), and 2018 series (January 2018 to December 2024) for retail prices. Descriptive analysis was conducted using measures of central tendency and dispersion, along with the Jarque-Bera test for normality, and correlation and covariance analyses. To assess unit roots and stationarity, both constant and constant-plus-trend models were employed for the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. Deterministic and stochastic seasonality were examined using the Hylleberg, Engle, Granger, and Yoo (HEGY) test and the Canova-Hansen (CH) test. Significant seasonal dummy variables identified through the CH test were included in both the multiple breakpoint analysis and the vertical price transmission model.

Structural breaks were identified using the Global Bai-Perron multiple breaks method, which estimates a linear regression model with constant and deterministic seasonal dummy variables. The model employed heteroskedasticity and autocorrelation consistent (HAC) standard errors and covariances, with pre-whitening based on lag selection using the Schwarz Information Criterion (SIC). Test statistics were computed using the Quadratic-Spectral kernel and Andrews' automatic bandwidth selection. Breakpoints were endogenously determined using 10% and 15% trimming guided by the Liu-Wu-Zidek (LWZ) information criterion.

The direction of price transmission was analyzed using the Toda-Yamamoto (TY) Granger non-causality test to infer which variables serve as dependent or independent in the system. If the variables were integrated of the same order, a Vector Autoregressive (VAR) model was estimated. When variables were integrated of order one and cointegration was confirmed through the Johansen test, a Vector Error Correction Model (VECM) was estimated. To further assess the degree of exogeneity or endogeneity of each variable, the Generalized Impulse Response Function (GIRF) and Generalized Forecast Error Variance Decomposition (GFEVD) were used to supplement the TY test results.

The Autoregressive Distributed Lag (ARDL) model was also employed due to its flexibility in handling a mix of $I(0)$ and $I(1)$ series and its ability to estimate both short-run dynamics

and long-run relationships in a single-equation framework. Following a general-to-specific approach, the linear ARDL(p, q) cointegration model developed by Pesaran and Shin (1999) and Pesaran, Shin, and Smith (2001) was specified as follows:

$$Y_t = \alpha_0 + \sum_{i=1}^p \beta_i Y_{t-i} + \sum_{j=0}^q \delta_j X_{t-j} + \gamma D_t + \epsilon_t \quad (4)$$

where:

Y_t = dependent variable at time t,

X_t = vector of independent variables at time t,

D_t = vector of dummy variables, including seasonal dummy variables and structural breaks, at time t,

α_0 = constant term,

β_i = coefficients for lagged dependent variable (with p lags),

δ_i = coefficients for lagged independent variable (with q lags),

γ = coefficients for dummy variables,

ϵ_t = error term at time t, assumed to be independent and identically distributed.

The linear ARDL in Error Correction Model (ECM) form and the Error Correction Term (ECT) are mathematically expressed as follows:

$$\Delta Y_t = \delta_0 + \sum_{i=1}^{p-1} \phi_i \Delta Y_{t-i} + \sum_{j=0}^{q-1} \theta_j \Delta X_{t-j} + \Omega \Delta D_t + \lambda(ECT_{t-1}) + u_t \quad (5)$$

where:

Δ = first difference operation,

δ_0 = constant term in ECM form,

ϕ_i , θ_j , and Ω = short-run dynamic coefficients,

ECT_{t-1} = error correction term (i.e., lagged residual from the long-run relationship),

λ = coefficient of the ECT, and

u_t = white noise error term.

To test for asymmetric relationships between independent and dependent variables, the specification by Shin, Yu, and Greenwood-Nimmo (2014) was used, decomposing the independent variable (X) into positive and negative changes.

The speed of price adjustment, measured in months, is calculated as -1 divided by the coefficient of the Error Correction Term (ECT). For the system to be stable and converge to long-run equilibrium, the ECT coefficient must be negative and statistically significant. This reflects how quickly prices return to equilibrium after a short-term shock.

Cointegration in the ARDL model was tested using the F-Bounds test to identify long-run relationships and the t-Bounds test to determine whether the equilibrium relationship is meaningful (Pesaran & Shin, 1999; Pesaran, Shin, & Smith, 2001). Wald tests were

used to assess both short-run and long-run asymmetries, following Shin et al. (2014) and Kamaruddin et al. (2021). Asymmetry in speed occurs when response timing differs by the sign of the shock, while asymmetry in magnitude refers to differences in transmission elasticities depending on whether the price change is positive or negative.

Model diagnostics were performed for both linear and non-linear ARDL models using the Jarque-Bera test for normality, Breusch-Godfrey LM test for autocorrelation, White's test for heteroskedasticity, Ramsey RESET for model specification errors, and CUSUM and CUSUM of Squares tests for parameter stability. Wald tests were also applied to confirm asymmetries.

If any diagnostic tests failed, alternative estimators were used. These included Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) to address endogeneity and serial correlation, and Quantile Regression (QR) to explore heterogeneous effects across different points of the conditional distribution.

Results and Discussion

Table 2 presents the descriptive statistics for farmgate prices of paddy, wholesale and retail prices of regular and well-milled rice, and NFA rice stocks. Based on the coefficient of variation (CV), farmgate prices exhibit the highest degree of fluctuation, while retail prices are relatively more stable. This pattern is consistent with economic theory and empirical evidence, which suggest that both the supply and demand at the farm level are more inelastic—particularly in the short run—compared to the retail level, where supply and demand tend to be more elastic. As a result, farmgate prices are more responsive to shocks, whereas retail prices are stickier. Wholesale prices also display significant fluctuations, indicating the presence of shocks between 2010 and 2024 that impacted wholesale markets. Among all the variables, NFA rice stocks show the highest coefficient of variation, reflecting the volatility in national rice buffer stock management, particularly in response to the RTL and other major policy reforms.

Table 2. Domestic paddy and milled rice prices and NFA rice stocks, Philippines, January 2010-December 2024

Descriptive Statistics	FP	WP-RMR	WP-WMR	RP (Old) - RMR	RP (Old) - WMR	RP (2012) - RMR	RP (2012) - WMR	RP (2018) - RMR	RP (2018) - WMR	NFA
Unit of Measurement	Php/kg	Php/kg	Php/kg	Php/kg	Php/kg	Php/kg	Php/kg	Php/kg	Php/kg	mt
Mean	17.755	34.690	38.168	35.766	39.889	38.580	42.346	42.030	46.534	529,658.400
Median	17.510	34.315	38.160	36.570	41.575	39.165	42.845	40.030	44.280	445,642.000
Maximum	25.030	47.690	50.860	45.570	48.970	46.190	49.830	51.250	56.440	2,037,400.000
Minimum	13.850	27.870	30.920	30.530	34.100	32.680	35.970	38.100	42.660	2,076.000
Std. Dev.	2.333	4.558	4.679	3.336	3.760	2.766	2.908	4.191	4.381	485,631.300
CV (%)	13.143	13.138	12.259	9.328	9.427	7.170	6.867	9.970	9.414	91.688
Skewness	1.088	1.015	0.817	0.044	(0.275)	(0.232)	(0.545)	1.087	1.252	1.388
Kurtosis	4.340	3.987	3.781	2.486	1.913	3.324	3.336	2.797	3.069	4.357
Jarque-Bera	48.953	38.187	24.605	1.496	8.164	1.607	6.514	16.697	21.950	71.592
Probability	0.000	0.000	0.000	0.473	0.017	0.448	0.038	0.000	0.000	0.000
Observations	180,000	180,000	180,000	132,000	132,000	120,000	120,000	84,000	84,000	180,000
Source of basic data: PSA (2025)										

Farmgate, wholesale, and retail prices exhibit strong positive correlations with each other and negative correlations with NFA rice stocks, ranging from 0.60 to 0.99 in their original form and from 0.67 to 0.99 in the log-transformed series. Additionally, the covariance between NFA rice stocks and domestic prices is relatively high (0.10), suggesting fluctuations in buffer stock levels are negatively associated with changes in market prices.

Table 3 shows fixed seasonal patterns in domestic prices. Farmgate prices are generally lower in September and October, coinciding with the main harvest season. According to USDA-FAS (2021), about 20% of annual paddy production occurs from July to September, and 40% from October to December. Wholesale prices tend to peak in August during the final planting season (July–September) in major producing regions like Central Luzon and Ilocos Norte but decline in October and November as harvesting begins. Retail prices follow a similar seasonal pattern—rising in August and September and falling in October—closely reflecting farmgate and wholesale price movements.

Table 3 also identifies potential structural breaks occurring in specific months of 2012, 2013, 2017, 2018, 2019, 2022, and 2023. The significance of these breakpoints, along with the seasonal dummy variables, will be validated in the subsequent vertical price transmission models.

Table 3. Deterministic seasonality and structural breaks of the series

Dependent Variable	Seasons	10%	15%
LNFP	9, 10	3: 2013M07 (+), 2019M05 (-), 2023M07 (+)	3: 2013M07 (+), 2019M06 (-), 2022M10 (+)
LNWP - RMR	10, 11	3: 2013M08 (+), 2019M06 (-, ns), 2023M07 (+)	2: 2013M08 (+), 2022M10 (+, ns)
LNWP - WMR	8, 10	4: 2013M08 (+), 2017M11 (+), 2019M05 (-), 2023M07 (+)	2: 2013M09 (+), 2022M10 (+, ns)
LNRP - RMR	8, 10	4: 2013M08 (+), 2017M12 (+), 2019M06 (-), 2023M07 (+)	2: 2013M09 (+), 2022M10 (+, ns)
LNRP - WMR	9, 10	4: 2013M09 (+), 2018M01 (+, ns), 2019M07 (-, ns), 2023M07 (+)	4: 2013M09 (+), 2017M06 (+, ns), 2019M09 (-, ns), 2022M10 (+, ns)
LNFA	none	4: 2012M02 (-), 2017M07 (-), 2019M02 (+, ns), 2022M03 (-)	4: 2012M05 (-), 2017M02 (-), 2019M05 (+, ns), 2022M03 (-)

Based on the TY test, as well as the generalized IRF and FEVS, the results indicate that NFA rice stocks influence farmgate prices, while farmgate and retail prices affect wholesale prices of regular milled rice. Additionally, NFA rice stocks, farmgate prices, and wholesale prices impact retail prices of well-milled rice. These vertical relationships are detailed in Tables 4 to 9. The consistent upstream-to-downstream flow of price transmission in well-milled rice supports the investigation for double marginalization in the supply chain.

ARDL estimation and robustness checks reveal that only farmgate prices exhibit strong seasonality, particularly in October. These prices are positively influenced by Typhoon Isang and the enhanced southwest monsoon in July 2013, three typhoons and reduced rice imports in October 2022, as well as the delayed impact of the Russia-Ukraine conflict. Wholesale and retail prices of regular milled rice (RMR) are positively affected by the four typhoons in August 2013, while wholesale RMR prices also respond to two typhoons, India's rice export ban, and low rice stocks in July 2023. Similarly, wholesale prices of well-milled rice (WMR) reflect these same events. In contrast, the Rice Tariffication Law (RTL) had a negative impact on farmgate prices in June 2019 and wholesale RMR prices in July 2019, but did not result in lower prices for the higher-quality WMR. In the long run, it takes one month for wholesale prices of WMR, three months for wholesale and retail prices of WMR, five months for retail prices of RMR, and six months for farmgate prices to return to equilibrium after a short-run shock.

There is positive asymmetric transmission from NFA rice stocks to farmgate prices (Table 4). In the short run, higher NFA stocks raise farmgate prices as government paddy procurement supports low market prices. However, in the long run, the effect becomes negative, with farmers more responsive to stock increases than decreases. A similar pattern is observed for retail prices of RMR (Table 7), where short-run increases in NFA stocks initially raise prices, followed by declines as stocks are released. In the long run, NFA stocks negatively affect retail RMR prices, with retailers also more sensitive to stock increases. For wholesale prices of WMR, price transmission is symmetric, with positive short-run effects and a negative long-run impact from NFA rice stocks.

Table 4. Asymmetric transmission from NFA rice stocks to farmgate prices

Dependent Variable: D(LNFP)									
Selected Model: ARDL(4, 3, 0)									
Case 3: Unrestricted Constant and No Trend									
Sample: 2010M01 2024M12									
Included observations: 176									
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Estimates					Short-Run Estimates				
C	0.503	0.084	6.010	0.000	C	0.503	0.069	7.249	0.000
LNNFA_POS	(0.055)	0.021	(2.637)	0.009	D(LNNFA_POS(-1))	0.020	0.007	2.939	0.004
LNNFA_NEG	(0.035)	0.015	(2.372)	0.019	D(LNNFA_POS(-2))	0.022	0.007	3.162	0.002
@SEAS(9)	(0.046)	0.007	(6.713)	0.000	@SEAS(9)	(0.046)	0.007	(6.827)	0.000
@SEAS(10)	(0.045)	0.007	(6.190)	0.000	@SEAS(10)	(0.045)	0.007	(6.233)	0.000
B2013M07	0.030	0.007	4.187	0.000	B2013M07	0.030	0.007	4.483	0.000
B2019M06	0.013	0.014	0.975	0.331	B2019M06	0.013	0.005	2.562	0.011
B2022M10	0.043	0.008	5.073	0.000	B2022M10	0.043	0.008	5.378	0.000
					CointEq(-1)*	(0.180)	0.025	(7.133)	0.000

Table 5. Price transmission from farmgate to wholesale prices of regular milled rice

Dependent Variable: LNWP												
Method: Quantile Regression												
Sample: 2010M01 2024M12												
Included observations: 180												
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
	(tau = 0.05)				(tau = 0.51)				(tau = 0.96)			
C	1.168	0.183	6.369	0.000	1.697	0.126	13.514	0.000	1.926	0.153	12.566	0.000
LNFP	0.800	0.066	12.079	0.000	0.615	0.046	13.470	0.000	0.538	0.056	9.658	0.000
@SEAS(10)	0.040	0.007	5.520	0.000	0.017	0.008	2.250	0.026	0.053	0.035	1.521	0.130
@SEAS(11)	0.036	0.006	6.277	0.000	0.015	0.006	2.372	0.019	0.009	0.009	0.992	0.323
B2013M08	0.030	0.012	2.585	0.011	0.071	0.008	8.519	0.000	0.136	0.030	4.516	0.000
B2019M06	0.026	0.006	4.182	0.000	0.022	0.005	4.246	0.000	(0.024)	0.026	(0.916)	0.361
B2023M07	0.030	0.013	2.363	0.019	0.091	0.019	4.758	0.000	0.112	0.016	6.855	0.000

Table 6. Price transmission from retail to wholesale prices of regular milled rice

Dependent Variable: D(LNWP)									
Selected Model: ARDL(6, 1)									
Case 3: Unrestricted Constant and No Trend									
Sample: 2010M01 2024M12									
Included observations: 174									
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Estimates					Short-Run Estimates				
C	0.216	0.125	1.727	0.086	C	0.216	0.027	7.947	0.000
LNRP	0.897	0.051	17.725	0.000	D(LNWP(-1))	(0.019)	0.076	(0.252)	0.801
@SEAS(10)	(0.011)	0.006	(1.859)	0.065	D(LNWP(-2))	0.092	0.061	1.514	0.132
@SEAS(11)	(0.014)	0.006	(2.358)	0.020	D(LNWP(-3))	0.168	0.060	2.824	0.005
B2013M08	0.017	0.008	2.193	0.030	D(LNWP(-4))	0.148	0.059	2.507	0.013
B2019M06	(0.014)	0.004	(3.394)	0.001	D(LNWP(-5))	0.145	0.058	2.508	0.013
B2023M07	0.026	0.011	2.432	0.016	D(LNRP)	0.887	0.103	8.634	0.000
					@SEAS(10)	(0.011)	0.006	(1.866)	0.064
					@SEAS(11)	(0.014)	0.006	(2.372)	0.019
					B2013M08	0.017	0.005	3.604	0.000
					B2019M06	(0.014)	0.004	(3.405)	0.001
					B2023M07	0.026	0.007	3.878	0.000
					CointEq(-1)*	(0.748)	0.095	(7.890)	0.000

Table 7. Asymmetric transmission from NFA rice stocks and price transmission from farmgate to retail prices of regular milled rice

Dependent Variable: D(LNRP)									
Selected Model: ARDL(1, 2, 4, 1)									
Case 3: Unrestricted Constant and No Trend									
Sample: 2010M01 2024M12									
Included observations: 175									
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Estimates					Short-Run Estimates				
C	0.484	0.097	4.983	0.000	C	0.484	0.062	7.846	0.000
LNFP	0.495	0.084	5.915	0.000	D(LNFP)	0.005	0.027	0.173	0.863
LNNFA_POS	(0.039)	0.011	(3.434)	0.001	D(LNFP(-1))	0.146	0.033	4.425	0.000
LNNFA_NEG	(0.029)	0.008	(3.753)	0.000	D(LNNFA_POS)	(0.012)	0.004	(3.478)	0.001
@SEAS(8)	0.003	0.003	0.987	0.325	D(LNNFA_POS(-1))	0.018	0.003	5.700	0.000
@SEAS(10)	(0.003)	0.003	(0.886)	0.377	D(LNNFA_POS(-2))	0.013	0.003	4.124	0.000
B2013M08	0.019	0.005	3.976	0.000	D(LNNFA_POS(-3))	(0.006)	0.003	(1.792)	0.075
B2017M12	0.004	0.006	0.666	0.506	D(LNNFA_NEG)	0.018	0.007	2.499	0.014
B2019M06	0.018	0.007	2.722	0.007	@SEAS(8)	0.003	0.003	1.018	0.310
B2023M07	0.243	0.104	2.343	0.020	@SEAS(10)	(0.003)	0.003	(0.905)	0.367
B2023M07*LNFP	(0.069)	0.034	(2.039)	0.043	B2013M08	0.019	0.003	5.605	0.000
					B2017M12	0.004	0.004	0.990	0.324
					B2019M06	0.018	0.004	4.006	0.000
					B2023M07	0.243	0.093	2.607	0.010
					B2023M07*LNFP	(0.069)	0.030	(2.315)	0.022
					CointEq(-1)*	(0.228)	0.029	(7.850)	0.000

Table 8. Transmission from NFA rice stocks and price transmission from farmgate to wholesale prices of well-milled rice

Dependent Variable: D(LNWP)									
Selected Model: ARDL(1, 1, 3, 5)									
Case 3: Unrestricted Constant and No Trend									
Sample: 2010M01 2024M12									
Included observations: 175									
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Estimates					Short-Run Estimates				
C	0.677	0.119	5.664	0.000	C	0.677	0.083	8.181	0.000
LNFP	0.586	0.077	7.568	0.000	D(LNFP)	0.221	0.023	9.755	0.000
LNNFA	(0.009)	0.005	(1.706)	0.090	D(LNFP(-1))	0.105	0.029	3.640	0.000
@SEAS(8)	0.006	0.003	2.242	0.026	D(LNFP(-2))	(0.042)	0.024	(1.743)	0.083
@SEAS(10)	0.005	0.003	1.834	0.069	D(LNNFA)	0.002	0.002	1.014	0.312
B2013M08	0.024	0.005	4.710	0.000	D(LNNFA(-1))	0.003	0.002	1.307	0.193
B2017M11	0.004	0.004	0.906	0.366	D(LNNFA(-2))	0.005	0.002	2.532	0.012
B2019M05	0.168	0.067	2.518	0.013	D(LNNFA(-3))	(0.004)	0.002	(1.810)	0.072
B2023M07	0.043	0.007	6.435	0.000	D(LNNFA(-4))	(0.005)	0.002	(2.208)	0.029
B2019M05*LNFP	(0.059)	0.023	(2.548)	0.012	@SEAS(8)	0.006	0.002	2.275	0.024
					@SEAS(10)	0.005	0.003	1.877	0.062
					B2013M08	0.024	0.003	6.940	0.000
					B2017M11	0.004	0.003	1.493	0.137
					B2019M05	0.168	0.049	3.398	0.001
					B2023M07	0.043	0.006	6.678	0.000
					B2019M05*LNFP	(0.059)	0.017	(3.368)	0.001
					CointEq(-1)*	(0.339)	0.041	(8.185)	0.000

Table 9. Price transmission from farmgate and wholesale to retail prices of well-milled rice

Dependent Variable: D(LNRP)									
Selected Model: ARDL(1, 2, 3, 0)									
Case 3: Unrestricted Constant and No Trend									
Sample: 2010M01 2024M12									
Included observations: 176									
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Estimates					Short-Run Estimates				
C	1.291	0.162	7.949	0.000	C	1.291	0.152	8.465	0.000
LNFP	(0.073)	0.055	(1.317)	0.190	D(LNFP)	(0.035)	0.021	(1.658)	0.099
LNWP_POS	0.944	0.100	9.458	0.000	D(LNFP(-1))	0.084	0.020	4.201	0.000
LNWP_NEG	0.874	0.108	8.073	0.000	D(LNWP_POS)	0.413	0.053	7.841	0.000
@SEAS(9)	0.003	0.002	1.607	0.110	D(LNWP_POS(-1))	0.321	0.056	5.710	0.000
@SEAS(10)	(0.004)	0.002	(1.746)	0.083	D(LNWP_POS(-2))	(0.146)	0.044	(3.297)	0.001
B2013M09	0.006	0.004	1.597	0.112	@SEAS(9)	0.003	0.002	1.632	0.105
B2018M01	(0.005)	0.003	(2.105)	0.037	@SEAS(10)	(0.004)	0.002	(1.792)	0.075
B2019M07	0.001	0.003	0.384	0.702	B2013M09	0.006	0.002	3.635	0.000
B2023M07	0.009	0.004	2.217	0.028	B2018M01	(0.005)	0.002	(3.107)	0.002
					B2019M07	0.001	0.002	0.672	0.502
					B2023M07	0.009	0.002	4.790	0.000
					CointEq(-1)*	(0.347)	0.041	(8.470)	0.000

Table 5 shows declining price transmission elasticities from retail to wholesale RMR prices across higher quantiles, indicating greater wholesaler market power at higher prices. Table 6 adds that wholesale prices are influenced by retail prices and their own five-month lags, suggesting price inertia. The low farm-to-wholesale elasticity for WMR (0.59), which drops further post-RTL (-0.06), points to excessive wholesaler markups (Table 7). Meanwhile, asymmetric transmission from wholesale to retail prices (0.97 for increases vs. 0.87 for decreases) suggests retailer pricing power consistent with the “rockets and feathers” effect. These coefficients are even lower based on the median QR estimates (0.87 for increases and 0.76 for decreases). These patterns reflect double marginalization, where both wholesalers and retailers apply independent markups, leading to compounded price increases for consumers.

Conclusion

Rice is a key staple in the Philippines, significantly impacted by policy reforms such as the RTL enacted in 2019. This study examined vertical price transmission within the rice supply chain using ARDL models, revealing that NFA stocks lower prices at all levels, with seasonal and external shocks influencing price dynamics. Price adjustments vary in speed across market segments, and evidence of double marginalization—particularly in the well-milled rice market—points to market power among wholesalers and retailers, with the latter exhibiting asymmetric pricing behavior consistent with the “rockets and feathers” effect.

This study highlights the market power of wholesalers and retailers in the rice supply chain, particularly for well-milled rice. To help farmers respond effectively, the DA's Bantay Presyo program should be strengthened to ensure timely and accessible market information.

To protect both farmers and consumers, the PCC should investigate both wholesalers and large retailers to identify and penalize entities engaging in unfair trade practices. At the same time, the DA, in coordination with the Department of Trade and Industry (DTI), should strengthen market surveillance to ensure compliance with fair pricing and quality standards.

Given evidence of double marginalization in the WMR supply chain, expanding access to affordable rice is essential. Scaling up the Rice-for-All program can protect consumers from excessive markups while improving food security. Strengthened market surveillance can ensure a steady supply of affordable rice by preventing price manipulation, hoarding, and cartel-like practices.

Given the significant impact of NFA rice stocks on domestic prices, it is important to reconsider the policy that removed the NFA's market intervention role. While the NFA has faced inefficiencies in the past, its historical experience may still make it better suited to perform these functions. A thorough assessment of the DA's capacity, compared to the NFA, is essential to determine the most effective approach.

Given the substantial impact of typhoons on rice prices, it is crucial to ensure that early warning systems are effectively communicated to farmers. In times of food security emergencies or when price freezes and ceilings are imposed, Local Price Coordinating Councils should be mobilized in coordination with the National Price Coordinating Council (NPCC). Additionally, swift post-disaster recovery efforts are essential to mitigate prolonged upward pressures on paddy and milled rice prices.

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References

- Bacon, R. W. (1991). Rockets and feathers: The asymmetric speed of adjustment of UK retail gasoline prices to cost changes. *Energy Economics*, 13(3), 211–218.
- Baquadano, F. G., & Liefert, W. M. (2014). Market integration and price transmission in consumer markets of developing countries. *Food Policy*, 44, 103–114.
- Baulch, B. (1997). Transfer costs, spatial arbitrage, and testing for food market integration. *American Journal of Agricultural Economics*, 79(2), 477–487.
- Briones, R. M. (2019). *Competition in the rice industry: An issues paper* (PCC Issues Paper No. 1, pp. 1–35). Philippine Competition Commission.
- Chaudhary, B., Morales, L. E., & Villano, R. (2019, February 12–15). *Rice price transmission between wholesalers and retailers in the Philippines: Are prices integrated in local markets?* Paper presented at the 63rd Australasian Agricultural and Resource Economics Society Conference, Melbourne, Australia.
- Chien, L. H., Jatuporn, C., & Naretto, O. M. C. (2011). Price analysis of domestic rice market in the Philippines. *The Empirical Economics Letters*, 10(7), 639–646.
- Clements, K., Sei, J. W., & Vo, H. L. (2023). The law of one food price. *Open Economies Review*, 34, 195–216.
- Cuevas, A. C. (2019). The effect of NFA buffer stocks on the retail price of rice in the Philippines. *Journal of Economics, Management and Agricultural Development*, 5(1), 55–76.
- DA [Department of Agriculture]. (2025). DA to cut further MSRP on imported rice to P45/kilo. <https://www.da.gov.ph/da-to-cut-further-msrp-on-imported-rice-to-p45-kilo/>
- DA-PhilMech [Department of Agriculture – Philippine Center for Postharvest Development and Mechanization]. (2020). *Reference manual on rice milling: A compilation of resources*.
- DA-PhilRice [Department of Agriculture – Philippine Rice Research Institute]. (2025). *Number of rice farmers* [Data set]. <https://www.philrice.gov.ph/ricelytics/profilemain>
- Fackler, P. L., & Goodwin, P. L. (2001). Spatial price analysis. In G. Rausser & B. Gardner (Eds.), *Handbook of agricultural economics* (Vol. 1, pp. 1–30). Elsevier.
- Gardner, B. L. (1975). The farm-retail price spread in a competitive food industry. *American Journal of Agricultural Economics*, 57(3), 399–409.
- Ghoshray, A. (2011). Underlying trends and international price transmission of agricultural commodities (ADB Working Paper Series No. 257). Asian Development Bank.
- Kamaruddin, R., Masbar, S., Syahnur, S., & Majid, S. A. (2021). Asymmetric price transmission of Indonesia coffee. *Cogent Economics & Finance*, 9, 1971354.
- Kidane, D. G. (2022). Market integration and price transmission in the regional grain markets in Ethiopia. *Journal of Applied Economics*, 25(1), 784–801.

- Kinnucan, H. W. (2022). A note on the correspondence between horizontal and vertical price transmission. *Journal of Agricultural Economics*, 73, 654–665.
- Kinnucan, H. W., & Zhang, D. (2015). Notes on farm-retail price transmission and marketing margin behavior. *Agricultural Economics*, 46, 729–737.
- Mangahas, M., Recto, A. E., & Ruttan, V. W. (1966). Price and market relationships for rice and corn in the Philippines. *American Journal of Agricultural Economics*, 48(3), 685–703.
- Meyer, J., & von Cramon-Taubadel, S. (2004). Asymmetric price transmission: A survey. *Journal of Agricultural Economics*, 55(3), 581–611.
- NFA [National Food Authority]. (2025). *Buffer stock management*. <https://www.nfa.gov.ph/programs-projects/buffer-stock-management>
- Official Gazette. (2025). <https://www.officialgazette.gov.ph>
- Pesaran, M. H., & Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis. In S. Strom (Ed.), *Econometrics and economic theory in the 20th century: The Ragnar Frisch centennial symposium* (pp. 371–413). Cambridge University Press.
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(1), 289–326.
- PIA [Philippine Information Agency]. (2025). More affordable rice now available for Filipinos. <https://pia.gov.ph/more-affordable-rice-now-available-for-filipinos/>
- PSA [Philippine Statistics Authority]. (2025). *OpenSTAT*. <https://openstat.psa.gov.ph>
- PSA. (2021). *Average annual per capita consumption of selected agricultural commodities, 2018*. <https://psa.gov.ph/content/average-annual-capita-consumption-selected-agricultural-commodities-2018>
- Reeder, M. (2000). Asymmetric prices: Implications on trader's market power in Philippine rice. *Journal of Philippine Development*, 27(1), 49–69.
- Rose, R., & Paparas, D. (2023). Price transmission: The case of the UK dairy market. *Commodities*, 2, 73–93.
- Rufino, C. C. (2011). Analyzing the Philippines inter-regional market integration for rice. *International Research Journal of Finance and Economics*, 69, 108–127.
- Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modeling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In W. C. Horrace & R. C. Sickles (Eds.), *Festschrift in honor of Peter Schmidt: Econometric methods and applications* (pp. 281–314). Springer.
- Silvapulle, P., & Jayasuriya, S. (1994). Testing for Philippines rice market integration: A multiple cointegration approach. *Journal of Agricultural Economics*, 45(3), 369–380.
- Umali, D. L., & Duff, B. (1992). The Philippine rice marketing system: Implications for grain quality improvement. In L. J. Unnevehr, B. Duff, & B. O. Juliano (Eds.), *Consumer*

- demand for rice grain quality* (pp. 175–198). International Rice Research Institute and International Development Research Centre.
- UN [United Nations]. (2025). *Monthly rice imports of the Philippines* [Data set]. UN Comtrade Database. <https://comtradeplus.un.org>
- Valera, H. G., Mayorga, J., Pede, V. O., & Mishra, A. K. (2022). Estimating food demand and the impact of market shocks on food expenditures: The case for the Philippines and missing price data. *Q Open*, 2(2), 1–25.
- von Cramon-Taubadel, S., & Goodwin, B. K. (2021). Price transmission in agricultural markets. *Annual Review of Resource Economics*, 13, 65–84.
- Yeung, P. (1972). A note on the rules of derived demand. *The Quarterly Journal of Economics*, 86(3), 511–517.

Rabbit Farming in Zamboanga Peninsula Region Philippines: Viability, Adoption, and Industry Trends

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Abstract

Rabbit farming in the Philippines is gaining traction as an alternative enterprise amid the rising cost of pork and ongoing food security concerns. This study examines the viability, adoption, and industry trends and challenges of rabbit farming in Zamboanga Peninsula Region, Mindanao, Philippines using a mixed-method approach incorporating survey data and regression modeling. A total of 173 farmers (123 raisers, 50 non-raisers) were surveyed to determine their socio-economic and perceptual factors influencing adoption. Qualitative insights through key informant interviews (KIs) with agricultural officers, experienced raisers, and local stakeholders were carried out to understand current trends and challenges, opportunities, and emerging patterns in rabbit farming. Logistic regression results indicate that training participation, access to credit, and favorable perceptions of rabbit meat as a functional food significantly increased the likelihood of adoption while doubts about demand and profitability, remains strong deterrent for many farmers to engage in rabbit production. High costs of breeder stock and prevailing cultural perceptions of rabbits as pets also identified as major barriers. Industry trends point to growing interest in rabbit farming, yet several systemic challenges persist, including low consumer acceptability, limited government support, and weak market linkages. Strategic interventions such as the provision of breeder stock subsidies, targeted training programs, consumer education campaigns, and stronger institutional support are recommended to enhance adoption and long-term sustainability. The findings offer empirical insights into the socio-economic and perceptual dynamics of rabbit farming, advocating for strategic interventions to support rabbit farming as a sustainable livelihood option in the Philippines.

Keywords: rabbit farming, livestock economics, adoption, agribusiness, market development

JEL code: Q12, Q13, Q18

SDG classification: SDG 1, SDG 2, SDG 8, SDG 12

Introduction

Rabbit farming globally, has emerged as a viable alternative to traditional livestock, that offers promising avenues to enhance rural livelihood and dietary supplements. One of the most compelling arguments in favor of rabbit farming is its resilience during crises affecting conventional livestock sectors. In the face of persistent challenges in food security, poverty alleviation, and rural livelihood development, the search for sustainable, accessible, and nutritionally valuable livestock has brought attention to rabbit farming. Gomez (2020) reported that rabbit meat became an attractive protein source due to its comparable taste and nutritional value, especially during the pork shortage caused by ASF.

Rabbit meat is widely regarded for its health benefits, often consumed by older, higher-income males in countries like Spain and Italy. It is much appreciated for its leanness and nutritional value (Szendro et al., 2024). Efforts to promote rabbit meat often center on its premium positioning as a healthy and high-quality product. Studies show that consumers are willing to pay more for rabbit meat if it is marketed with emphasis on health benefits and environmental sustainability (Szakály et al., 2009; Al-Soufi et al., 2024). In Hungary and Spain, consumers preferred rabbit meat fed with seaweed due to perceived reductions in antibiotic use and increased nutritional value (Al-Soufi et al., 2024).

In Brazil, although urban men with higher income and education levels show high acceptance of rabbit meat, its unavailability remains a major consumption barrier, suggesting the need for vertical integration and supply chain development (de Cerqueira Magalhães et al., 2022). Similarly, in Malaysia and Hungary, limited marketing efforts and perceptions of rabbits as pets further inhibit market expansion (Idris et al., 2023; Bodnar & Horvath, 2008). Nina et al. (2020) also noted that while rabbit meat is liked by 74% of consumers in certain African markets, limitations in availability and high prices hinder expansion. Additionally, cultural perceptions pose significant barriers to widespread consumption in other regions, with emotional attachments and unfamiliarity deterring consumer acceptance and adoption. (Idris et al., 2023; Bodnar & Horvath, 2008).

Furthermore, ethical considerations around animal welfare increasingly influence consumer preferences, as seen in Italy, where there is strong demand for meat from humane, welfare-based farming systems (Crovato et al., 2022). A study conducted in France by Chiron et al. (2021) on the adoption of pro-welfare innovations by rabbit farmers identified several key factors influencing farmers' decisions. These include the perceived benefits of animal welfare improvements, societal expectations, and the influence of market actors. Farmers who were more engaged with consumers or integrated into value chains that prioritize welfare standards were more likely to adopt welfare-friendly practices. However, the study also revealed that economic constraints and uncertainty regarding consumer willingness to pay for higher welfare products remain significant barriers.

In addition to health and market resilience, the economic advantages of rabbit farming further solidify its potential. Mutsami, (2018) noted that rabbit farming requires relatively low initial capital and operational costs, making it an accessible venture for smallholder farmers. In several countries, rabbit farming plays a critical socio-economic role, especially in rural and peri-urban settings. In Kenya, commercialization of rabbit production was found to significantly reduce multidimensional poverty, primarily by

improving access to credit, education, and reducing family sizes (Mutsami & Karl, 2020). Likewise, in Nigeria, rabbit production substantially raised household incomes, particularly for male farmers with access to credit and extension services, though forage scarcity and disease remained pressing challenges (Ayeni et al., 2023). In Ghana, rabbit farming served as a supplementary income source for young, educated men, though water pollution and diseases constrained productivity (Mensah et al., 2024).

Youth engagement in rabbit farming has also gained traction due to its profitability and lower startup costs compared to large-scale livestock systems. In Nigeria, youth agripreneurs recorded a substantial net profit and returns on capital, although the lack of government support and weak extension systems continued to hinder broader adoption (Mukaila, 2022). The situation is similar in Ghana, where profitability indicators like Net Present Value and Internal Rate of Return confirm the economic feasibility of rabbit farming, though fodder shortages and low market prices remain key constraints (Mensah et al., 2014).

In Southeast Asia, Indonesia and Thailand have seen incremental growth in rabbit farming. In Indonesia, the enterprise is primarily small to medium scale, supported by increasing consumer demand and the need for diversified protein sources (Priyanti & Raharjo, 2012). Meanwhile, in Thailand, rabbit production operates under an extensive system, with two main slaughterhouses connecting producers to local markets and restaurants, though limited access to commercial feeds and veterinary services affects productivity (Kovitvadhi et al., 2016).

Elsewhere, countries have made strides in genetic improvement and productivity enhancement. In Russia, breeding programs have developed rabbits with higher live weights and daily weight gains, aimed at increasing meat yield and efficiency (Kotlyarova et al., 2024). However, economic inefficiencies still plague the industry in countries like Argentina, where high feed conversion ratios and poor market competitiveness limit profitability (Scialfa et al., 2022).

On a broader scale, the integration of rabbit farming into national strategies for food security and economic development has shown substantial promise. In China, policies supporting agricultural diversification and rural livelihood systems underscore the potential of small livestock like rabbits in enhancing nutrition and income opportunities (Zreik & Iqbal, 2024). Similarly, in Burkina Faso, rabbit farming has been identified as a pathway for improving climate resilience and productivity through selective breeding based on morphometric traits (Giovannini et al., 2024). In Bangladesh, despite rabbit farming's marginal status, its potential as a manageable, income-generating enterprise for rural populations is significant, with about 25% of the population involved in livestock farming (Amin et al., 2011). In Mattoanging Village, Indonesia rabbit production has gained momentum, operating near break-even yet showing clear growth potential through better marketing and Sharia-guided production systems (Tang, 2023).

Despite its recognized potential, rabbit farming remains an underutilized enterprise in many developing countries, including the Philippines. Rabbit farming in the country remains largely informal and under-documented but emerging interest in its economic potential is evident. Its adoption remains uneven and poorly understood. This study is conducted with the aim of identifying the specific characteristics of farmers who are more inclined to adopt rabbit farming and what motivates their decision. Understanding who adopts and why, can guide more targeted and efficient government interventions and

making sure that support reaches those with the highest potential to succeed in rabbit production. This will help in accelerating the growth of the industry and enhancing its role in improving rural livelihoods, food security, and income diversification.

To address this, the study is guided by the following research questions: (a) what are the characteristics of the farmer- respondents? (b) what are the key determinants that influence the likelihood of adopting rabbit farming among farmers? and (c) what are the current industry trend and challenges and what strategic interventions can enhance the growth and sustainability of rabbit farming in the Zamboanga Peninsula region and in the Philippines in general.

Methodology

Time and place of the study

This study was conducted during the first half of 2024 in the Zamboanga Peninsula Region (Region IX) of Mindanao, Philippines. It covered the provinces of Zamboanga del Norte, Zamboanga del Sur, and Zamboanga Sibugay. The region has a tropical climate favorable for diversified agriculture and small livestock production such as rabbit farming. It is home to various ethnic groups including Bisaya, Subanen, Chavacano, Tausug, and Sama-Bajau, reflecting a rich cultural and agricultural landscape. Major crops in the region include rice, corn, coconut, rubber, and banana. The region has five key cities Zamboanga City, Dipolog, Dapitan, Pagadian, and Isabela City. The area was selected for this study due to its strong agricultural base and the growing interest in rabbit farming as a sustainable livelihood option.

Theoretical framework

This study was guided by Rogers' Diffusion of Innovations Theory (2003) and Ajzen's Theory of Planned Behavior (1991), which helped explain the adoption of rabbit farming among smallholder farmers in the Zamboanga Peninsula. Rogers' theory emphasized factors like perceived profitability, ease of management, and market potential, while Ajzen's theory focused on how attitudes, norms, and perceived control shaped farmers' intentions. The study found that socioeconomic factors, training, access to credit, and positive perceptions of rabbit meat significantly increased adoption, while concerns about profitability and demand acted as barriers.

Data collection and sampling procedure

Primary data were gathered through a structured survey administered to 153 farmers across the Zamboanga Peninsula, including both rabbit raisers and non-raisers for comparative analysis. The questionnaire, developed from a comprehensive literature review and guided by the study's theoretical frameworks, was validated by experts in animal science and agricultural economics. It underwent pretesting to refine question clarity and structure. A stratified random sampling method was used, with strata based on province and municipality, and farmers were randomly selected through a fishbowl technique from lists provided by local agricultural offices.

Empirical strategy and modeling

The analysis includes three main components. First, descriptive statistics were used to profile rabbit farmers and farming operations focusing on their sociodemographic characteristics such as age, sex, education, household size, and income sources. In addition, farmers' perceptions were assessed through structured questions that captured their views on the profitability, market demand, cost of breeder stocks, and cultural acceptability of rabbit as food. They were made to rate via a 5-point Likert's scale. These perception variables helped frame the behavioral context of adoption.

Second, a binary logistic regression model was applied to identify the factors influencing adoption, with a binary outcome variable distinguishing adopter from non-adopters.

The dependent variable is binary defined as:

$$Y_i = \begin{cases} 1 & \text{if the farmer adopted rabbit farming} \\ 0 & \text{otherwise} \end{cases}$$

The first model analyzes the association between socioeconomic and demographic characteristics and adoption. The binary logistic regression model is specified as:

$$\log \left(\frac{P_i}{1 - P_i} \right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \cdots + \beta_k X_{ki} + \varepsilon_i$$

Equation 1

Where:

- P_i = Probability that the i^{th} respondent adopts rabbit farming
- X_{1i} = Age
- X_{2i} = Sex (1 = Male, 0 = Female)
- X_{3i} = Marital Status (1 = Married, 0 = Otherwise)
- X_{4i} = Household Size
- X_{5i} = Educational Attainment (ordinal or categorical)
- X_{6i} = Membership in Organization (1 = Yes, 0 = No)
- X_{7i} = Household Income (in ₱)
- X_{8i} = Major Source of Income (1 = Farm income, 0 = Otherwise)
- X_{9i} = Training Participation (1 = Yes, 0 = No)
- X_{10i} = Access to Credit/Capital (1 = Yes, 0 = No)
- ε_i = Error term

The second model investigates how perceptual factors affect the likelihood of adopting rabbit farming. The binary logistic regression model is specified as:

$$\log \left(\frac{P_i}{1 - P_i} \right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i$$

Where:

- P_i = Probability that the i^{th} respondent adopts rabbit farming
- X_{1i} = Perceived Demand and Profitability
- X_{2i} = Perceived Cost of Breeder Stock
- X_{3i} = Perception and Acceptability of Rabbit as Functional Food
- ε_i = Error term

Lastly, the analysis explored the current industry challenges and identified strategic interventions that could enhance the growth and sustainability of rabbit farming in the Zamboanga Peninsula and the Philippines more broadly. Both quantitative (Likert-scale responses) and qualitative data (open-ended survey responses and key informant interviews) are analyzed. A SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) framework is used to synthesize industry-level insights.

Estimation and hypothesis testing

All models are estimated using Stata 18. Model fitness is assessed using likelihood ratio tests and pseudo-R-squared values for logistic regression. Multicollinearity is checked using VIF (Variance Inflation Factor). Hypothesis tests are conducted at the 1%, 5%, and 10% significance levels. Key hypotheses include:

H_{01} : Socioeconomic and perceptual factors do not significantly influence the adoption of rabbit farming.

Ethical considerations

This study strictly followed ethical research standards. Participation was voluntary, and all respondents were given informed consent before the interview or survey. The purpose, procedures, and their rights including the right to refuse or withdraw at any time were clearly explained. All information collected was kept confidential and anonymous, and used only for academic purposes.

Results and Discussion

Descriptive statistics on socioeconomic and demographic characteristics of farmers

The study surveyed 173 respondents composed of 71.1% adopters and 28.9% non-adopters of rabbit farming. The average age was 35, ranging from 17 to 66 years. Most respondents were male (61.8%) and married (56.0%), with an average household size of five members. In terms of education, 71.5% had reached college level, indicating a

relatively educated sample. However, organizational membership was low at only 15.6%. The average monthly household income was ₱8,984.97, with most respondents earning primarily from farm income (49.7%) and wages (39.8%). Only 24.8% had attended relevant training, but 72.8% had access to credit or capital.

The study found a generally positive outlook on rabbit farming's market potential and profitability, with a mean score of 3.89 (Agree). However, while 46.6% of respondents were optimistic, 26.1% remained neutral and 20.2% disagreed, suggesting concerns about market uncertainties. Regarding the perceived cost of rabbit breeder stocks, a mean score of 3.66 (Agree) indicates that while the cost is recognized as a barrier by many, nearly 30% of respondents expressed disagreement, highlighting concerns about affordability despite access to capital. In terms of acceptability, the highest mean score of 4.37 (Strongly Agree) reflects strong consumer and community acceptance of rabbit as food, suggesting minimal cultural barriers.

These statistics indicate that while respondents have moderate access to financial resources, there is a gap in capacity building and organizational support that could impact rabbit farming adoption and sustainability.

Table 1. Summary statistics on the socioeconomic and demographic Profile of Respondents, the Zamboanga Peninsula Region, 2024

Variables	No of observation	Percentage	Min	Max	Mean	Std. Deviation
Adoption	173	1-Adopters= 71.1% 2- Non-adopters= 28.9%				
Age	173		17	66	35	1.15
Sex	173	1-Male= 61.8% 2- Female=38.2%	1	2	-	0.48
Marital Status	173	1-Single= 34.6% 2-Married=56.0% 3-Widow(er)= 3.4% 4-Separated= 5.7%	1	4	0.592	0.592
Household Size	173		1	8	5	0.549
Educational Attainment	173	1-Elementary graduate =8.1% 2-High School level= 11.5% 3-High School graduate=5.7% 4-College level=23.6% 5-College graduate=47.9% 6-Post Graduate=2.8%	2	6	5.156	1.127

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Variables	No of observation	Percentage	Min	Max	Mean	Std. Deviation
Membership in Organization	173	1-Yes= 15.6% 0-No=84.4%	1	2	0.362	0.363
Household Income (Php) (1PhP=0.0175)	173		1,000	6,000	8,984.971	11,549.13
Major Source of Income	173	1- wage/salary =39.8% 2- property income =4.6% 3-farm income 49.7% 4-pension=5.7%	1	4	-	0.952
Training Participation (with, without)	173	1-Yes=24.8% 2-No=75.2%%				
Access to credit/capital	173	1-Yes= 72.8% 2- No= 27.2%				
Perceived Demand and Profitability	173	5-Strongly Agree = 17.7% 4-Agree= 28.9% 3-Neutral = 26.1% 2-Disagree= 20.2% 1-Strongly Disagree= 6.9%			3.89 (Agree)	
Perceived cost of rabbit breeder stocks	173	5-Strongly Agree = 20.2% 4-Agree=32.9% 3-Neutral = 11.5% 2-Disagree=29.4% 1-Strongly Disagree=5.7%			3.66 (Agree)	
Perception acceptability of rabbit as food	173	5-Strongly Agree =19.0% 4-Agree=33.5% 3-Neutral = 18.5% 2-Disagree=17.9% 1-Strongly Disagree=10.1%			4.37 (Strongly Agree)	

Socioeconomic factors affecting adoption

The results of the logit regression model reveal key socioeconomic and institutional factors that influence the adoption of rabbit farming in the Zamboanga Peninsula Region. The model shows a good fit, with a Pseudo R^2 value of 63.93%, indicating that the explanatory variables collectively account for a substantial proportion of the variation in the likelihood of rabbit production adoption. Among the 173 observations, three variables emerged as statistically significant determinants of adoption: *educational attainment*, *training participation*, and *access to credit or capital*.

Access to credit or capital is found to be the most influential predictor in the model, with a logit coefficient of 4.797 ($p < 0.01$) and a marginal effect of 0.290. This implies that farmers with access to credit are 29 percentage points more likely to adopt rabbit production compared to those without such access. This finding aligns with studies of (Mutsami & Karl) in 2020 which found that commercialization of rabbit farming in Kenya significantly reduced multidimensional poverty, largely due to improved access to credit and education. Ayeni et al., (2023), also highlight the role of financial resources in improving participation and income from rabbit production in Nigeria. This implies the critical role of financial resources in enabling investment, which may require startup capital for housing, breeding stock, and feed of rabbit production.

Training participation also shows a strong and statistically significant effect ($\beta = 3.509$, $p < 0.05$), with a marginal effect of 0.212. Farmers who have undergone relevant training are 21.2 percentage points more likely to adopt rabbit production than those who have not. This is consistent with the insight from Mukaila (2022) who documented that youth Agripreneurs achieved notable profitability in rabbit farming yet faced constraints due to limited training and government support. Similarly, Chiron et al. (2021) put forward that farmers are more inclined to adopt innovation or welfare-based practices when exposed to consumer preferences and value chain integration which often happen through training and extension engagements. This highlights the importance of knowledge transfer and capacity-building initiatives, suggesting that farmers are more likely to engage in rabbit production when equipped with the appropriate skills and technical know-how.

Educational attainment significantly contributes to the probability of adoption as well ($\beta = 0.575$, $p < 0.05$), with a marginal effect of 0.034. This means that a one-level increase in educational attainment (e.g., from high school to college) raises the probability of adoption by 3.4 percentage points. This corroborates the findings of Rugarabamu et al. (2023), which highlighted how both formal education and informal extension training empower farmers with knowledge, decision-making skills, and openness to adopting innovative practices such as commercial rabbit production. Afful (2020), found that educated farmers tend to be early adopters of an enterprise due to their better comprehension of technical recommendations and perceived profitability while Aminu (2020) identified education as a significant determinant of income from rabbit production.

Conversely, the remaining variables such as age, sex, marital status, household size, membership in organizations, household income, and the major source of income were not statistically significant predictors of adoption. Their respective marginal effects were relatively small, ranging from -0.039 to 0.012 which suggest that these characteristics have limited direct influence on the decision to adopt rabbit production in this context.

Moreover, household income and major income source were not significant, which indicate that rabbit farming appeals to a wide range of income groups, or that income alone does not determine openness to adopting this enterprise. The lack of significance in organizational membership also suggests that group affiliation may not strongly influence adoption unless it is linked with capacity-building or financial access.

The results suggest that adoption of rabbit farming in the region is primarily driven by access to financial and informational resources, rather than by demographic characteristics. These findings point to the need for supportive policies and programs that improve farmers' access to training and capital. Doing so can significantly enhance the uptake of rabbit production as a viable livelihood and nutrition-enhancing enterprise in the Zamboanga Peninsula.

Table 3. Binary logistic regression results for factors influencing rabbit farming adoption in the Zamboanga Peninsula region, 2024 (n=173)

Variables	Coefficient (Log-Odds)	Standard Error	Marginal Effects (dy/dx)
Intercept	-4.343	2.982	
Age	-0.176	0.322	-0.010
Sex	-0.231	0.679	-0.014
Marital Status	-0.173	0.549	-0.010
Household Size	0.065	0.686	0.003
Educational Attainment	0.575**	0.273	0.034**
Membership in Organization	-0.654	1.101	-0.039
Household Income	0.000	0.000	-0.000
Major Source of Income	0.204	0.348	0.012
Training Participation	3.509**	1.551	0.212**
Access to credit/capital	4.797***	0.712	0.290***
Model Fit:			
Pseudo R ²	63.93%		
AIC	87.12		
Log Likelihood	-37.52		

Note: *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.10$

Perceptual factors influencing rabbit farming adoption

The second model investigated how farmers' perceptions influence their adoption of rabbit farming in the Zamboanga Peninsula Region. This model demonstrates excellent explanatory power, with a Pseudo R² of 82.53%, indicating that the included perception variables explain more than 80% of the variation in adoption behavior. The model's low AIC (44.34) and log-likelihood (-18.172) also reflect a good model fit. Among the three

perception-based variables, two were found to be statistically significant: perceived demand and profitability, and perception and acceptability of rabbit as a functional food.

The perceived demand and profitability have a negative and significant effect on the probability of adoption ($\beta = -2.162$, $p < 0.01$), with a marginal effect of -0.065. This result may appear counterintuitive, it aligns with previous observations in Brazil, where de Cerqueira Magalhães et al. (2022) found that limited availability and poor market development hindered consumer access, thereby constraining adoption. Similarly, Idris et al. (2023) reported that in Malaysia, weak marketing and the perception of rabbits as pets limited demand. However, the negative sign suggests that farmers who perceive low demand and low profitability are significantly less likely to adopt rabbit farming by about 6.5 percentage points. This indicates that skepticism toward market opportunities remains a strong barrier to adoption. In other words, if farmers do not believe rabbit farming can generate consistent income or attract consumer demand, they are unlikely to invest in it.

On the other hand, positive perception and acceptability of rabbit meat as a functional food has a strong and significant positive influence on adoption ($\beta = 4.697$, $p < 0.01$), with a marginal effect of 0.142. This means that favorable attitudes toward the nutritional or health value of rabbit meat increase the likelihood of adoption by 14.2 percentage points. This supports findings by Al-Soufi et al. (2024), who emphasized consumer willingness to pay more for rabbit meat when marketed as a healthy, environmentally sustainable option. Furthermore, in Spain and Italy, rabbit meat has gained importance among health-conscious consumers, especially older and higher-income males, due to its leanness and high nutritional value (Szendro et al., 2024). These consumption trends may have influenced producers' decisions, particularly those attuned to shifting dietary preferences and health concerns.

In contrast, the perceived cost of breeder stock was not statistically significant ($\beta = 0.198$, $p > 0.10$), with a marginal effect of only 0.006. This suggests that although the initial cost of acquiring rabbit breeder stock may be a consideration for some, it does not serve as a major barrier or driver of adoption overall. It is possible that farmers who are already convinced of the profitability or health benefits of rabbit farming are willing to overlook or absorb the cost of initial investment.

Generally, the results underscore the critical importance of perception-related factors in shaping adoption decisions. Specifically, trust in the market viability of rabbit products and the acceptability of rabbit meat as a healthy food play major role. These findings suggest that promotion campaigns and development efforts should focus not only on training and credit support, but also on market assurance and consumer education to boost adoption. Enhancing public perception and visibility of rabbit as both profitable and healthy can significantly increase its adoption among farmers in the region.

Table 4. Logistic regression results on the influence of perceptual factors on rabbit farming adoption, zamboanga peninsula, mindanao philippines 2024 (n=173)

Variables	Coefficient (Log-Odds)	Standard Error	Marginal Effects
Intercept	-4.66*	2.33	
Perceived Demand and profitability	-2.162***	0.610	-0.065***
Perceived Cost of Breeder stock	0.198	0.475	0.006
Perception and Acceptability of Rabbit as functional food	4.697***	1.066	0.142***
Model Fit			
Pseudo R2	82.53%		
Number of Observation	173		
AIC	44.34		
Log-likelihood	-18.172		

Trends, challenges, and strategic interventions in rabbit farming

A. Industry trends

The themes presented in Table 5 were generated through thematic analysis of the survey results, key informant interviews, and stakeholder discussions, with supporting evidence and potential implications identified for the rabbit farming industry. Results reveal positive perceptions regarding rabbit meat's health benefits and profitability, under the "Perception and Acceptability" factor. Likewise, qualitative interviews support an increasing interest among farmers, especially those looking for low-input, fast-reproducing livestock options. Although still considered a niche, there is observable growth in backyard and semi-commercial operations.

Table 5. Emerging trends in rabbit farming based on survey and interview findings

Observed trend	Evidence	Implication
1. Increasing interest in rabbit as livestock	High perception scores on profitability and health benefits	Opportunity to promote rabbit as a mainstream livestock option
2. Rise of backyard rabbit farming	KII mentions and survey demographics	Indicates grassroots-level adoption among smallholders
3. Rabbit meat seen as a healthy alternative protein	4.42 mean on "rabbit meat as nutritious functional food"	Leverage health-conscious consumer segments
4. Growing demand in niche markets	Respondents note demand in events/restaurants	Targeted marketing can boost sales

Observed trend	Evidence	Implication
5. Lack of established commercial supply chains	Limited visibility in supermarkets	Indicates need for institutional support and organization

B. Industry challenges

Despite the positive trends, several challenges continue to limit rabbit farming's full potential. These include high start-up costs specifically high cost of breeder stock, limited access to quality breeder stocks, and low consumer awareness and acceptability of rabbit meat. Furthermore, the lack of dedicated support from government agencies and weak value chains pose risks to sustainability. Both survey data and key informant interviews reinforce these structural bottlenecks.

On the lighter side, though challenges remain in the acceptability of rabbit meat, several studies have shown that processing opportunities for rabbit products have led to increased consumer acceptance. As Petracci & Cavani (2013) highlight, while rabbit meat was traditionally consumed immediately after slaughter due to its small size, today there is a wide variety of processed products, such as ready-to-cook and ready meals, driven by the growing demand for convenience.

Table 6. Summary of industry challenges identified by respondents and key informants

Challenges	Source	Frequency/Emphasis	Qualitative Insights
1. Limited consumer awareness and cultural acceptability	Survey + KIs	72% of the respondents Agree	Seen more as a pet than food
2. High cost and low availability of breeder stocks	Survey + KIs	68% of the respondents Agree	Difficult to source and expensive
3. Lack of technical training and extension services	Survey	75% No prior training	Farmers self-learn through YouTube, Facebook or peers
4. Poor market access and fragmented supply chains	KIs	Repeated concern	No cold storage or institutional buyers
5. Weak policy support	Secondary Data + KIs	Consistently mentioned	Not included in DA Region's livestock development priorities

C. Strategic interventions

In response to these challenges, the study proposes several interventions grounded in both best practices and stakeholder recommendations. These focus on increasing awareness, lowering barriers to entry, building capacity, and strengthening institutions

that can sustain growth in the long term. Before, rabbit farming was less embraced, as seen by Lukefahr et al. (2004), but as of now, there are many opportunities in rabbit production, as several authors contend. These include advancements in production techniques, increasing consumer demand for sustainable protein, and the rise of processed rabbit products, all contributing to the growing acceptance and viability of the industry (Cullere & Dalle Zotte, 2018; Kumar et al., 2024; Siddiqui et al., 2023).

Table 7. Proposed Strategic Interventions to Address Key Challenges

Strategic Intervention	Target Challenge Addressed	Proposed Implementer	Expected Outcome
1. Awareness campaigns on rabbit meat	Low consumer acceptance	DA, LGUs, NGOs	Increased demand and public interest
2. Subsidies or starter kits	High cost of breeder stocks	DA, PCAARRD	Greater adoption among smallholders
3. Establish training and research centers and demo farms	Lack of technical skills	ATI, SUCs	Improved husbandry practices; Affordable breeding stock
4. Organize farmer marketing cooperatives	Weak market access	LGUs, farmer groups	Enhanced supply chain efficiency
5. Lobby for policy inclusion of rabbit farming	Weak gov't support	DA, National Policy Makers	Better institutional and financial support

SWOT analysis

To gain a comprehensive understanding of the rabbit farming sector's potential and sustainability, a SWOT analysis was conducted. This framework identifies the industry's internal strengths and weaknesses, as well as external opportunities and threats. The goal is to position rabbit farming within a strategic development context and guide evidence-based interventions.

Table 8. SWOT analysis of rabbit farming in Zamboanga Peninsula, Mindanao, Philippines 2024

Strengths: 1. Fast reproduction rate rabbits can produce offspring monthly, ensuring quick returns. 2. Low feed cost and flexible feed options can thrive on forage, kitchen waste, and low-cost pellets.	Weaknesses: 1. Limited public awareness- rabbit meat is still unfamiliar to most Filipino consumers. 2. Lack of formal government programs or inclusion in mainstream livestock development policies.

3. Small space requirement ideal for backyard farming even in urban or peri-urban areas. 4. Low initial investment compared to larger livestock.	3. Insufficient technical knowledge many raisers lack formal training or veterinary support. 4. Fragile supply chain access to breeder stocks, quality feeds, and markets remains fragmented.
Opportunities: 1. Rising demand from health-conscious consumers seeking lean, white meat alternatives. 2. Growing agri-tourism and niche restaurant markets that can feature rabbit dishes. 3. Potential for inclusion in DA and LGU livelihood programs as a poverty alleviation tool 4. Export potential with halal and specialty meat markets in ASEAN.	Threats 1. Cultural perception-rabbits are often seen as pets, not food animals. 2. Strong competition from well-established poultry and pork industries. 3. Disease outbreaks and lack of biosecurity measures can quickly wipe out small-scale farms. 4. Climate-related risks and feed availability issues in rural areas.

Conclusion

This study explored the adoption of rabbit farming in the Zamboanga Peninsula Region, analyzing both the socio-economic factors and perceptual drivers influencing adoption behavior. The findings revealed that educational attainment, training participation, and access to credit or capital are significant determinants of adoption, underscoring the importance of knowledge, capacity building, and financial support in influencing farmers' decisions. Among the perceptual factors, the perceived acceptability of rabbit as a functional food had the strongest positive effect on adoption, while perceived demand and profitability, although generally rated positively, unexpectedly showed a negative statistical relationship suggesting a possible gap between market belief and actual risk perception.

The industry is characterized by strengths such as rapid rabbit reproduction and low feed requirements but faces weaknesses like poor awareness and limited institutional support. Opportunities exist in rising health-conscious consumer markets and potential integration into agri-tourism, though cultural stigma and market competition with traditional meat remain key threats.

To promote growth and sustainability of the sector, strategic interventions such as expanding training programs, offering breeder stock support, launching awareness campaigns, and mainstreaming rabbit farming in national livestock development policies are recommended. These insights contribute to shaping targeted, data-driven policies that can enhance rabbit adoption and position the industry as a viable, inclusive, and sustainable livelihood option in the Philippines.

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References

- Afful, J. (2020). *Stakeholders' preference and adoption of improved cowpea varieties in the Northern Region, Ghana* (Doctoral dissertation, University of Cape Coast). <http://hdl.handle.net/123456789/4567>
- Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, 50(2), 179-211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Al-Soufi, S., Vivero-Saavedra, C., Pernas, A. M., Miranda, M., & López-Alonso, M. (2024). Consumer perception of supplementing rabbit diets with seaweed to reduce antibiotic use in rabbit production in Spain. *World Rabbit Science*, 32(2), 129-143. <https://doi.org/10.4995/wrs.2024.21157>
- Amin, M. R., Taleb, M. A., & Rahim, J. (2011). Rabbit farming: a potential approach towards rural poverty alleviation. *Research on Humanities and Social Sciences*, 1(2), 1-10.
- Ayeni, M. D., Adewumi, M. O., Bello, M. A., AdiAdi, K. F., & Osungade, A. A. (2023). Effects of rabbit production on income and livelihood of rural households in Nigeria. *Heliyon*, 9(8). <https://doi.org/10.1016/j.heliyon.2023.e18568>
- Bodnar, K., & Horvath, J. (2008). Consumers' opinion about rabbit meat consumption in Hungary. [Proceedings of the 9th World Rabbit Congress, Verona, Italy, 10-13 June 2008](https://www.cabidigitallibrary.org/doi/full/10.5555/20113318956), 2008, 1519-1522 ref. 8. Retrieved from: <https://www.cabidigitallibrary.org/doi/full/10.5555/20113318956>
- Chiron, P., Doré, A., & Lamothe, L. F. (2022). Factors affecting French rabbit farmers' adoption of pro-welfare innovations. *World Rabbit Science*, 30(4), 249-265.
- Crovato, S., Pinto, A., Di Martino, G., Mascarello, G., Rizzoli, V., Marcolin, S., & Ravarotto, L. (2022). Purchasing habits, sustainability perceptions, and welfare concerns of Italian consumers regarding rabbit meat. *Foods*, 11(9), 1205. <https://doi.org/10.3390/foods11091205>
- Cullere, M., & Dalle Zotte, A. (2018). Rabbit meat production and consumption: State of knowledge and future perspectives. *Meat science*, 143, 137-146. <https://doi.org/10.1016/j.meatsci.2018.04.029>
- de Cerqueira Magalhães, L. C., Costa, R. B., & de Camargo, G. M. F. (2022). Consumption of rabbit meat in Brazil: potential and limitations. *Meat science*, 191, 108873. <https://doi.org/10.1016/j.meatsci.2022.108873>
- Giovannini, S., Chiattelli, D., Cartoni Mancinelli, A., Dal Bosco, A., Sarti, F. M., Sunzini, P., & Castellini, C. (2024). Unlocking the potential of local rabbit population: morphological insights for sustainable rabbit farming in Burkina Faso's challenging

- environments. *Italian Journal of Animal Science*, 23(1), 523-531. <https://doi.org/10.1080/1828051X.2024.2329719>
- Gomez, E. J. (2020, February 13). *Rabbit meat eyed as pork alternative amid ASF*. The Manila Times. <https://www.manilatimes.net/2020/02/13/business/business-top/rabbit-meat-eyed-as-pork-alternative-amid-asf/685613/>
- Idris, N. H., Muhammad, N. S., Abas, A., & Kasmn, M. N. (2023). Are Malaysians ready for Rabbit Meat? An exploratory to assess readiness of Malaysians to accept rabbit meat as an alternative protein source. *Environment-Behaviour Proceedings Journal*, 8(SI15), 149-154. <https://doi.org/10.21834/e-bpj.v8iSI15.5099>
- Kotlyarova, C. N., Dobudko, A. N., Yastrebova, O. N., Breslavets, Y. P., Hohlova, N. A., & Dorofeev, A. F. (2024). Current trends in directed work on production of rabbit breeding products. In *BIO Web of Conferences* (Vol. 139, p. 08001). EDP Sciences. <https://doi.org/10.1051/bioconf/202413908001>
- Kovitvadhi, A., Sanyathitiseree, P., Gasco, L., & Rukkwamsuk, T. (2016, June). Meat rabbit production in Central, Western and Eastern Thailand: Social network and current status. In *Proceedings of the 11th World Rabbit Congress, Qingdao, China* (pp. 961-964).
- Kumar, P., Sharma, N., Narnoliya, L. K., Verma, A. K., Umaraw, P., Mehta, N., ... & Sazili, A. Q. (2024). Improving quality and consumer acceptance of rabbit meat: Prospects and challenges. *Meat Science*, 109660.. <https://doi.org/10.1016/j.meatsci.2024.109660>
- Lukefahr, S. D., Cheeke, P. R., McNitt, J. I., & Patton, N. M. (2004). Limitations of intensive meat rabbit production in North America: A review. *Canadian Journal of Animal Science*, 84(3), 349-360. <https://doi.org/10.4141/A04-002>
- Mensah, J. O., Aidoo, R., Amponsah, D., Buah, A. E., Aboagye, G., & Acquah-Harrison, N. S. (2014). Assessing the feasibility of commercial meat rabbit production in the Kumasi Metropolis of Ghana. <http://www.sciencedomain.org/abstract.php?iid=312&id=2&aid=2433>
- Mensah, A., Adams, F., Prah, S., & Afriyie, S. O. (2024). Prospects for Commercialization of Rabbit Production in Africa: Empirical Evidence from Ghana. *Cleaner and Circular Bioeconomy*, 9, 100122. <https://doi.org/10.1016/j.clcb.2024.100122>
- Mukaila, R. (2022). Agricultural entrepreneurship among the youth: The case of youth involvement in rabbit production in Nigeria. *International Entrepreneurship Review*, 8(1), 35-46. 10.15678/IER.2022.0801.03
- Mutsami, C., & Karl, S. (2020). *Commercial rabbit farming and poverty in urban and peri-urban Kenya*. *Front. Vet. Sci.*, 7, 353. <https://doi.org/10.3389/fvets.2020.00353>
- Mutsami, C. (2018). An economic assessment of structure, conduct, and performance of rabbit market in Nakuru, Kiambu and Nyeri counties, Kenya. Master's Thesis <http://hdl.handle.net/11295/104610>
- Nina, D. A., Flore, A. E. E., Séverin, K. K. A., Rose-Monde, M., Athanase, O. K., Joseph, K. N., & Sébastien, N. L. (2020). Critical analysis of rabbit (*Oryctolagus cuniculus*) meat consumption in Abidjan, cote d'Ivoire. *Annu. Res. Rev. Biol.*, 34: 1-7. <https://doi.org/10.9734/arrb/2019/v34i530162>

- Petracci, M., & Cavani, C. (2013). Rabbit meat processing: historical perspective to future directions. *World Rabbit Science*, 21(4), 217-226. <http://dx.doi.org/10.4995/wrs.2013.1329>
- Priyanti, A., & Raharjo, Y. C. (2012). Market driving to develop rabbit meat products in Indonesia. *Wartazoa*, 22(3), 99-106.
- Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of innovations. In *An integrated approach to communication theory and research* (pp. 432-448). Routledge. (5th ed.), Free Press, New York, NY (2003)
- Rugarabamu, O. M., Kidudu, J. S., & Shausi, G. L. (2023). Extension and the Adoption of Commercial Rabbit Production in Hai District. *European Journal of Agriculture and Food Sciences*, 5(6), 1-8. [10.24018/ejfood.2023.5.6.737](https://doi.org/10.24018/ejfood.2023.5.6.737)
- Scialfa, E., Rodríguez, M., Rivero, M., & Pane, S. (2022). Economic analysis in a small-scale farm producing rabbit for meat purposes in Argentina. *Hayvan Bilimi ve Ürünleri Dergisi*, 5(2), 103-113. <https://doi.org/10.51970/jasp.1158657>
- Siddiqui, S. A., Gerini, F., Ikram, A., Saeed, F., Feng, X., & Chen, Y. (2023). Rabbit meat—production, consumption and consumers' attitudes and behavior. *Sustainability*, 15(3), 2008. <https://doi.org/10.3390/su15032008>
- Szakály, Z., Szigeti, O., & Szente, V. (2009). Analysis of consumer habits and attitudes on the Hungarian beef and rabbit market. *APSTRACT: Applied Studies in Agribusiness and Commerce*, 3, 67-70. [10.22004/ag.econ.49229](https://doi.org/10.22004/ag.econ.49229)
- Szendró, K., Dalle Zotte, A., Fülöp, N., & Nagy, M. Z. (2024). A survey on rabbit meat perception and consumption in seven countries. *Czech Journal of Animal Science*, 69(10), 419. DOI: 10.17221/123/2024-CJAS
- Tang, M. (2023). Analysis of Rabbit Farming Business and Marketing in Increasing Family Income from a Sharia Economic Perspective. *ETDC: Indonesian Journal of Research and Educational Review*, 2(4), 111-119. <https://doi.org/10.51574/ijrer.v2i4.1164>
- Zreik, M., & Iqbal, B. A. (2024). Evaluating China's strategies for achieving Zero Hunger and SDG 2: from policy to plate. *Academia Nutrition and Dietetics*, 1(1). <https://doi.org/10.20935/AcadNutr7387>

Bridging the Disconnect: A Systematized Review of Market-level Food Diversity and Household Dietary Diversity in Vietnam

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Abstract

Despite implementing various nutrition and health policies in Vietnam according to the National Nutrition Strategy for 2021-2030, limited dietary diversity, imbalanced dietary, and restricted access to nutrient-rich foods have led to a persistently high rate of stunting and anemia. This paper examines the relationship between market-level food diversity and household food diversity, identifying key gaps that hinder improved dietary practices in Vietnam. A systematized review from 23 studies and eight reports was conducted using five scientific databases (Scopus, PubMed, EBSCOhost, Springer Link, and Journal of Vietnam Agricultural Science and Technology, which were directly searched through its official websites to ensure the inclusion of relevant Vietnamese-language studies) and four grey literature sources. The search strategy included keywords related to food groups consumed, nutrition policy interventions, and economic constraints affecting diverse food choices, such as food prices, household income levels, food expenditure patterns, food affordability, and market access in Vietnam. It is found that there is a disconnect between market-level food diversity and household dietary diversity. This reveals a major food policy gap in Vietnam: although income constraints, market access, and low nutrition literacy weaken the link between market-level food diversity and household dietary diversity, current policies largely overlook these structural barriers. Most interventions emphasize education but lack targeted actions to improve food affordability, market accessibility, and support for vulnerable groups. Therefore, there is a need for specific studies assessing their economic barrier and behavioral impacts, as well as strategies to enhance policy enforcement and consumer adherence.

Keywords: food consumption, nutrition policies, household dietary diversity, market-level food diversity, food security

JEL code: I18, Q18, D12

SDG classification: SDG 2, SDG 3, SDG 12

Introduction

Enhancing dietary diversity is an essential public health and development goal, particularly in low- and middle-income countries where malnutrition continues to be a significant issue. In Vietnam, despite considerable progress in implementing nutrition-sensitive policies through the National Nutrition Strategy 2021–2030, rates of stunting, anemia, and micronutrient deficiencies remain high, particularly among rural and low-income populations. Therefore, the point is that households often struggle to access and consume a diverse range of necessary foods for adequate nutrition, even when such foods are available in markets.

While Vietnam has seen a marked increase in the diversity and quantity of food available at the national level, this trend has not been mirrored by proportional improvements in dietary consumption. According to FAO food balance data illustrated in Figure 1, the national supply of vegetables, fruits, meat, and dairy products rose substantially between 1961 and 2013, with vegetables and fruits reaching a combined availability of over 500 grams per capita per day, and milk supply increasing by more than 750%.

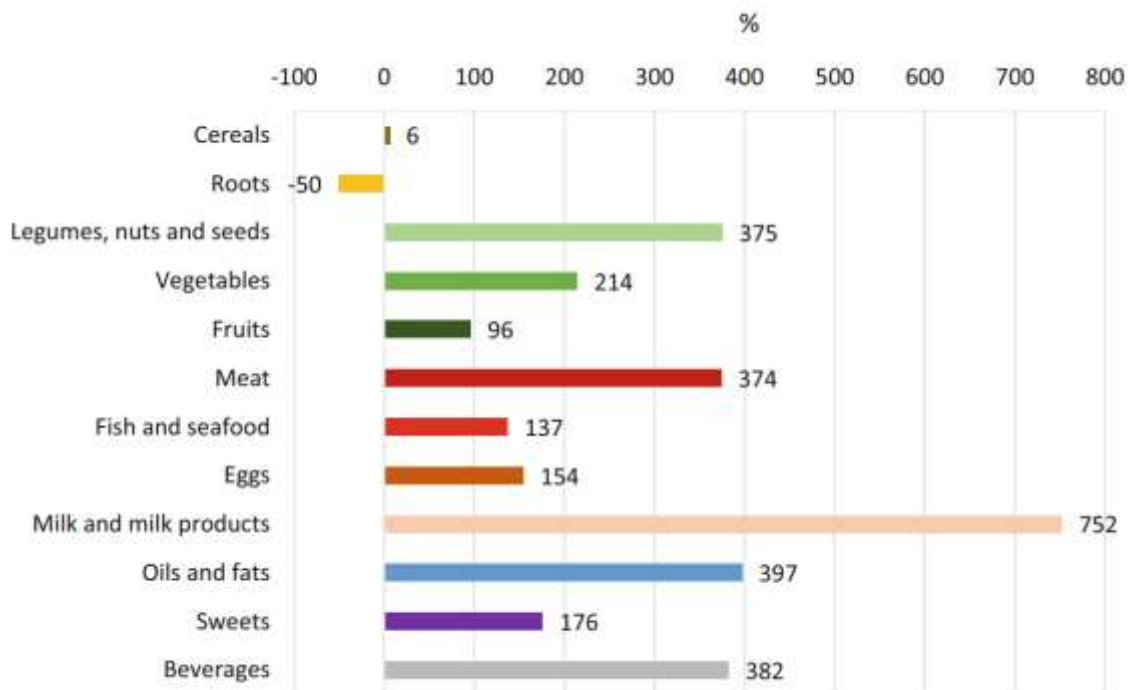


Fig. 1 Percent change in food supply (kg/capita/year), 1961– 2013

Source: Harris et al, 2020

However, Table 1 presents a contrasting reality: actual average daily consumption of vegetables declined from 214 grams in 1985 to 190 grams in 2009, while fruit intake, despite increasing, remained modest at only 61 grams per day. This stark mismatch between supply and intake highlights a central paradox in Vietnam's nutrition transition greater market food diversity does not necessarily lead to improved dietary diversity. Economic, cultural, and behavioral constraints continue to inhibit households, especially

in rural and low-income settings, from transforming food availability into healthier eating patterns.

Table 1. Food consumption per capita per day (g/capita/day)

Food Type	1985	1989	2000	2009
Cereal	458	452	397	373.2
Roots	68.2	37.6	8.9	4.1
Vegetables	214	171.3	178.6	190.4
Fruits	2.2	4.1	62.4	60.9
Tofu/Beans/Peas	2.4	9.6	19.4	19.5
Pulses/Nuts	3	3.8	4.3	4.5
Meat	11.1	24.4	51	84
Fish	35	41.2	45.5	59.8
Eggs and Milk	0.8	2.9	10.3	29.5
Oils and Fats	1.6	3	6.8	8
Sweets	0.9	0.8	7.8	3.8

Source: NIN – General Nutrition Survey 2010

This paper is motivated by the growing recognition that the diversity of foods available in markets referred to as Market-level Food Diversity (MFD) should play a vital role in shaping Household Dietary Diversity (HDD).

However, empirical evidence from comparable countries across studies increasingly suggests a disconnect between food availability and actual consumption. This gap is influenced by several socio-economic and structural constraints, including low household income, high food prices, limited market infrastructure, and unequal access across regions. These constraints are essential to designing more effective interventions that not only improve food supply but also address demand limitations and behavioral barriers.

The objective of this paper is to critically examine the relationship between MFD and HDD through a systematized review of empirical studies and relevant Vietnamese policy documents. Specifically, the study aims to (1) synthesize global and regional empirical evidence on how MFD influences HDD; (2) identify key factors that moderate this relationship, such as income, education, and market access; and (3) evaluate the extent to which current Vietnamese policies address these issues. In doing so, the study seeks to contribute to ongoing efforts to realign nutrition policy with the structural realities of food systems and household-level decision-making in Vietnam.

The paper aims to improve food policy in Vietnam by addressing the structural realities of food systems and household decision-making. It serves to inform policymakers, development practitioners, researchers, and civil society stakeholders involved in food security, nutrition, agriculture, and rural development. It highlights where existing policies fall short, and where more targeted, equity-sensitive interventions may be needed to

ensure that improvements in food supply systems are translated into tangible dietary benefits, particularly for vulnerable populations such as women, children, the rural poor, and ethnic minorities.

Previous studies have explored the roles of farm production diversity, education, and income in shaping dietary outcomes, yet few have systematically assessed how market-level food environments interact with household constraints in the Vietnamese context. To provide a more integrated perspective that bridges empirical evidence with policy discourse, this paper employs systematized review for identifying both the determinants of dietary diversity and the current gaps in Vietnam's policy response, thereby offers more insights into how food systems can be made more nutrition-sensitive.

The remainder of the paper is organized as follows: Section 2 describes the methodology and criteria for selecting and analyzing the literature. Section 3 presents the main findings from the empirical studies, focusing on the MFD andHDD relationship and its key determinants. Section 4 analyzes Vietnamese policy frameworks in relation to these findings, identifying strengths and gaps. Section 5 concludes with key recommendations for policy and future research.

Methodology

This paper adopted a Systematized review approach by drawing from international literature to understand the broader dynamics between Market-level Food Diversity (MFD) and Household Dietary Diversity (HDD) with a focus on Vietnam as the context for policy analysis.

Systematized Review is a type of evidence synthesis that applies selected elements of a Systematic Review (Grant et al, 2009) such as a structured search strategy, inclusion/exclusion criteria, and source documentation, while allowing greater flexibility in scope and methodology. It is particularly suited for emerging or interdisciplinary research areas where a full systematic review may be too resource-intensive or restrictive.

It has advantages over narrative and scoping review approaches in terms of transparency, replicability, and analytical depth. While narrative reviews often summarize existing studies without a clear or transparent search process, Systematized Reviews follow a structured and replicable method for selecting and analyzing sources, which minimizes bias and facilitates the verification of the research process. Unlike scoping reviews investigate broad subjects and outline existing literature, Systematized Reviews conduct deeper analysis by concentrating on specific research questions and providing a more detailed synthesis of key findings. Thus, Systematized Reviews are more suited for objectives that require not only describing previous studies but also recognizing patterns, variables, or gaps that can inform future research or policy decisions.

However, Systematized Reviews do have certain limitations. These primarily relate to their methodological compromises in contrast to comprehensive systematic reviews. Systematized Reviews usually do not employ formal quality assessment tools or evaluations of bias risk, which can weaken the evidence evaluation process. They often lack meta-analytic methods, resulting in more descriptive findings rather than quantitative findings. Furthermore, since Systematized Reviews are frequently undertaken by individual researchers or small teams, they may be more prone to subjective biases during the screening and data extraction stages.

The theoretical basis of this paper lies in the assumption that market-level food diversity, defined as the variety and availability of food groups in local markets. It directly influences household dietary diversity, which reflects the variety of food groups consumed at the household level. This foundation is observed based on previously published evidence rather than original hypothesis testing or modeling.

The data for review were derived from five academic databases: Scopus, PubMed, EBSCOhost, Springer Link, and the Journal of Vietnam Agricultural Science and Technology (directly searched through its official website to capture relevant Vietnamese-language studies) and four grey literature sources, including government and institutional repositories. From the initial search and screening process, a total of 23 studies and 8 grey literature sources were selected. These documents were published between 2013 and 2024. The studies were categorized as follows:

- Systematized Review (20 studies):

Studies that quantitatively explored the MFD and HDD relationship, or used relevant proxies such as market-level food diversity indicators, market food availability index, household dietary diversity scores, food consumption score, and food variety score.

- Variable Extraction (18 studies):

A subset of studies from the above, which provided sufficient detail on specific factors influencing either MFD or HDD, and an empirical model for the relationship between both.

- Policy Review (3 studies + 8 grey literature documents):

Though not directly testing the MFD–HDD relationship, they provided essential insights into current policy responses and implementation gaps. These sources assessed food and nutrition policies in Vietnam, focusing on consumer behavior, food system structure, and the implementation of national nutrition strategies according to the extracted policy implications from the Systematized Review part.

In terms of policy selection criteria for review and analysis

To narrow down the range of policies discussed across peer-reviewed studies and grey literature, only policies meeting the following criteria were included in the policy review matrix:

- i. Policy Implementation in Vietnam: Only policies that were implemented or evaluated in the Vietnamese context were included to ensure local relevance.
- ii. Relevance to Nutrition and Food Systems: Policies must have explicit objectives or components targeting food security, nutrition improvement, or dietary quality.
- iii. Connection to Market-level Food Diversity (MFD): Policies should directly or indirectly address market food environments.
- iv. Impact on Household Dietary Diversity (HDD): Policies must aim to influence household food consumption patterns, either through education, access to diverse foods, or economic support.

Results and Discussion

Summary of empirical evidence on market food diversity and household dietary diversity

This paper synthesizes evidence from 20 empirical research papers conducted between 2013 and 2024 across 18 countries in Africa and Asia. The main objective of these studies was to understand what factors shape Household Dietary Diversity (HDD), key indicators of food and nutrition security. Among these, the Household Dietary Diversity Score (HDDS) was the most frequently used outcome variable, applied in 18 out of 21 studies, confirming its status as a widely accepted metric for assessing household nutritional quality.

A notable pattern that emerges from the review is the growing emphasis on market-level food diversity (MFD) and market access as critical determinants of household dietary outcomes. Specifically, 12 out of the 21 studies explicitly examined how access to food through markets, or the diversity of food available in those markets, affects dietary diversity at the household level. This group of studies consistently found a positive association between MFD and HDD, often identifying market access as a more influential factor than farm production diversity alone.

The studies utilized a variety of indicators to evaluate different aspects of food and nutrition security. Commonly used measures of household dietary diversity included the Household Dietary Diversity Score (HDDS), Women's Dietary Diversity Score (WDDS), Child Dietary Diversity Score (CDDS), and the Food Variety Score (FVS). To address market-level food diversity, indicators such as Market-level Food Diversity (MFD), Market Food Variety (MFV), and the Market Food Availability Index (MFAI) were employed. Additionally, several studies applied food security measures, including the Household Food Insecurity and Access Scale (HFIAS), Household Food Insecurity (HFI), Household Food Availability (HFA), and the Food Consumption Score (FCS). Nutritional outcomes were sometimes evaluated using anthropometric measures like Height-for-Age Z-scores (HAZ).

Table 2. Key patterns in household dietary diversity, market diversity, and food production research

Author	Country	Study Population	Key Variables	Key Findings	Policy implication
Bauman et al (2013)	Lao	96 households	(FCS)	The original Food Consumption Score (FCS) underestimates food insecurity in Laotian households. Adjusting the FCS by excluding small food quantities improved its accuracy, making it more reflective of local consumption and culture. While useful, the FCS still needs refinement to better suit the Laotian context	Nonspecific policy implication
Jones et al (2014).	Malawi	6623 households	(HDDS), (FCS), (FPD)	A consistent positive relationship between farm production diversity and household dietary diversity. This finding enhances the limited empirical evidence available that connects agricultural production diversity to improved dietary quality, particularly in rural settings	Support for Diverse Farming Practices, Focus on Nutrient-Dense Foods, Addressing Wealth Disparities,
Maxwell et al (2014).	Ethiopia	300 household	(HFIAS), (FCS), (HDDS).	Employing various food security indicators (such as CSI, rCSI, HFIAS, HHS, FCS, HDDS, and SAFS) shows differing classifications of food insecurity among households. This highlights potential issues in relying on a single indicator for food security assessments and underscores the importance of using multiple indicators for a comprehensive understanding of food insecurity	Use Multiple Indicators Understanding Indicator Sensitivity
Sibhatu et al (2015)	Indonesia, Kenya, Ethiopia, and Malawi	16,460 household	(HDDS) (FPD)	While there is a positive association between farm production diversity and dietary diversity among smallholder households, this relationship is complex and not universally applicable. The research emphasizes that factors like market access and off-	Enhancing Market Access, Supporting Off-Farm Income Opportunities,

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				farm income play a more substantial role in enhancing dietary diversity.	
Bellon et al (2016)	Benin	954 households	(OFD), (MFD), (HDDS)	The finding highlights the importance of market access in enhancing dietary diversity. The study identifies socioeconomic status as a key determinant of market participation, which accounts for how wealth and asset ownership influence access to diverse food.	Support for Diverse Production Systems. Market Access Improvements. Complementarity of Self-Production and Market Purchases. Targeted Interventions for Vulnerable Populations.
Zanello et al (2019)	Afghanistan	14,079 households	(FCS), (CDI), (LDI), (MFAI).	A significant portion of dietary diversity derives from market purchases, which highlights that market dynamics must also be considered.	Invest in Infrastructure. Facilitate Market Access. Subsidize Nutrient-Dense Crops. Promote Food Storage Technologies. Implement Seasonal Plans.
Muthini et al (2020).	Kenya	755 households, 550 women, and 205 children	(HDDS), (WDDS), (CDDS), (FPD).	While greater farm production diversity is linked to improved dietary diversity among smallholders, the overall effect is modest. This study suggests the limited impact stems from two pathways: subsistence production benefits and market dependence drawbacks. However, improving market access may be more effective in enhancing nutrition than simply increasing production diversity.	Strengthening Market Access, Promoting Market Incentives, Targeted Support for Smallholder Farmers, Research and Contextual Adaptation.

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Mekonnen et al (2020).	Ethiopia	4101 households.	(HDDS)	The research reveals significant nutrient inadequacies among households with many members, linking them to dietary patterns and emphasizing the need for diverse food consumption for adequate nutrition	Nonspecific policy implication
Mehraban et al (2021)	Indonesia	2785 rural households	(HDDS).	Increasing agricultural specialization in rural Indonesia is associated with a decline in household dietary diversity, despite rising incomes. This suggests that while market access may slightly improve dietary diversity, it does not compensate for the loss of diverse food groups produced by households themselves.	Support for Production Diversity, Market Access Enhancement, Research and Education programs.
Nandi et al (2022)	India	254 farm household	(FCS), (HDDS), (CDI), (MFD).	The findings suggest a complex interplay where market food diversity can complement dietary options alongside farm production, rather than simply replacing it, particularly in providing non-staple and nutritious food items that may not be produced on their farm.	Promotion of Local Markets. Addressing Market Food Safety. Incentives for Retailers.
Usman et al (2022)	Ethiopia and Tanzania	6,530 households from Ethiopia and 2,511 households from Tanzania	(HDDS), (FVS), (FPD).	Previous studies focused on single aspects of food security, like production or market access. This study employs various metrics to evaluate dietary diversity and consumption expenditure, tackling previous research's measurement challenges in accurate household food security indicators.	Improving Market Access. Encouraging Off-farm Income Generation. Promoting Agricultural Production Diversity. Addressing Infrastructure Gaps.
Khando et al (2022)	Bangladesh	11,720 household	(HDDS) (PDS)	A strong positive association among farm production diversity, income and dietary diversity though the extent of the association is small. This proposes that for increasing dietary diversity, efforts should be	Nonspecific policy implication

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				taken to increase farm production diversity combined with diverse income and market access	
Kabeta et al (2023)	Ethiopia	4,703 household	(HDDS) (CDI)	The Household Dietary Diversity Score (HDDS) was positively influenced by factors such as crop variety, income from livestock, the education level of the household head, and women's decision-making power. Time taken to reach local markets showed no significant effect on HDDS	Nonspecific policy implication
Vuong et al (2023)	Viet Nam	552 household	(HDDS), (HFI), (HFA),	Food-insecure households consistently exhibited reduced diet diversity, independent of other influential factors such as income sufficiency and education. Increasing food availability is positively associated with higher diet diversity, indicating that both access to diverse foods and overall food security status are critical.	Increasing the availability and access to diverse, healthy foods, Support for Agricultural Diversification, Investment in Livelihood Support Programs, Investment in Livelihood Support Programs, Cultural Considerations in Food Programs.
Hongyun Zheng and Wanglin Ma (2023)	China	1529 household	(HDDS), (CDI)	Higher level of agricultural diversity production is positively and significantly associated with higher dietary diversity. The analysis reveals that increasing the level of agricultural diversity production significantly increases the consumption levels of legumes, fruits, livestock meat, and poultry meat.	Nonspecific policy implication
Melinda Smale and	Mali	2,400 households	(OFD), (MFD)	Contrary to previous meta-analyses, local market purchase tends to have a greater overall impact on	Promotion of Crop Diversification.

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Amidou Assima (2024)			(HDDS),	women's diet quality compared to the effects of on-farm crop diversity. This study quantifies and establishes that the effect of on-farm crop diversity is indeed more significant than previously understood.	Integration of Market Development. Targeting Specific Demographics. Regional Considerations.
Huelsen et al (2024)	Malawi	In total are 701 households, out of which 563 households had at least one child.	(MFV), (CDDS), (HAZ),	While Market Food Variety is associated with better child nutrition, the relationship is weakened when controlling for household income, and maternal education. Food availability alone does not guarantee improved nutrition—a nuanced understanding of household-level constraints is necessary.	Enhancing Market Access. Supporting Processed Food Markets. Integrating Nutritional Needs. Investing in Food Retail Infrastructure.
Morrisey et al (2024).	Uganda	3123 household	(HDDS) (OFD)	While previous literature has highlighted the benefits of market access for food security, this study reveals that increased on-farm crop diversity leads to higher farm sales but does not necessarily result in increased market purchases of food.	Support for Both Crop Diversity and Market Engagement Targeted Interventions for Female-Headed Households. Encouraging Local Market Development, Education and Awareness Programs,
Rahman et al (2024)	Bangladesh	750 household	(HDDS)	Households that perform farming and livestock significantly enhance household dietary diversity in climate-vulnerable coastal areas of Bangladesh.	Strengthen agricultural extension services Provide training programs

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Abeeb Babatunde Omotoso and Abiodun Olusola Omotayo (2024).	Nigeria	480 household	(HDDS) (FCS), (CD)	Households engaged in climate-smart farming is more likely to achieve higher levels of food consumption score, dietary diversity, and food security.	Promotion of Crop Diversification. Enhanced Agricultural Extension Services Education and Training.

Zanello et al. (2019) from Afghanistan demonstrated that a significant portion of dietary diversity comes from market purchases, not self-production, especially for nutrient-rich and perishable foods. Bellon et al. (2016), working in Benin, showed that households with better market access consumed more diverse and nutritionally important foods, indicating that markets are essential in supplying what households cannot produce themselves. Similarly, Smale and Assima (2024), in their study in Mali, found that market purchases had a stronger positive impact on women's dietary diversity than on-farm crop diversity.

Other studies emphasized that while markets offer potential benefits, the ability of households to take advantage of them depends on economic access, having enough income to purchase a variety of foods. Huelsen et al. (2024), analyzing data from Malawi, found that the positive effect of market food variety on child nutrition diminished when controlling for household income and maternal education, suggesting that market access alone is not sufficient to improve diets.

The findings reveal that market food diversity is necessary but insufficient for enhancing household dietary diversity. Its effectiveness relies on broader socio-economic factors like income, purchasing power, nutritional knowledge, and gender equity. Policy implications urge investments in market infrastructure, subsidies for nutrient-dense foods, and targeted interventions for vulnerable populations to convert market improvements into dietary gains.

In addition to market-related factors, the review also explored the role of farm production diversity (FPD) in dietary outcomes. A total of 14 studies addressed this relationship, and most found a positive relationship. Jones et al. (2014) and Sibhatu et al. (2015) provided early evidence of the link between diversified agricultural production and dietary diversity. However, studies such as Mehraban et al. (2021) in Indonesia and Morrissey et al. (2024) in Uganda observed that even when farm production diversity increases, it does not necessarily lead to improved diets unless households are also integrated into food markets. This finding suggests that agricultural diversification must be paired with strong market systems to produce meaningful dietary benefits.

Other socio-economic and contextual factors further influence HDD. Several studies (e.g., Kabeta et al., 2023; Huelsen et al., 2024) identified maternal education, women's decision-making power, and access to off-farm income as important enablers of diverse diets. Usman et al. (2022) and Rahman et al. (2024) highlighted the role of livestock ownership, climate resilience, and income diversification as supporting factors. While the literature confirms that farm production diversity contributes to household dietary diversity, it is the diversity and accessibility of foods in markets that appear to play a more consistent and scalable role across contexts. The evidence points to a shift in development strategies: from focusing solely on production to recognizing the importance of market-oriented food systems. Therefore, the most effective interventions for improving dietary diversity will be those that combine support for local food production, enhanced market functionality, and inclusive socio-economic policies that empower households.

Key determinants influencing the relationship between market and household dietary diversity

Table 3 builds upon the empirical literature reviewed in table 2 by extracting and synthesizing the key variables used in quantitative models. This table focuses specifically on those studies that employed empirical models or statistical analyses to test these relationships systematically. By summarizing the dependent and independent variables across multiple models, it offers a more detailed understanding of the specific factors that influence this relationship.

This approach allows for the identification of variables such as income, market distance, farm size, education, and household composition that mediate or moderate the effect of market food diversity on diet quality. The comparative structure of the table 3 contributes to an interpretation of how market mechanisms interact with socioeconomic and demographic variables to shape dietary diversity outcomes at the household level.

Table 3. Synthesis of studies on factors influencing the linkages between agricultural production diversity, market-level food diversity

Authors	Year of Study	Dependent Variables	Independent Variables											
			OFD	MFD	HDDS	Farm size	The distance to the nearest market	Income	Household size	Education	Age	Assets	Food Expenditure	Non-food Expenditure
Jones et al	2014	FCS	(+)			(+)		(+)	(+)		(-)		(+)	(-)
		HDDS	(+)			(+)		(+)	(+)		(-)		(+)	(-)
Sibhatu et al	2015	HDDS	(+)				(-)	(+)						
Bellon et al	2016	OFD				(+)	(+)				(-)			
		MFD					(-)			(+)	(+)	(+)		
		HDDS		(+)	(+)									
Zanello et al	2019	FCS	(+)	(+)			(-)				(+)			
Muthini et al	2020	HDDS	(+)			(+)	(+)		(+)	ns	(-)	ns		
		WDDS	(+)			(+)	(+)		(+)	ns	(-)	ns		
		CDDS	(-)			(-)	(+)		(+)	ns	ns	ns		
Mekonnen et al	2020	HDDS				(+)	(+)		(-)	(+)				
Mehraban et al	2021	HDDS				ns	ns	(+)	(+)		ns			

Authors	Year of Study	Dependent Variables	Independent Variables											
Khando ker et al	2022	HDDS	(+)			(+)	(-)	(+)	(+)	(+)	ns			
Usman et al	2022	HDDS	(+)			(+)	(-)	(+)	(+)	(+)				
		FVS	(-)			(+)	(-)	(+)	(+)	(+)				
Vuong et al	2023	HDDS						(+)				(+)		
Hongyu n Zheng and Wanglin Ma	2023	HDDS	(+)			ns			(+)	(+)				
Kabeta et al	2023	HDDS	(+)					(+)		(+)				
Morrissey et al	2024	HDDS	(+)	(+)		(+)				(+)				
Melinda Smale and Amidou Assima	2024	WDDS	(+)	(+)		(+)		(+)	(-)					
		MDD-W		(+)		(+)		(+)	(-)					
Huelsen et al	2024	CDDS		(+)			(-)							
		HAZ		(+)										
		Stunting		(-)										

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Authors	Year of Study	Dependent Variables	Independent Variables											
		MFV					(-)							
Rahman et al	2024	HDDS	(+)											

Notes: (+) a positive association between the independent and dependent variables.

(-) a negative association between the independent and dependent variables.

ns: The variable was included in the model but was not statistically significant.

Blank cells: The variable was not examined in the respective study.

HDDS – Household Dietary Diversity Score; WDDS – Women's Dietary Diversity Score; CDDS – Child Dietary Diversity Score; FVS – Food Variety Score; HFIAS – Household Food Insecurity and Access Scale; HFI – Household Food Insecurity; HFA – Household Food Availability; FCS – Food Consumption Score; HAZ – Height-for-Age Z-scores; MFD – Market-level Food Diversity; MFV – Market Food Variety; MFAI – Market Food Availability Index; FPD – Farm Production Diversity; OFD – On-farm Diversity; CDI – Crop Diversity Index; LDI – Livestock Diversity Index.

Table 3 compiles evidence from 17 studies, spanning from 2014 to 2024, which quantitatively investigated the effects of both farm-level and market-level variables on dietary diversity indicators such as the Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), and Women's/Child Dietary Diversity Scores (WDDS, CDDS, MDD-W). Across these studies, the dependent variables predominantly include HDDS (used in 11 studies), followed by FCS, WDDS, CDDS, and anthropometric outcomes like stunting or height-for-age (HAZ) in child-focused research.

Among the independent variables, the most frequently examined factor was on-farm production diversity (OFD), included in 10 studies, and found to have a positive association with dietary diversity in nearly all cases. This reinforces the idea that cultivating a wider variety of crops or raising different livestock types improves the range of foods consumed at the household level. For instance, Jones et al. (2014) and Sibhatu et al. (2015) both found that OFD significantly increased HDDS and FCS, respectively, confirming earlier empirical claims about the nutritional benefits of diversified farming. Similar positive effects were found in more recent studies by Khandoker et al. (2022) and Usman et al. (2022).

In parallel, Market-level Food Diversity (MFD) or broader market access variables were modeled in 7 studies, reflecting increasing scholarly attention to how market dynamics shape nutrition. Positive associations between MFD and dietary diversity were observed in studies such as Bellon et al. (2016), Zanello et al. (2019), Smale & Assima (2024), and Morrissey et al. (2024). These results suggest that access to a diverse range of food items through the market can complement or even substitute for limited on-farm diversity, particularly in rural or resource-constrained settings. For instance, Smale and Assima (2024) reported that market food variety had a stronger influence on women's dietary quality than on-farm production, a pattern also reflected in their positive estimates for WDDS and MDD-W.

Beyond production and market diversity, the studies incorporated a range of household and the household's head socioeconomic variables. Farm size, household income, and assets were among the most commonly included variables. Income was shown to have a positive and statistically significant association with dietary diversity in at least 9 studies, including Jones et al. (2014), Muthini et al. (2020), and Kabeta et al. (2023). These findings indicate that economic access is a crucial determinant of diet quality, enabling households to afford a more diverse food basket. Similarly, asset ownership was positively associated with dietary diversity in studies such as Bellon et al. (2016) and Usman et al. (2022).

Another critical variable is distance to the nearest market, a proxy for physical market access, which appeared in 6 studies. The results were mixed: Jones et al. (2014) and Muthini et al. (2020) found a negative association, indicating that greater distance reduces dietary diversity, while other studies such as Mehraban et al. (2021) reported non-significant effects. This suggests that market distance may not be uniformly influential and its impact likely depends on broader infrastructural and mobility factors.

Variables such as education, household size, and age of the household head were included in several models, often with consistent patterns. Education, especially that of the household head or mother, was associated with better dietary outcomes in studies such as Kabeta et al. (2023) and Zheng & Ma (2023). Meanwhile, larger household size was often negatively associated with dietary diversity, as shown in Jones et al. (2014).

and Mekonnen et al. (2020), possibly reflecting resource dilution effects. Food expenditure was positively associated with dietary diversity in a few studies, underscoring the role of consumption behavior and affordability.

The synthesis of table 3 highlights three core findings. First, agricultural production diversity (OFD) consistently improves household and individual dietary diversity, though its magnitude may be context-dependent. Second, market-level food diversity (MFD) has an equally important, and sometimes greater, effect on dietary outcomes, particularly where households rely heavily on food purchases. Third, economic and educational factors—including income, assets, and schooling—moderate the effect of both farm and market variables, reinforcing the notion that dietary diversity is shaped by both availability and capability. These findings emphasize the disconnect between market food diversity and household dietary diversity. Although theory suggests a direct relationship, the economic constraints, including high food prices, low household income, unstable food supply chains, and regional disparities in market access, weaken this link.

Policy integration and gaps in the Vietnamese context

There are key Vietnamese policies related to nutrition, agriculture, and food systems, offering a useful lens through which to assess the national policy response to factors influencing Household Dietary Diversity (HDD) and Market-level Food Diversity (MFD). Table 4 complements the empirical insights from table 2 and 3 by evaluating the extent to which current Vietnamese policies address the various determinants of dietary diversity identified.

Overall, Vietnam has made notable progress in promoting dietary diversity through education and public awareness programs, particularly in recent years. Out of the 13 listed policies, seven policies explicitly incorporate dietary guidelines and nutrition education, aiming to improve food knowledge across various groups. This aligns well with empirical findings from Table 3, where studies such as Kabeta et al. (2023) and Hongyun & Wanglin (2023) show that education has a consistently positive effect on household dietary diversity. In this respect, Vietnam's policy framework has proactively addressed one of the core determinants of dietary diversity.

Table 4. Summary of food policies and their coverage concerning agricultural production, market food diversity, and dietary diversity

Policy Code	Policy Name	Year	Target Population	Key Objectives	Relevant Nutrition Components	Agri Integration	Market Food Diversity	Dietary Diversity Education
A	Decision 222/2006/QĐ UBND	2006	Farmers, local communities	Encourage safe vegetable production	–	Encourages home gardens	–	–
B	Decision 641/QĐ-TTg (2011)	2011	Children	Improve child nutrition	Dietary guidelines	–	–	Yes
C	Decision 226/QĐ-TTg (2012)	2012	General population	Nutrition communication	–	–	–	Yes
D	Decision 3073/QĐ-BNN-QLCL	2013	Farmers, consumers	Build safe agri-food supply chains	–	–	Strengthens safe food markets	–
E	Decision 272/QĐ-BCT (2015)	2015	Rural & urban consumers	Connect rural produce to urban markets	–	–	Strengthens food supply chains	–
F	Decision 9762/QĐ-BCT (2015)	2015	Rural & urban consumers	Improve market linkages	–	–	Strengthens food markets	–
G	Decree 09/2016/ND-CP	2016	General population	Fortify food with micronutrients	Micronutrient supplementation	–	–	–
H	Decision 712/QĐ-TTg (2018)	2018	General population	Improve public awareness	–	–	–	Yes

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Policy Code	Policy Name	Year	Target Population	Key Objectives	Relevant Nutrition Components	Agri Integration	Market Food Diversity	Dietary Diversity Education
I	Decision 885/QD-TTg (2020)	2020	Farmers, producers	Promote organic farming	–	Promotes diversified clean farming	–	–
J	Decision 5924/QD-BYT (2021)	2021	Children	Promote healthy school meals	Dietary guidelines	–	–	Yes
K	Decision 2195/QD-BGDDT (2022)	2022	Children	Improve school meals	Dietary guidelines	–	–	Yes
L	Decision 1294/QD-BYT (2022)	2022	General population	Prevent non-communicable diseases (NCDs) via diet	Dietary guidelines	–	–	Yes

Moreover, Vietnam has taken initial steps toward improving agricultural diversity and food safety, with policies like Policy I promoting organic and clean farming, and Policy A encouraging safe vegetable production through home gardens. These policy directions are in line with findings from table 2, particularly from studies such as Jones et al. (2014) and Khandoker et al. (2022), which emphasize the importance of farm production diversity (FPD) in improving dietary quality. However, despite these initiatives, the scope remains narrow and lacks a coordinated national strategy specifically targeting on-farm diversification for nutrition outcomes.

However, gaps begin to surface when we consider other influential variables identified in tables 1 and 2, especially those related to market mechanisms and production diversity for nutrition. While international studies such as Bellon et al. (2016), Zanello et al. (2019), and Smale & Assima (2024) repeatedly underscore the role of Market-level Food Diversity (MFD) in improving household dietary diversity (HDD), Vietnam's policy framework is largely silent on this issue. Only Policy E and F refer to improving market linkages and food supply chains. Even so, these initiatives focus on logistics and food safety rather than the availability, affordability, and diversity of nutrient-rich foods in rural and urban markets. No policy directly targets enhancing market food diversity as a nutritional objective, despite its proven importance in multiple empirical models in Table 3.

Another critical gap lies in the limited integration of agricultural production with nutritional outcomes. As shown in Table 2, studies such as Jones et al. (2014) and Sibhatu et al. (2015) recommend promoting diverse farming systems, particularly smallholder-level crop and livestock diversification, to support diet quality. Although Vietnam has policies that promote safe or organic farming Policy I, these focus mainly on food safety or environmental goals, with no explicit linkage to nutrition. Furthermore, as highlighted in table 3, variables such as farm size, income, and access to markets were found to significantly affect dietary outcomes, but Vietnamese policies do not currently address how these agricultural or economic conditions intersect with household nutrition. This reveals a disconnect between food production policy and nutrition planning.

A third major gap is Vietnam's lack of socioeconomic targeting and equity-sensitive policies. Many studies reviewed in table 2, such as Vuong et al. (2023) in Vietnam and Usman et al. (2022) in East Africa, show that low-income, food-insecure, or female-headed households face disproportionately lower dietary diversity. Similarly, table 3 reveals the importance of household income, assets, and food expenditure as determinants of HDD (in Jones et al. 2014, Usman et al. 2022, Muthini et al. 2020). Yet, most Vietnamese nutrition and food policies remain universal in design, with few targeted interventions for vulnerable groups such as rural poor, ethnic minorities, or climate-affected populations. There is currently no national policy that links livelihood support or income generation explicitly to dietary outcomes, despite global evidence suggesting the value of integrated strategies of market incentives for farmers, subsidies for nutritious food, or off-farm income promotion).

Furthermore, physical access to markets, such as distance to the nearest food outlet, was found to negatively impact dietary diversity in multiple studies (Jones et al., 2014; Muthini et al., 2020), yet Vietnamese policy does not currently prioritize rural market infrastructure for nutrition. Investment in rural roads or food distribution systems exists (often under broader development plans), but nutrition-sensitive planning remains absent.

Conclusion and Recommendations

This paper highlights a critical policy gap in Vietnam's nutrition strategy, which is the absence of a coherent link between market food diversity (MFD) and household dietary diversity (HDD), despite empirical evidence underscoring the importance of this relationship. Vietnamese policies in nutrition education are advanced, and public awareness initiatives align with evidence that education improves dietary diversity. However, these initiatives are not complemented by necessary actions to enhance the diversity, accessibility, and affordability of food in the market, especially in rural and low-income areas.

While there exist nutrition guidelines to promote health and nutrition, they are not effectively integrated with the agricultural and market systems that influence food environments. Additionally, there is organic food production policy, it prioritizes environmental and food safety objectives over the need for nutrition-sensitive agricultural diversity. While food availability may increase, economic and infrastructural constraints could prevent this availability from translating into improved household consumption.

Moreover, current Vietnamese nutrition-related policies tend to adopt a universal approach, with limited socioeconomic targeting. This contradicts evidence from both Vietnamese and international contexts that dietary diversity is significantly lower among vulnerable population, including food-insecure households, the rural poor, and female-headed households. The lack of targeted income support, livelihood diversification, or market subsidies in national nutrition planning limits the effectiveness of broader dietary interventions. Furthermore, physical access to markets, identified in multiple studies as a determinant of HDD is still not a focal point in Vietnamese policy frameworks, especially from a nutrition perspective.

To address these challenges, several policy recommendations emerge from this Systematized Review. First, Vietnam should integrate nutrition objectives into agricultural and market development policies. This entails promoting production systems that prioritize nutrient-sensitive food crops and investing in rural market infrastructure to ensure consistent, localized access to diverse foods. Second, based on global evidence that market diversity significantly influences dietary outcomes when households rely on purchased food, Vietnam national programs should explicitly aim to enhance market food diversity not only through supply chain improvements but also by supporting the affordability of healthy, perishable foods in both rural and urban markets.

Third, supported by findings in the Systematized Review indicating that food-insecure and low income households are affected by limited dietary diversity, equity-sensitive design must become a target group of Vietnam's nutrition strategy. Policies must focus on the dietary requirements of at-risk groups through specific support mechanisms, including conditional cash transfers, subsidies on nutritious foods, and agricultural resources for disadvantaged smallholders. Moreover, collaboration across sectors is vital: nutrition objectives should be integrated into agriculture, trade, education, and social protection strategies to guarantee systematic and coordinated actions as emphasized across multiple systematized review studies, which highlight the limitations of single-sector approaches. Lastly, increasing investments in food and nutrition education, particularly through community initiatives and school programs, can enhance consumer demand, enabling individuals to make healthier dietary choices by consistent positive associations between education and HDD found throughout the empirical evidence base.

Furthermore, future research should emphasize context-specific studies to empirically identify the economic and behavioral challenges that hinder the transition from market food diversity to better household dietary practices, as identified in the synthesis of determinants of systematized reviews. While market food diversity (MFD) is essential, it alone does not ensure improved nutrition unless households are both able and willing to opt for a variety of food choices. Thus, there is an urgent requirement for empirical studies exploring how variables like food prices, household income trends, gender roles in food purchasing decisions, and consumer food knowledge impact household dietary diversity (HDD). These investigations should adopt context-sensitive strategies, utilizing either mixed-methods or quasi-experimental frameworks to evaluate the effectiveness of targeted initiatives, such as food subsidies, nutrition training, or gender empowerment programs on dietary diversity results as recommended by multiple empirical studies reviewed in this paper. Such evidence would be instrumental in designing more equitable and effective food and nutrition policies in Vietnam.

References

- Baumann, S. M., Webb, P., & Zeller, M. (2013). Validity of food consumption indicators in the Lao context: moving toward cross-cultural standardization. *Food and nutrition bulletin*, 34(1), 105-119.
- Bellon, M. R., Ntandou-Bouzitou, G. D., & Caracciolo, F. (2016). On-farm diversity and market participation are positively associated with dietary diversity of rural mothers in Southern Benin, West Africa. *PloS one*, 11(9), e0162535.
- Dagar, V., & Malik, S. (2023). Nexus between macroeconomic uncertainty, oil prices, and exports: evidence from quantile-on-quantile regression approach. *Environmental Science and Pollution Research*, 30, 48363–48374.
- Even, B., Thi, T., Thu, T., Nguyen, T. D., Thai, H. T. M., Pham Thi, H. M., ... & Bene, C. (2023). Are policies in Vietnam conducive of healthy food environments? Insights from a multi-sectoral policy landscape analysis.
- Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health information & libraries journal*, 26(2), 91-108.
- Huelsen, V., Khonje, M. G., & Qaim, M. (2024). Market food environments and child nutrition. *Food Policy*, 128, 102704.
- Huynh, V. H., Nguyen, T. K. Q., Tran, M. P., Tran, T. T. H., Pham, M. D. (2018). Survey of fish consumption by women and children in An Giang province. *Journal of Vietnam Agricultural Science and Technology*, 01(86), 106-112.
- Jones, A. D., Shrinivas, A., & Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy*, 46, 1-12.
- Kabeta, T., Holst, R., Wondafrash, B., Frigessi, A., & Gebremariam, M. K. (2023). Determinants of household dietary diversity in rural Ethiopia: a household panel study. *Journal of Agriculture and Food Research*, 12, 100550.

- Khandoker, S., Singh, A., & Srivastava, S. K. (2022). Leveraging farm production diversity for dietary diversity: evidence from national level panel data. *Agricultural and Food Economics*, 10(1), 15.
- Khoi, D. K., & Linh, N. (2018). Food policy in Vietnam.
- Maxwell, D., Vaitla, B., & Coates, J. (2014). How do indicators of household food insecurity measure up? An empirical comparison from Ethiopia. *Food policy*, 47, 107-116.
- Mehraban, N., & Ickowitz, A. (2021). Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise. *Global Food Security*, 28, 100502.
- Mekonnen, D. A., Talsma, E. F., Trijsburg, L., Linderhof, V., Achterbosch, T., Nijhuis, A., ... & Brouwer, I. D. (2020). Can household dietary diversity inform about nutrient adequacy? Lessons from a food systems analysis in Ethiopia. *Food security*, 12, 1367-1383.
- Ministry of Health. (2012). *National Nutrition Strategy for 2011–2020, with a Vision toward 2030*. <https://faolex.fao.org/docs/pdf/vie142707.pdf>
- Morrissey, K., Reynolds, T., Tobin, D., & Isbell, C. (2024). Market engagement, crop diversity, dietary diversity, and food security: evidence from small-scale agricultural households in Uganda. *Food Security*, 16(1), 133-147.
- Muthini, D., Nzuma, J., & Qaim, M. (2020). Subsistence production, markets, and dietary diversity in the Kenyan small farm sector. *Food Policy*, 97, 101956.
- Nandi, R., & Nedumaran, S. (2022). Rural Market Food Diversity and Farm Production Diversity: Do They Complement or Substitute Each Other in Contributing to a Farm Household's Dietary Diversity?. *Frontiers in Sustainable Food Systems*, 6, 843697.
- National Institute of Nutrition. (2022). *Vietnam National Nutrition Strategy for 2021–2030, with a vision toward 2045*. <https://www.n4d.group/wp-content/uploads/2023/02/Vietnam-National-Nutrition-Strategy.pdf>
- Omotoso, A. B., & Omotayo, A. O. (2024). Enhancing dietary diversity and food security through the adoption of climate-smart agricultural practices in Nigeria: a micro level evidence. *Environment, Development and Sustainability*, 1-18.
- Pham, H. V., Valentin, D., Nguyen, T. T., Kunkar, S., & Perret, G. (2020). Thói quen người tiêu dùng Việt Nam và vai trò của thực phẩm tươi. *Journal of Vietnam Agricultural Science and Technology*, 14-23.
- Rahman, M. S., Zulfiqar, F., Ullah, H., Himanshu, S. K., Rahman, M., & Datta, A. (2024). Does the adoption of homestead gardening increase dietary diversity in climate-vulnerable coastal areas? Evidence from Bangladesh. *Asia-Pacific Journal of Regional Science*, 8(3), 859-878.
- Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proceedings of the national academy of sciences*, 112(34), 10657-10662.
- Smale, M., & Assima, A. (2024). Do diverse crops or diverse market purchases matter more for women's diet quality in farm households of Mali?. *Global Food Security*, 43, 100813.

- Trinh, T. H., Dao, T. A., Le, V. T. (2016). Comparison of food consumption behaviour and sourced macronutrients of perishable foods between Hanoi and Ho Chi Minh City from 2004 to 2016. *Journal of Vietnam Agricultural Science and Technology*, 12(97), 49-57.
- UNICEF. (2015). Actions and accountability to advance nutrition and sustainable development. *Global Nutrition Report*.
- Usman, M. A., & Haile, M. G. (2022). Market access, household dietary diversity and food security: Evidence from Eastern Africa. *Food Policy*, 113, 102374.
- Vuong, T. N., Dang, C. V., Jagals, P., Toze, S., Gallegos, D., & Gatton, M. (2023). Household food insecurity negatively impacts diet diversity in the Vietnamese Mekong Delta: a cross-sectional study. *Asia Pacific Journal of Public Health*, 35(4), 276-283.
- Zanello, G., Shankar, B., & Poole, N. (2019). Buy or make? Agricultural production diversity, markets and dietary diversity in Afghanistan. *Food Policy*, 87, 101731.
- Zheng, H., & Ma, W. (2023). Impact of agricultural commercialization on dietary diversity and vulnerability to poverty: Insights from Chinese rural households. *Economic Analysis and Policy*, 80, 558-569.

Urban Food Environment, Consumer Spatial Behavior, and Their Implications for Household Diet Diversity in Mandalay City, Myanmar

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Abstract

With increasing awareness on the global Sustainable Development Goals (SDGs), particularly SDG 3, and evolving public needs, the vision for food and nutrition security has transformed. Within the food system, dietary choices are shaped by food environments, which influence food availability, accessibility, and consumption behavior. This study examined these factors within the QGIS-determined food catchment areas (0.5, 1.0, and 1.5 km) of Zegyo Central Market in Mandalay City, Myanmar. Zegyo Market stands as the commercial hub of Mandalay, playing a crucial role in the local economy and food distribution network. Both primary and secondary data on retail food outlets, market classification, and consumer behavior were collected from a total of 146 households who were identified through grid sampling. To determine household diet diversity scores, demographic data and detailed household diet composition using a 24-hour diet recall period were collected through face-to-face interviews with the aid of structured questionnaire. Aside from descriptive analysis, a modified Retail Food Environment Index (mRFEI) was used to analyze the physical environment, while flow-data analysis by QGIS was utilized to know the spatial patterns of consumer behavior. Additionally, the influence of local spatial autocorrelation between consumer behavior and diet diversity was examined using Local Moran's Index. Findings from this study offered context-specific insights into urban food environments, their spatial distribution, and clustered link between consumption habits and diet diversity, providing essential evidence for the design, implementation, and monitoring of targeted policy interventions to enhance diet diversity and nutrition in Mandalay. Relevant policy recommendations were provided.

Keywords: food environment, diet diversity, spatial behavior, food choices.

JEL code: D12, I12, R22, Q18

SDG classification: SDG 2, SDG 3, SDG 11, SDG 12

Introduction

Food and nutrition security are closely linked to food system transactions, supply chains, and the broader food environment, all of which influence consumer behavior, dietary choices, and health outcomes. As studies in Southeast Asia (Gaupholm et al., 2023; Vy Thao Vuong et al., 2023) suggest, industrializing countries require localized approaches to understand the complex interactions between food environments and nutrition. In Myanmar, changing food systems have reshaped consumption patterns, especially in urban areas. The Myanmar Household Welfare Survey (2021–2022) reported declining dietary quality and diversity across all socioeconomic groups (Kristi M. et al., 2023). However, limited research exists on how urban food environments affect dietary outcomes, particularly in Upper Myanmar.

This study focuses on Mandalay City and its central food hub, Zegyo Market, to explore how urban food environments shape consumer spatial behavior and household diet diversity. Specifically, it aims to: describe the urban food environments in Mandalay City; determine household diet diversity within different food environments; examine consumers' spatial behavior and market order ranking when buying food; analyze the spatial association between consumer behavior and diet diversity within food catchment areas; and draw policy implications based on the study's findings.

The importance of market infrastructure and consumer accessibility in influencing food demand in urban Mandalay, Myanmar was emphasized in this study. The research was structured into sections including the introduction, theoretical foundation, methodology, results and discussion, conclusion, and policy recommendations through which valuable insights were provided for the enhancement of food supply chains, the improvement of access to diverse food sources, and the support of better nutrition outcomes in urban settings.

Theoretical Foundation

Central Place Theory (CPT), introduced by Christaller, W. (1933), explains the spatial distribution of markets and services based on consumer behavior. It highlights how central places—cities, towns, and villages—are organized hierarchically to serve surrounding areas. The theory is built on two key concepts: range (the distance consumers are willing to travel for goods) and threshold (the minimum population needed to support a service). Higher-order markets like central markets offer a wider variety of goods and require higher thresholds, while lower-order markets serve more localized needs with lower thresholds. CPT helps explain how distance and accessibility influence consumer decisions, with people seeking to minimize travel costs while maximizing access to goods. This principle is supported by Becker's (1965) utility theory, which emphasizes time and budget constraints in consumer choice. In Mandalay City, the spatial arrangement of Zegyo Market and surrounding smaller markets reflects this hierarchy, with concentric zones representing different food environments that shape household spatial behavior and dietary decisions. Apart from these, other factors can also influence household food choices and diet diversity. As food demand comes from consumer theory, choices and utility are the basic consumption structure.

Methodology

The study was conducted in March 2025 in Mandalay City, the main commercial and economic center of Upper Myanmar. Zegyo Market, the city's central retail hub, was identified as the focal point for analyzing the urban food environment and its impact on household diet diversity. Using QGIS software, three concentric buffer zones—0.5 km, 1 km, and 1.5 km—were generated around the market to delineate the study areas. A stratified random sampling method was employed to ensure representation from each zone. The sample size was determined using Cochran's formula, based on a 90 percent confidence level, a 10 percent margin of error, and an estimated population proportion of 0.30. A total of 146 households were selected: 48 from the 0.5 km zone, and 49 each from the 1 km and 1.5 km zones. Within each zone, households were chosen using a grid-based random sampling technique, where one household per grid cell was randomly selected. This approach ensured equal selection probability across the sampling frame and minimized selection bias.

The study collected both primary and secondary data from retail food outlets and household surveys. A structured questionnaire captured demographic information, socio-economic factors, and a 24-hour food recall to compute the Household Diet Diversity Score (HDDS). The retail food environment was analyzed using the modified Retail Food Environment Index (mRFEI). Market order index was determined based on the selected attributes and consumer spatial behavior was examined by flow-data analysis using GIS tools, then Local Moran's I in QGIS 3.42.1 was used to assess spatial patterns related to consumer spatial behavior and diet diversity.

Results and Discussion

A total of 146 respondents, representing individual households, participated in the study. These included household heads and primary food preparers, selected for their active roles in managing food-related decisions. The socio-economic analysis focused on demographics, education, household size, income, expenditure, and asset ownership across 0.5 km, 1 km, and 1.5 km buffers from Central Zegyo Market (Table 1).

Almost half of the respondents were in middle adulthood (40–59 years), and the mean age was nearly the same across all buffer zones. The sample was predominantly female, ranging from 72.92 percent to 85.71 percent across the buffers, highlighting the vital role of women in household food management. Education levels were fairly balanced in Zone A, while significantly higher numbers of respondents had completed secondary and high school in Zones B and C. Monastery education, which is common in Myanmar, was grouped under primary education. Household sizes were mainly medium, with an average of five members across all buffers, reflecting typical urban family structures. Households reported diverse income sources, with trade being the most common in Zone A (43.75%) and Zone C (44.90%), while vocational work was the most common in Zone B (42.46%). Meanwhile, Zone B had the fewest casual workers compared to Zones A and C. The presence of casual laborers without stable employment reflects the diverse socio-economic backgrounds of households within the same buffer zones in Mandalay's urban economy.

Table 1. Distribution by demographic characteristics and by buffer zone, 146 household food decisionmakers, Mandalay City, 2025

Characteristics	Category	Frequency	(%)	Mean	Frequency	(%)	Mean	Frequency	(%)	Mean
		Zone A (n=48)			Zone B (n=49)			Zone C (n=49)		
Respondent's Age	20-39 years	10	24.66	51 (13.26)	12	24.49	49 (13.55)	14	28.57	48 (13.51)
	40-59 years	22	48.63		25	51.02		24	48.98	
	≥60 years	16	26.71		12	24.49		11	22.45	
Gender	Male	13	27.08	-	13	26.53	-	7	14.29	-
	Female	35	72.92		36	73.47		42	85.71	
Education Level	Primary School	12	25.00	-	4	8.16	-	7	14.29	-
	Secondary School	14	29.17		14	28.57		17	34.69	
	High School	11	22.92		20	40.82		15	30.61	
	Higher Education	11	22.92		11	22.45		10	20.41	
Household Size	Small (2-4)	22	45.83	5 (2.30)	22	44.90	5 (2.26)	24	48.98	5 (2.17)
	Medium (5-10)	24	50.00		26	53.06		24	48.98	
	Large (>10)	2	4.17		1	2.04		1	2.04	
Primary Income Source	Merchant	9	43.75	-	21	14.29	-	22	44.90	-
	Vocational	21	18.75		7	42.46		10	20.41	
	Others	9	18.75		18	36.73		11	22.45	
	Causal Workers	9	18.75		3	6.12		6	12.24	
Household Income (US\$)	Below Living Wage (≤115)	13	27.08	247 (201)	12	24.49	341 (796)	9	18.37	330 (432)
	Above Living Wage (>115)	35	72.92		37	75.51		40	81.63	
Food Expenditure Share (%)	Very High (>75)	14	29.17	65 (20.71)	10	20.41	61 (17.05)	8	16.33	58 (17.92)
	High (65-75)	11	22.92		9	18.37		8	16.33	
	Medium (50-65)	7	14.58		22	44.90		17	34.69	
	Low (<50)	16	33.33		8	16.33		16	32.65	
	Yes=1	33	68.75		41	83.67		42	85.71	

Market Systems, Economics, and Agribusiness

Characteristics	Category	Frequency	(%)	Mean	Frequency	(%)	Mean	Frequency	(%)	Mean
		Zone A (n=48)			Zone B (n=49)			Zone C (n=49)		
Ownership of House	No=0	15	31.25		8	16.33		7	14.29	
Motorcycle Asset	Yes=1	35	72.92		42	85.71		40	81.63	
	No=0	13	27.08	-	7	14.29	-	9	18.37	-
Private Car Asset	Yes=1	9	18.75		11	22.45		12	24.49	
	No=0	39	81.25	-	38	77.55	-	37	75.51	-
Credit Asset	Yes=1	10	20.83		7	14.29		5	10.20	
	No=0	38	79.17	-	42	85.71	-	44	89.80	-

Source: Author's observation

Based on a living wage threshold of US\$115 in Myanmar (WageIndicator Foundation, 2018), the majority of households earned above this level. However, a noticeable proportion still earned below this basic required wage. In addition, the large income deviation observed in Zone B indicated that household economic conditions within the personal food environment were highly varied. Food expenditure served as a proxy for economic vulnerability. Among the identified buffers, Zone A had the highest food share (65%) on average, while the remaining two zones had its share of 61 percent (Zone B) and 58 percent (Zone C). Specifically, more than half of the household food expense shares were very high and high share in Zone A, while lower shares were noted in the remaining zones. Asset ownership indicated a moderately stable economic base. Within the buffers, a high proportion of house ownership and motorcycle ownership was commonly found in Zone B and Zone C. Overall, private car ownership is still low among households, but the ownership rate is relatively higher in Zone B and Zone C compared to Zone A. Mandalay City used to rely on bicycles for transportation, but it has now shifted to motorcycles and private cars. On the other hand, the credit asset rate was higher in Zone A, suggesting that households there had unstable incomes and still rely on credit (Table 1).

The Household Dietary Diversity Score (HDDS) assesses the variety of food groups consumed by the household over a 24-hour period, serving as a proxy for food access and nutritional security. In this study, the overall mean HDDS across Zones (A, B, and C) was 5.36 (SD = 1.64) or medium diversity. Zone B reported the highest mean HDDS at 5.76, while Zone A had the lowest at 4.98. Although still within medium diversity, among the three zones, it can be said that Zone B households had more diverse diets. In terms of diet diversity tertiles, for all zones, medium diversity was the most prevalent at 50.68 percent with Zone A having the highest proportion (58.33%) and Zone C had the least (42.86%). For the high diversity group, Zones B and C dominated with equal proportions of 42.86 percent. Those with low diversity accounted for 11.64 percent with highest prevalence in Zone A (14.58%) and least in Zone B at 6.12 percent (Table 2).

Table 2. Distribution by household dietary diversity score (24-hour recall) by buffer zone, 146 household food decisionmakers, Mandalay City, 2025

Zone of Residence	HDDS		Diet Diversity Tertile					
	Mean	SD	Low		Medium		High	
			(≤3 food groups)		(4–5 food groups)		(≥6 food groups)	
			Fre-quency	%	Fre-quency	%	Fre-quency	%
A	4.98	1.47	7	14.58	28	58.33	13	27.08
B	5.76	1.76	3	6.12	25	51.02	21	42.86
C	5.35	1.63	7	14.29	21	42.86	21	42.86
All Zones	5.36	1.64	17	11.64	74	50.68	55	37.67

Source: FAO, 2006

A physical assessment of the retail food environment was conducted within the three zones radiating from Zegyo Central Market using a Retail Food Environment Index (mRFEI) modified from NAICS (2017). Healthy food retailers (e.g., markets, mobile vendors, and registered healthy eateries) and unhealthy retailers (e.g., fast food, street food stalls, and snack shops) were identified to calculate the mRFEI score for each household in the buffer zones. Households were then classified into: food desert if mRFEI=0; food swamp if mRFEI $\leq$ 0.40; and health if mRFEI $\geq$ 0.40 based on its medium value.

Table 3. Distribution by mRFEI by buffer zone, 146 household food decisionmakers, Mandalay City, 2025

Classification	Zone A		Zone B		Zone C		All Zones	
	Mean	Number	Mean	Number	Mean	Number	Mean	Number
mRFEI	0.38 (0.07)	48	0.42 (0.10)	49	0.36 (0.09)	49	0.39 (0.09)	146
Food Desert	-	0	-	0	-	0	-	0
Swamp	0.34 (0.06)	26	0.31 (0.08)	17	0.31 (0.06)	36	0.34 (0.06)	79
Healthful	0.44 (0.02)	22	0.48 (0.05)	32	0.48 (0.05)	13	0.44 (0.05)	67

Source: Desert, swamp and healthful dummies are created according to the CDC's definitions. (CDC 2011b)

Results revealed that there was no food desert since there was no recorded mRFEI of zero in the study areas. In Zone A, 26 households were in food swamps and 22 in healthy environments. Zone B had 17 in food swamps and 32 in healthy environments. Zone C showed the greatest disparity, with 36 households in food swamps and only 13 in healthy environments (Table 3).

The comparative analysis of urban food environments across the study zones in Table 4 revealed clear spatial disparities in access to healthy food. In Zone A (0.5 km from Zegyo Market), the food environment was fairly balanced, with 54 percent of households in food swamps and 46 percent in healthy zones. Zone B (1 km buffer) had the highest proportion of households (65%) in healthy food environments, indicating better access to nutritious options. In contrast, Zone C (1.5 km buffer) was predominantly a food swamp, with 73 percent of households exposed to unhealthy food outlets. The findings highlighted the varying levels of availability of healthy food across different urban zones and the proximity to the central market influences food environment quality, with healthier options more accessible when closer to the market. While the classification differs from the USDA's broader food environment definition (USDA, 2009), it aligns with density-based methods (Amin, 2021) and effectively distinguishes food swamps from healthy environments using mRFEI scores (Table 4).

Table 4. Comparison of urban food environments by zone, 146 household food decisionmakers, Mandalay City, 2025

Buffer Zone	Food Desert Environment		Food Swamp Environment		Healthy Environment	
	Frequency	(%)	Frequency	(%)	Frequency	(%)
Zone A	0	0	26	54	22	46
Zone B	0	0	17	35	32	65
Zone C	0	0	36	73	13	27
All Zones	0	0	79	54	67	46

To examine consumers' spatial behavior by market order ranking in the study areas, six key indicators such as market size (number of vendors), product range (number of product types), forward linkage (average distance traveled by consumers), visitor volume (number of visitors), operating hours, and attractiveness vector were considered. Market size, product range and operating hours were adopted from the secondary data from the Market and Slaughterhouse Department, Mandalay City Development Committee (2025). Linkage (distance from households and visitor volume were obtained from household respondents and market car and motorcycle parking attendants. These can describe the structural and functional composition of markets in the identified study area. Then, market attractiveness was used as a proxy for consumer behavior in selecting markets for primary household food purchases.

This was done in two steps: households first assigned weights to key market attributes: travel time (0.3601), price (0.2337), range of goods (0.2205), and quality (0.1858), then rated each market on these attributes using a 7-point Likert scale. Attractiveness scores were calculated by multiplying each market's attribute score with the corresponding weight. The results showed that the fresh produce market (6.36) and central market (6.26) were the most attractive, followed by the assembly market (5.97), with the supermarket ranking lowest (5.04), reflecting household preferences across the study zones (Table 5).

Table 5. Assessment of market attractiveness by attribute, within 0.5 km, 1 km, and 1.5 km ring from the Central Zegyo market, 146 respondents, Mandalay City, 2025

Attributes	Weighted Vector	Market Attractiveness Metrics			
		Central market	Fresh produce market	Assembly market	Super-market
Travel time	0.3601	5.82	6.79	6.80	5.65
Price	0.2337	6.35	5.71	5.05	3.29
Quality	0.1858	6.44	6.41	6.16	5.67
Range of goods	0.2205	6.74	6.32	5.41	5.37
Attractiveness vector		6.26	6.36	5.97	5.04

Source: adapted from Cadwallader, M. C. (1975) and developed using literature in market information.

As shown in Table 6, markets were categorized based on key functional attributes. Each attribute was classified into four hierarchical levels using equal class intervals. For instance, market size was based on vendor numbers, ranging from 11 to 8,272. The range (8,261) was divided by four (2,065) to define class intervals, which were applied iteratively to categorize markets. The same method was used for other attributes, including market attractiveness.

Table 6. Classification of markets by hierarchical group, 131 respondents, Mandalay City, 2025

Size (Vendor Number)	Range (Product Number)	Linkage (Distance km)	Volume (Visitors Number)	Operating hours	Attractive- ness	Index
11-2,076	5	0.31-0.52	70-6,302	5-7.75	5.97-6.07	1
2,077- 4,141	6	0.53-0.73	6,303-12,535	7.76-10.5	6.08-6.17	2
4,142- 6,206	7 - 8	0.74-0.94	12,536-18,768	10.6-13.25	6.18-6.27	3
6,207- 8,272	9	0.95-1.16	18,769-25,000	13.26-16	6.28-6.36	4

Source: adapted from Ofori, B. D., & Asiedu, A. B. (2013) and developed by the author based on the primary data and secondary data on market information in the study area

To capture the spatial behavior, market order index for 12 markets in the study areas were determined using six indicators: market size, product range, forward linkage, visitor volume, operating hours, and attractiveness. Total scores ranged from 6 to 22 and were grouped into four market orders: first-order (18–22), second-order (14–17), third-order (10–13), and fourth-order (6–9). Zegyo Market emerged as the only first-order market with a top score of 22, reflecting its large vendor base (8,272), diverse product offerings, high visitor volume (25,000), long operating hours (13 hours), and strong attractiveness (6.26). Seven markets, including Man Thiri and Yadanarbon, fell into the second-order group with scores between 14 and 17, showing moderate performance across indicators. Myoma Market was the only third-order market (score of 13), characterized by smaller size, moderate linkage, and lower visitor volume. The remaining three markets, namely, 31st, Post Office, and Railway, were classified as fourth-order, with scores from 6 to 9, reflecting limited scale, short operating hours, low attractiveness, and minimal consumer reach (Table 7).

Table 7. Market order index ranking in the identified 0.5 km, 1 km and 1.5 km buffers, 131 respondents, Mandalay City, 2025

Markets	Class and Order							Market Order
	Size (Vendor Number)	Range (Product Number)	Linkage (distance km)	Volume (Visitors Number)	Operating hours	Attractiveness vector	Total	
Zegyo	4 (6,206-8272)	4 (9)	4 (0.94-1.16)	4 (18769-25000)	3 (10.5-13.25)	3 (6.17-6.27)	22 (18 – 22)	First
Man Thiri	1 (11-2075)	4 (9)	4 (0.94-1.16)	1 (70-6302)	3 (10.5-13.25)	4 (6.27- 6.36)	17 (14 – 17)	Second
Nyaung Pin	1 (11-2075)	4 (9)	3 (0.73-0.94)	1 (70-6302)	3 (10.5-13.25)	4 (6.27-6.36)	16 (14 – 17)	Second
Yadanarbon	1 (11-2075)	4 (9)	1 (0.31-0.52)	3 (12536-18768)	4 (13.25-16)	4 (6.27- 6.36)	17 (14 – 17)	Second
Man Yadanar	1 (11-2075)	4 (9)	3 (0.73-0.94)	1 (70-6302)	3 (10.5-13.25)	4 (6.27- 6.36)	16 (14 – 17)	Second
Yaw Min Gyi	1 (11-2075)	3 (7-8)	4 (0.94-1.16)	1 (70-6302)	2 (7.75-10.5)	4 (6.27-6.36)	15 (14 – 17)	Second
Pyi Kyaw	1	4 (9)	4	1	3	4	17	Second

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Markets	Class and Order							Market Order
	Size (Vendor Number)	Range (Product Number)	Linkage (distance km)	Volume (Visitors Number)	Operating hours	Attractiveness vector	Total	
	(11-2075)		(0.94-1.16)	(70-6302)	(10.5-13.25)	(6.27- 6.36)	(14 – 17)	
Yan Gyi Aung	1 (11-2075)	4 (9)	4 (0.94-1.16)	1 (70-6302)	1 (7.75-10.5)	4 (6.27- 6.36)	16 (14 – 17)	Second
31st market	1 (11-2075)	1 (5)	1 (0.31-0.52)	1 (70-6302)	1 (5-7.75)	1 (5.97- 6.07)	6 (6-9)	Fourth
Myoma	1 (11-2,075)	3 (7-8)	3 (0.73-0.94)	1 (70-6,302)	1 (5-7.75)	1 (5.97- 6.07)	12 (10-13)	Third
Post office	1 (11-2075)	3 (7-8)	1 (0.31-0.52)	1 (70-6,302)	1 (5-7.75)	1 (5.97-6.07)	8 (6-9)	Fourth
Rainway	1 (11-2075)	3 (7-8)	1 (0.31-0.52)	1 (70-6,302)	1 (5-7.75)	1 (5.97-6.07)	8 (6-9)	Fourth

Drawing on central place theory, the market distribution by consumer spatial behavior data (Table 8) and the flow-data analysis (Figure 1) in Mandalay City can be analysed by considering two key concepts: threshold (the minimum population or consumer base required to sustain a market's operations) and range (the maximum distance consumers are willing to travel to access a market's goods and services). Zegyo Market stood out as a regional hub with high threshold, attracting 45.8 percent of households (60 households) despite an average travel distance of 1.16 km and a broad range of 0.02 to 4.02 km. Its high market order reflected an ability to support diverse offerings and draw consumers from far beyond its immediate surroundings, in line with the theory that higher-order centers meet larger thresholds and offer extensive ranges.

Several markets fall into the second-order category, each reflecting a balance between localized service and a moderate consumer draw. Man Thiri in Zone A and Nyaung Pin in Zone C showed mean travel distances close to 0.96 km and 0.92 km, respectively, with ranges that suggest consumers are willing to travel beyond their neighborhoods when specific needs are met. Similarly, markets like Yadanarbon and Man Yadanar in boundary areas demonstrated lower mean travel distances (0.51 km and 0.83 km) and limited ranges (0.26–0.77 km and 0.40–1.13 km), indicating that while they fulfill the threshold requirement for a localized population, their range is naturally constrained by their service area. Additionally, Yaw Min Gyi (Zone C) with a mean distance of 1.05 km and a wide range (0.16–4.38 km) highlighted that even within the same market order, some centers can pull consumers from broader areas—potentially due to specialized goods or better pricing—thereby slightly extending their effective range. Pyi Kyaw and Yan Gyi Aung in Zone B and Boundary areas maintained a moderate consumer draw with similar travel patterns (mean distances around 1.01–1.02 km and ranges of 0.80–1.29 km), supporting their role as reliable secondary centers that satisfy local thresholds while offering a consistent service range.

Table 8. Market distribution by consumer spatial behavior, 131 respondents, Mandalay City, 2025

Market Name	No. of House holds	(%)	Mean (Distance km from Household)	Range (km)	Market Order	Market Location
Zegyo	60	45.80	1.16 (1.00)	0.02-4.02	1st	Zone A
Man Thiri	10	7.63	0.96 (0.67)	0.16-2.41	2nd	Zone A
Nyaung Pin	13	9.92	0.92 (0.92)	0.16-3.22	2nd	Zone C
Yadanarbon	2	1.53	0.51 (0.36)	0.26-0.77	2nd	Boundary
Man Yadanar	3	2.29	0.83 (0.38)	0.40-1.13	2nd	Boundary
Yaw Min Gyi	10	7.63	1.05 (1.40)	0.16-4.38	2nd	Zone C
Pyi Kyaw	7	5.34	1.01 (0.17)	0.80-1.29	2nd	Zone B
Yan Gyi Aung	6	4.58	1.02 (0.19)	0.80-1.29	2nd	Boundary
31st market	4	3.05	0.48 (0.23)	0.32-0.80	4th	Zone B
Myoma	9	6.87	0.73 (0.60)	0.02-2.09	3rd	Zone B

Market Name	No. of House holds	(%)	Mean (Distance km from Household)	Range (km)	Market Order	Market Location
Post office	4	3.05	0.40 (0.28)	0.16-0.80	4th	Zone B
Rainway	3	2.29	0.40 (0.08)	0.32-0.48	4th	Zone C

Myoma, categorized as a third-order market in Zone B, exhibited a more localized catchment with a mean distance of 0.73 km and a range up to 2.09 km. This reflected its transitional role in serving neighborhood needs while still attracting consumers from slightly farther afield, albeit with a lower threshold than higher-order markets. Finally, the fourth-order markets, namely, 31st Market, Post Office, and Rainway (located in Zones B and C), showed minimal consumer reach, with mean distances between 0.40 and 0.48 km and narrow ranges (mostly under 0.80 km). These markets meet only the local threshold, serving immediate, walk-in traffic, and do not extend a wide range, which is typical of centers catering to highly localized needs.

The integration of threshold and range concepts from central place theory into the flow-data analysis of these market orders demonstrated a clear hierarchy: higher-order markets like Zegyo require and attract larger consumer bases and support longer travel distances, while lower-order markets serve primarily localized communities. Second-order markets occupy a middle ground, with some variation reflecting differences in product specialization and consumer preference. This approach highlighted how structural factors (such as vendor count and product diversity) and spatial behavior interact to shape the urban food landscape in Mandalay City (Figure 1).

Overall, in Zone A (0.5 km), most consumers predominantly rely on nearby markets, minimizing the need for longer travel. However, by 1 km (Zone B), consumer movement patterns become more diversified, with some opting for more distant markets. This shift is likely influenced by factors such as transport accessibility and the greater variety of products available. At 1.5 km (Zone C), a significant portion of consumers travel beyond the inner zones, highlighting the importance of market specialization, affordability, and proximity to workplaces as key drivers of food sourcing behavior. Zone B exhibits a more diverse range of food sources, spanning from the first-order markets located in the central area to the fourth-order markets situated within its buffer, as well as extending to other surrounding buffers and boundaries.

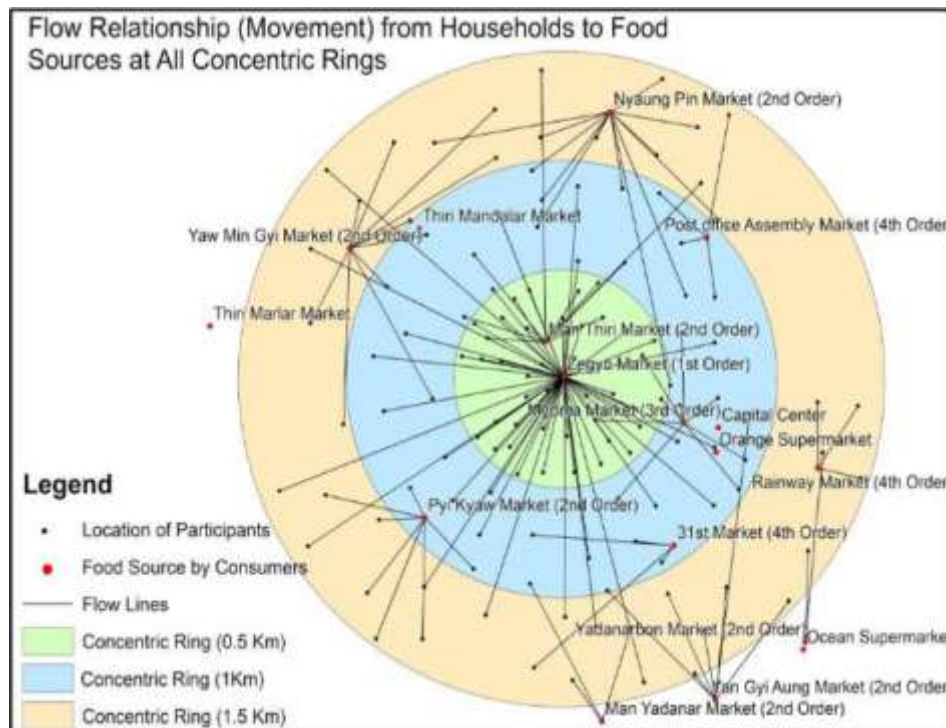


Figure 1. Consumer spatial behavior by Flow-Data-Analysis

The market order index (MOI) was used to assess how consumer behavior varies across space, specifically, how markets are spatially arranged in a hierarchy (from higher-order markets offering more goods and services to lower-order markets offering basic necessities) and how consumers interact with them based on proximity. It should be noted that given this market characterization, it was assumed that different food environments exist within each market order. The Local Moran's I analysis was employed to evaluate the presence and significance of spatial clustering and outlier patterns in household-level attributes, particularly market order index for market preferences as food sources. Spatial relationships were defined using fixed-distance spatial weights matrices at three neighborhood scales: 0.5 km, 1 km, and 1.5 km. Each household point was assigned a unique identifier, and spatial weights matrices were generated using the "Generate Spatial Weights Matrix" tool in QGIS 3.42.1. The "Local Moran's I" tool, a local indicator of spatial association (LISA), was then used to compute the Moran's I index, Z-scores, and p-values for each feature to assess the degree of spatial autocorrelation (Anselin, L., 1995). The results were mapped to visualize local spatial structures and therefore food environments and summarized across the defined scales. HH and LL clusters indicated spatial concentration of similar values, while HL and LH outliers highlighted locations where a feature diverged from its neighbors. Statistical significance was determined at a threshold of $p \leq 0.05$, aligning with common spatial epidemiology practices (Michimi & Wimberly, 2010).

The data in Table 9 provided information at three spatial scales: 0.5 km, 1.0 km, and 1.5 km, with the indicators such as total observations which represents the number of spatial observations (the number of households in each zone), ($p \leq 0.05$) which is the number of statistically significant observations at the 5 percent level, significant (%) means the

percentage of total observations that are statistically significant, High–Low transitions means consumers are moving from a higher-order market to a lower-order market and Low-High transitions means vice versa.

Table 9. Spatial autocorrelation analysis for consumer behavior, 146 respondents, Mandalay City, 2025

Scale	Total Observations	(p ≤ 0.05)	Significant (%)	High- High	Low- Low	High- Low	Low- High
0.5 km	48	13	27.08333	5	2	5	1
1 km	49	3	6.122449	2	0	1	0
1.5 km	49	15	30.61224	2	3	0	10

The highest percentage of significant observations (27.08%) was found at the 0.5 km scale, suggesting a more localized spatial relationship between market choices. The relatively high number of "High-High" and "High-Low" observations indicates that certain households tend to cluster in the higher-order market zones, while others are concentrated in lower-order market zones within close proximity to the central market. This reflected a higher preference for centrality and accessibility in market choice, which aligns with the concept of convenience and proximity in consumer behavior.

A sharp drop in the significance rate to just 6.12 percent at the 1 km scale suggests a weaker spatial autocorrelation. With only 3 significant observations, the spatial distribution of market order choices appears to be less cohesive, possibly indicating that households begin to exhibit more diverse behavior as they move further from the central market. The presence of a single "High-Low" observation reflected the influence of the central market's proximity, but this influence appears to diminish at the 1 km radius.

At the 1.5 km scale, there is a return to a higher percentage of significant observations (30.61%). This suggests that, at farther distances from the central market, there are significant patterns of clustering. The high percentage of "Low-High" observations (10 in total) indicated that lower-order market zones influence household choices, and these households may opt for the higher-order markets at this greater distance. The dominance of "Low-Low" relationships at this scale suggested that households at the periphery are more likely to frequent local markets that are smaller and less diverse but provide more convenience. The overall spatial association of consumer behavior pattern is illustrated in Figure 2.

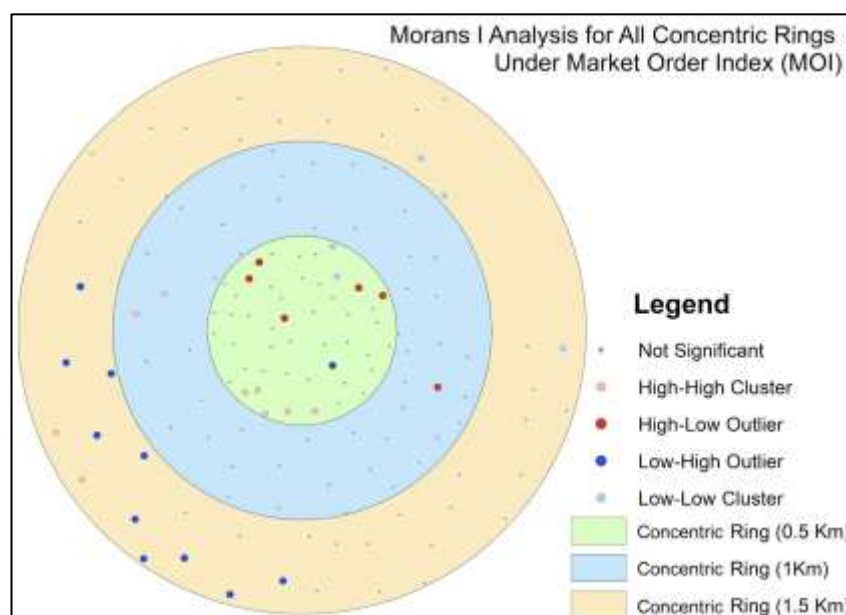


Figure 2. Spatial association of consumer behavior in market selection

The results of spatial autocorrelation analysis for household diet diversity using local Moran's I statistics at three different spatial scales: 0.5 km, 1.0 km, and 1.5 km can be seen in Table 9. The analysis aimed to assess the degree of spatial clustering or dispersion of diet diversity across households from the central Zegyo Market in Mandalay City. The local indicators of spatial association (LISA) resulted to the classification of local spatial associations into four categories; High-High (HH) - high diet diversity households surrounded by others with high diversity, Low-Low (LL) - low diversity households near others with low diversity, High-Low (HL) - high diversity households surrounded by low diversity neighbors (spatial outliers) and Low-High (LH) – low diversity households surrounded by high diversity neighbours (spatial outliers).

Table 10. Spatial autocorrelation analysis for household diet diversity, 146 respondents, Mandalay City, 2025

Scale	Total Observations	($p \leq 0.05$)	Significant (%)	High-High	Low-Low	High-Low	Low-High
0.5 km	48	8	16.67	0	1	3	4
1.0 km	49	25	51.02	6	6	4	9
1.5 km	49	5	10.20	0	1	1	3

As shown in Table 10, only 8 out of 48 observations (16.67%) showed significant spatial autocorrelation within 0.5 km scale. Mostly, spatial outliers dominated 3 High-Low and 4 Low-High, with just 1 Low-Low and no High-High clusters. This suggests that at a very local scale (neighbourhoods within 500 meters), household diet diversity is highly mixed and not strongly clustered, perhaps due to localized heterogeneity. Studies have shown that localized differences, including factors like socioeconomic status, cultural practices, or the food environment, can create variability that makes it difficult to identify distinct

clustering patterns (Cummins et al., 2014). Within 1 km scale, the strongest spatial pattern can be seen with 25 out of 49 observations (51.02%) as significant. The presence of 6 High-High and 6 Low-Low clusters indicates clear spatial clustering of both high and low diet diversity households. Another 4 High-Low and 9 Low-High outliers also suggest some spatial heterogeneity, but the dominant pattern is clustering. It indicates that this urban community shared access to food environments, socio-economic conditions, or infrastructure could influence diet diversity similarly among nearby households. Only 5 out of 49 observations (10.20%) are significant, indicating weakened spatial autocorrelation at a broader neighborhood scale of 1.5 km with the details of 1 Low-Low, 1 High-Low, and 3 Low-High associations are present, but no High-High clusters. The weak pattern suggests that diet diversity becomes spatially diluted at larger distances, possibly because households farther apart have more diverse contextual influences.

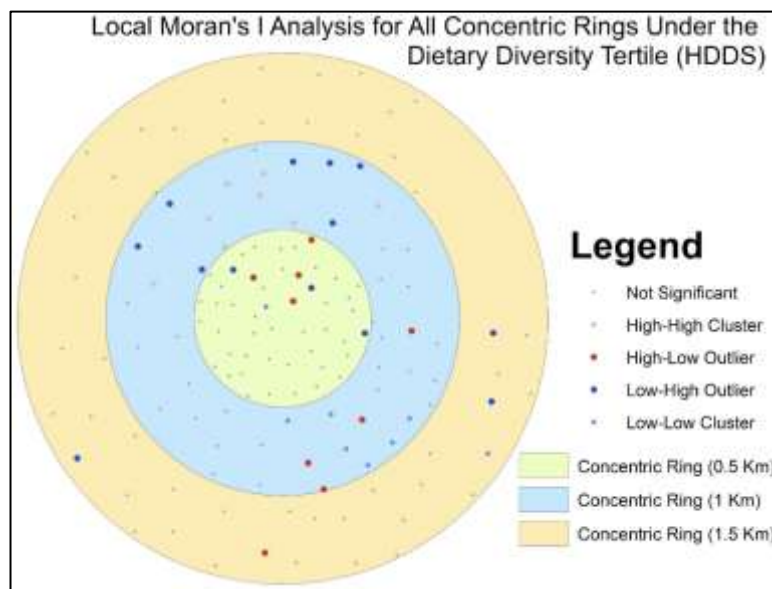


Figure 3. Spatial association of households diet diversity tertiles

The 1.0 km scale exhibited the strongest spatial autocorrelation, with 51.02 percent of observations showing statistically significant local clustering ($p \leq 0.05$). The remaining 0.5 km and 1.5 km showed much weaker spatial patterns, with 16.67 percent and 10.20 percent of observations significant, respectively. This suggests that household diet diversity is most spatially structured at the 1.0 km neighbourhood level, indicating that meaningful clustering or spatial processes occur most clearly at this intermediate distance (Figure 3).

Conclusion

In conclusion, Zone B (1 km buffer) had the most favorable food environment, with 65 percent of households in healthy zones, indicating better access to nutritious foods. As a transitional area, it reflects central place dynamics with access to diverse market orders from central first-order to local fourth-order markets showcasing complex and adaptive consumer food sourcing within the urban landscape. This is because the spatial hierarchy

of markets in the study zones reflected classic central place dynamics, where market order, consumer range, and threshold are closely linked.

The spatial patterns of consumer behavior, as observed in the Market Order Index and Household Diet Diversity Score, revealed important insights into the complexity of urban food environments and their impact on household food choices. At the 1 km scale, while market order choices exhibit weaker spatial autocorrelation, likely due to increased diversification and varying accessibility to different market types, diet diversity demonstrates a stronger spatial association. This suggests that the availability of a diverse food environment within this range promotes more varied dietary patterns. The presence of spatial clusters of households with similar diet diversity outcomes, as well as areas where individual households deviate from their neighbors, highlights the role of accessibility, socio-economic factors, and local food culture in shaping food choices and dietary outcomes. These findings highlight the need for comprehensive strategies to improve food access, affordability, and reduce inequalities in urban settings.

In terms of policy recommendations, it is crucial to improve access to smaller, localized markets, especially for low-income urban households who often depend on these markets for their daily food needs due to limited mobility and financial resources. Enhancing transportation infrastructure, walkability, and the overall accessibility of these markets is essential in reducing the physical barriers faced by vulnerable populations. Also, transportation facilities can reinforce the backward linkages within the food supply chain through improved sourcing from local producers. Conversely, it can also enhance the efficiency of distribution systems empowering market actors and enabling them to provide a broader selection of fresh, high-quality products at affordable prices across various market levels. In addition, encouraging stronger collaboration among producers, intermediaries, and retailers through improved communication facilities (e.g., mobile communication) is vital to maintaining a stable and accessible food supply, especially in lower-order markets. Improvement in the operational efficiency of stakeholders throughout the supply chain and addressing both spatial and socio-economic disparities among consumers can help build a more sustainable, inclusive, and equitable urban food environment.

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References

- Amin, M. D., Badruddoza, S., McCluskey, J. J. (2021). Predicting access to healthful food retailers with machine learning, *Food Policy*, Volume 99, 2021, 101985, ISSN 0306-9192, <https://doi.org/10.1016/j.foodpol.2020.101985>

- Anselin, L. (1995). Local Indicators of Spatial Association—LISA. *Geographical Analysis*, 27(2), 93–115. <https://doi.org/10.1111/j.1538-4632.1995.tb00338>.
- Becker, G. S. (1965). A theory of the allocation of time. *The Economic Journal*, 75(299), 493-517.
- Cadwallader, M. C. (1975). A behavioral model of consumer spatial decision making. *Economic Geography*, 51(4), 339-349. <https://doi.org/10.2307/142918>
- CDC (2011b). Census Tract Level State Maps of the Modified Retail Food Environment Index (mRFEI). Retrieved from https://www.cdc.gov/obesity/downloads/census-tract-level-state-maps-mrfei_TAG508.pdf.
- Christaller, W. (1933). Central Place Theory. Die zentralen Orte in Süddeutschland. Jena: Gustav Fischer.
- Cummins S., Flint E, Matthews S. A. (2014). New neighborhood grocery store increased awareness of food access but did not alter dietary habits or obesity. *Health Aff (Millwood)*. 2014 Feb;33(2):283-91. doi: 10.1377/hlthaff.2013.0512. PMID: 24493772; PMCID: PMC4201352.
- FAO (2006). Baseline Survey Report Protecting and Improving Household Food Security and Nutrition in HIV/AIDS Affected Areas in Manica and Sofala Province, Maputo, Mozambique. (available at http://www.foodsec.org/tr/nut/baseline_june07.pdf)
- Gaupholm J., Papadopoulos A., Asif A., Dodd W. & Little M. (2023). The influence of food environments on dietary behaviour and nutrition in Southeast Asia: A systematic scoping review. *Nutrition and Health*. 2023;29(2):231-253. doi:[10.1177/02601060221112810](https://doi.org/10.1177/02601060221112810)
- Kristi M., Derek H., Olivier E., Andrew C. & Salauddin T. (2023). Dietary quality and nutrition in Myanmar: Past progress, current and future challenges, Strategy summer program, Working paper 29, IFPRI Myanmar, February 2023.
- Michimi, A., & Wimberly, M. C. (2010). Spatial patterns of obesity and associated risk factors in the conterminous United States. *American Journal of Preventive Medicine*, 39(2), e1–e12.
- Ofori, B. D., & Asiedu, A. B. (2013). Hierarchy of market centres along the Volta Lake in Ghana: A regional development framework. *Journal of Geography and Regional Planning*, 6(8), 280-293.
- USDA. (2009). U.S. Dept. AGRIC. Access to affordable and nutritious food: Measuring and understanding food deserts and their consequences—Report to Congress, AP-036, USDA, 2009. Econ. Res. Service. Retrieved from <http://www.ers.usda.gov/Publications/AP/AP036/>.
- Vy Thao Vuong, Kathryn J. Fiorella, Andrew D. Jones, Huong Thi Trinh, Colin K. Khoury, Tuyen Thi Thanh Huynh, Ky The Hoang, Kien Tri Nguyen. (2023), The association between food environment, diet quality and malnutrition in low- and middle-income adult populations across the rural-urban gradient in Vietnam, *Journal of Human Nutrition and Dietetics/ Volume 36, Issue 6/ p. 2201-2218, October 2023*, <https://doi.org/10.1111/jhn.13242>

Food Consumption Behavior Across Generations

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Abstract

Income levels, technological developments, and lifestyle changes play a significant role in shaping the consumption patterns of each generation. These differences reflect nutritional adequacy and food diversification and provide valuable insights into how we obtain and consume food. As these aspects are integral to achieving the SDGs' goals of zero hunger, good health and well-being, and responsible consumption and production, it becomes crucial to investigate food consumption patterns across generations using Susenas data in 2023. The six generation categories- Gen-Alpha, Gen-Z, Millennials, Gen-X, Baby Boomers, and Silent-Gen-serve are analyzed in this research. Meanwhile, the indicators for observing consumption patterns are the amount of food expenditure and the nutritional adequacy value of carbohydrate and calorie consumption. Descriptive analysis shows that the share of non-food spending is greater than food in all categories of generations living in urban areas. The opposite is true for those living in rural areas. The average food expenditure (in Rupiahs) in urban areas is much greater than in rural areas. Engel's Law has also been proven to apply in all categories of generations where there is a decrease in the share of food expenditure when the income increase. Food and beverages (32%) and grains (11%) are the main expenditures. Notably, the higher the income, the more food diversification occurs. However, when analyzed by gender, there is no difference in food expenditure patterns in all generation categories.

Keywords: beverages, carbohydrates, Engel's law, expenditure, grains

JEL code: D12, D18, L66, Q18,

SDG classification: SDG 2, SDG 3, SDG 12

Introduction

Social, economic, and technological changes can affect consumption patterns; Their influence on differences in preferences in choosing types of food, how to access food, and the values that underlie consumption. These differences are influenced by several factors, namely the development of information technology, which affects access to information and nutritional awareness, especially among Millennials and Gen Z. Changes in family structure and lifestyle, where the younger generation tends to live more individualistically and chooses practical and ready-to-eat foods (Maulida et al., 2016). Increased awareness of health and sustainability issues is more prominent among the younger generation, which supports organic, plant-based, and environmentally friendly foods. Income and education levels affect purchasing power and the ability to choose healthy foods. These changes in consumption patterns between generations have significant implications for the food industry, food policy, and public health.

Understanding the dynamics of intergenerational consumption is essential to support a sustainable and inclusive food system, especially when facing global challenges such as urbanization and food crises. Differences in consumption between generations can affect food market demand, so nutritional intervention policies must be adjusted to the characteristics of the targeted generation. In addition, food consumption is not only about fulfilling biological needs, but also reflects cultural values, social status, and responses to economic and technological changes. In the context of intergenerational, there are significant differences in food preferences, frequency of eating out, attention to nutritional labels, and awareness of sustainability issues (Makowska et al., 2024). This impacts the dynamics of the food industry, the formulation of national dietary policies, and efforts to promote public health.

Previous studies have identified general trends in food consumption based on age. Some of these studies show that concern for nature and the environment significantly influences sustainable consumption behavior among Gen Z in Semarang, an Indonesian city (Diponegoro & Fatmasari, 2024) . There are differences in motivation between Gen Z and Gen Millennials in implementing sustainable consumption patterns (Savin et al., 2024) . Generation Z shows a great interest in ethical values and is concerned for future generations, while Millennials are motivated by concern for the environment and personal health. However, this study is limited by the sample size of 207 respondents. Other studies related to intergenerational consumption patterns for the case of Indonesia were conducted by Putri & Yeshika (2024) ; Wibowo et al., (2023); Pradanimas & Julaihah (2023) , while in China it was conducted by Liang et al., (2024) . In addition, previous studies also strengthen the evidence that economic change and globalization are shifting global consumption patterns (Popkin, 2006 ; Grunert, 2006) However, these studies are still local, case studies, or involve only certain commodities and relatively few respondents, especially in Indonesia. Therefore, our study analyzes the consumption patterns between generations in Indonesia more deeply, involving all population.

This study can provide evidence-based understanding of differences in food consumption between generations. It will become the basis for more targeted nutrition interventions and food education, and enrich the literature with specific generational dimensions because it involves many respondents. Thus, the government is designing more segmented policies. The food and beverage industry is adjusting its products and marketing strategies. Likewise, with local farmers and producers are due to changes in market preferences.

Therefore, this study aims to analyze food consumption patterns between generations. In more detail, this consumption pattern is described in two objectives: analyzing household food and non-food expenditure patterns and analyzing household food consumption diversification patterns. This study uses secondary data from Indonesia's 2023 National Socio-Economic Survey (Susenas). The structure of this study starts with an introduction, methodology, results, discussion, and conclusion.

Methodology

The analysis method in this study is descriptive analysis. The data used are secondary data from Indonesia's National Socio-Economic Survey (Susenas) in 2023, including Susenas KP and KOR. The analysis was conducted at the national level, with observations of more than 276 million people and more than 73 million households.

In the first objective of this study, i.e. analyzing household food and non-food expenditure patterns, the average expenditure for food and non-food groups was calculated, per capita per month, for each generation group. The age data in Susenas 2023 is grouped by generation based on empirical studies of social and demographic researches, with the following groupings. Moreover, the calculation of the average food and non-food expenditure is further detailed with cross-tabulation between generation groups with location (urban and rural), gender (male and female), and expenditure quintile.

Table 1. Classification of generation based on age

Generation	Year of birth	Age in 2023 (years)
Silent Generation	1928 – 1945	78 – 95
Baby Boomers	1946 – 1964	59 – 77
Gen X	1965 – 1980	43 – 58
Millenials	1981 – 1996	27 – 42
Gen Z	1997 – 2012	11 – 26
Alpha	2013 – 2023	0 – 10

The second objective of this study focused on consumption and expenditure on the food side. In this objective, the analysis is on the pattern of food diversification, observed in terms of carbohydrate consumption.

The data presented are carbohydrate intake (in grams/capita/week) and expenditure value (USD/capita/week) for each of the 14 food groups, consisting of: (a) rice, (b) tubers, (c) fish/shrimp/squid/shellfish, (d) meat, (e) eggs and milk, (f) vegetables, (g) nuts, (h) fruits, (i) oil and coconut, (j) drink ingredients, (k) spices, (l) other food ingredients, (m) prepared food and beverages, and (n) cigarettes and tobacco. Further in-depth study was conducted by observing the expenditure value of 14 food groups (USD/capita/week) for each generation group.

The next analysis is the calculation of the average carbohydrate intake from its primary sources. Based on Susenas data, there are 6 primary sources of carbohydrates identified, namely: (a) rice, (b) cassava, (c) instant noodles, (d) white bread, (e) sweet bread, and (f)

meatball noodles / boiled noodles / fried noodles. In addition to the calculation at the national/aggregate level, the carbohydrate intake of the six types of food above is disaggregated based on expenditure quintile groups, generation, location, and gender.

Results and Discussion

Household food and non-food expenditure patterns

Based on Susenas data in 2023, food expenditures include spending on food and beverage consumption, both at home and outside the house. Examples include purchases for rice and cereals, meat, fish, and eggs, vegetables and fruit, oil, spices, and processed foods and beverages. Meanwhile, non-food expenditures include housing and fuel costs (rent, electricity, water), education and health, transportation and communication, clothing, recreation, and personal care.

Nationally, the monthly household expenditure for non-food is greater than food in the silent gen, baby boomers, Gen X, millennials, Gen Z, and alpha groups. The total spending (sum of food and non-food expenditure) from the Silent Generation to Gen X continues to increase, and the highest is Gen X expenditure. This group has sufficient work experience, so they already at their settle income. The amount of this income is in line with the amount of expenditure. The increase in spending for non-food is more critical than food in the three groups. After that, the millennial and Gen Z groups have expenses for food and non-food that tend to decrease.

Gen X and millennial groups are productive generations with more complex and modern consumption patterns. Gen X is the generation with highest average expenditure in USD 99.52/month/capita (Figure 1), followed by Baby Boomers and Millennials. Gen Alpha has the lowest total expenditure (USD 79.02/month/capita). Meanwhile, non-food expenditure is higher in the Gen X, Millennials, and Baby Boomers generations, indicating a preference for modern consumption. Gen Alpha is the only generation with higher food expenditure than non-food.

Although food expenditure patterns are relatively similar across generations, the gap between non-food and food expenditure is decreasing along with the younger generation. This shows that the younger generation spends more on technology and entertainment, while the older generation focuses on health and household needs (OECD, 2019a). The shift towards non-food spending is considered an indicator of increasing welfare. An increase in non-food spending, especially education and health, can support long-term economic growth (World Bank, 2019) .

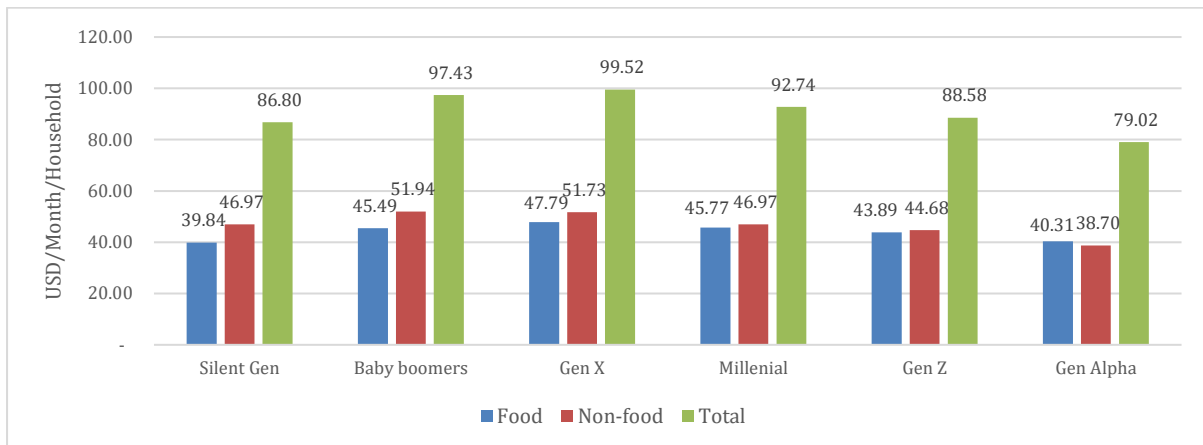


Figure 1. Average household food and non-food expenditure by generation

Source: Susenas (2023)

When viewed based on generation and location of residence, it can be seen that expenditure on food is greater than non-food for households in rural areas. The opposite occurs for those living in urban areas. This phenomenon applies to all types of generations. In addition, urban households have higher total expenditure than rural households across all generations. The highest average total expenditure in urban areas is for Baby Boomers (USD118.09/month/capita), while in rural areas, the highest is for Gen X (USD77.22/month). The most significant gap between rural and urban regions occurs in the non-food component, reflecting the city's higher need for modern services and goods (transportation, education, housing).

This finding is in line with the results of the analysis from BPS (2022). Urban households allocate more for non-food items, such as transportation, communication, and education, while in villages, spending is still dominant for basic needs (food). Urbanization influences this, driving a shift in consumption to more complex goods and services (non-food). Urban infrastructure accelerates changes in consumption patterns.

Next, the Silent and Baby Boomers groups focus on food and health. Meanwhile, Millennials and Gen Z spend more on non-food (lifestyle, online transportation, entertainment, digital subscriptions) or those related to technology. Gen Alpha is not yet financially independent, so its proportion follows adult households. If associated with Engel's law, it can be said that the proportion of spending on food will decrease as income increases, clearly seen in urban areas and productive generations.

Gen X and Baby Boomers have the highest total expenditure, indicating that the productive and near-retirement age groups have higher purchasing power. Gen Alpha (children) has the lowest expenditure, reflecting limited purchasing power due to dependence on parental households. The younger generation (Millennials and Gen Z) tends to show relatively higher non-food expenditure, reflecting modern consumption patterns such as gadgets, online transportation, and digital lifestyles.

Table 2. Average household food and non-food expenditure by generation and location (USD/month/capita)

Type of Generation	Categories	Rural	Urban
Silent	Food	35.10	44.13
	Non-food	27.08	65.01
	Total	62.18	109.14
Baby Boomers	Food	40.09	49.77
	Non-food	31.29	68.32
	Total	71.38	118.09
Gen X	Food	42.60	51.46
	Non-food	34.62	63.83
	Total	77.22	115.29
Millennials	Food	40.25	49.59
	Non-food	30.85	58.16
	Total	71.10	107.75
Gen Z	Food	39.12	47.19
	Non-food	29.80	54.98
	Total	68.92	102.18
Alpha	Food	36.07	43.51
	Non-food	26.91	47.60
	Total	62.98	91.11

Source: Susenas (2023)

Food and non-food expenditure patterns based on gender and generation show differences in total expenditure between male and female. The highest total expenditure is in Gen-X, where female's expenditure is USD101.24/month/capita and men's is USD97.79/month/capita (Table 3). The gap in this group is the highest where female heads of households spend more, especially on non-food components. Female heads of families in almost all generations allocate more for non-food, such as education, health, and transportation, indicating concern for the household's quality of life. Female tend to be more economical in food consumption but higher in education and health. Meanwhile, expenditure in the Baby Boomer and Silent groups is almost identical between male and female.

Female are more sensitive to children's needs and education, so non-food allocations tend to be higher, while male tend to focus on food spending and immediate needs (Rachmawati et al., 2024). The Silent Gen and Baby Boomers groups are more conservative, spending a lot on food and health. Gen-X and Millennials are shifting to non-food consumption, such as lifestyle and transportation. Gen Alpha does not yet have an independent consumption pattern, so they are following the household pattern. Gen-X and Baby Boomers have the highest total expenditure, reflecting their central economic

role in the family. Gen-Alpha has the lowest total spending in all categories, because they are still dependent (children). In each generation, the non-food component tends to be greater than food, except for Gen-Alpha.

Table 3. Average household food and non-food expenditure by generation and gender (USD/month/capita)

Type of Generation	Categories	Male	Female
Silent	Food	39.78	39.88
	Non-food	46.88	47.03
	Total	86.66	86.91
Baby Boomers	Food	46.14	44.88
	Non-food	51.38	52.47
	Total	97.52	97.35
Gen X	Food	47.62	47.97
	Non-food	50.16	53.27
	Total	97.79	101.24
Millennials	Food	46.66	44.86
	Non-food	46.53	47.42
	Total	93.19	92.28
Gen Z	Food	44.58	43.19
	Non-food	43.98	45.41
	Total	88.56	88.60
Alpha	Food	40.42	40.20
	Non-food	38.92	38.48
	Total	79.34	78.68

Source: Susenas (2023)

Monthly household expenditure is divided into five groups (quintiles): quintile 1 = the poorest 20% and quintile 5 = the wealthiest 20%. Susenas 2023 data show an evident increasing trend from Quintile 1 to Quintile 5, both in food and non-food expenditure. Quintile 5 (the richest) spends 3–8 times more than Quintile 1, especially for non-food components. For example, for the Silent Generation, non-food expenditure increased from USD 11.97/month/capita (Q1) to USD 169.48/month/capita (Q5). This proves the validity of Engel's Law, where as income increases, the proportion of expenditure on non-food increases more sharply than food.

The Silent Generation and Baby Boomers in the upper quintile (Q5) have the highest total expenditures compared to other generations. Gen Alpha has lower total spending across all quintiles, consistent with their role as dependents. The composition of consumption patterns across generations is quite similar, but older generations tend to have a higher proportion of non-food expenditures as they move up the quintile.

Table 4. Average household food and non-food expenditure by generation and expenditure groups (USD/month/capita)

Type of Generation	Categories	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Silent	Food	19.96	29.55	38.05	49.46	82.49
	Non-food	11.97	19.38	28.30	42.71	169.48
	Total	31.92	48.93	66.35	92.17	251.97
Baby Boomers	Food	20.42	29.69	38.67	50.44	82.94
	Non-food	12.02	19.43	28.07	42.00	143.47
	Total	32.43	49.11	66.74	92.44	226.41
Gen X	Food	20.46	29.49	38.38	50.30	83.85
	Non-food	12.53	19.89	28.37	42.33	126.20
	Total	32.99	49.38	66.76	92.63	210.05
Millennials	Food	20.54	29.60	38.60	50.39	84.95
	Non-food	12.36	19.61	28.10	41.99	124.18
	Total	32.90	49.22	66.69	92.37	209.12
Gen Z	Food	20.43	29.48	38.24	49.93	81.37
	Non-food	12.41	19.85	28.41	42.36	120.62
	Total	32.84	49.32	66.65	92.29	202.00
Alpha	Food	20.30	29.51	38.20	49.57	79.80
	Non-food	12.16	19.61	28.25	42.38	117.33
	Total	32.46	49.12	66.45	91.95	197.13

Source: Susenas (2023)

Household food consumption diversification patterns

The amount of carbohydrate consumption (in grams per capita per week) reached 2,118 grams/capita/week with expenditure (in USD per capita per week) of USD 10.42/capita/week (Table 5). Grains (especially rice) are the most dominant food group, reaching 1,264.8 grams/capita/week, or around 60% of total carbohydrate consumption. Followed by processed foods and beverages (376.5 grams) and drink ingredients (146.9 grams). Consumption of carbohydrate from meat, fish, and eggs is relatively small in volume but has a reasonably significant expenditure value.

Prepared food and beverages are the food group with the largest expenditure, which is USD 3.33/capita/week, reflecting the trend of consuming ready-to-eat food or eating out. Although not having a gram consumption, cigarettes and tobacco recorded the second highest expenditure (USD 1.33/capita/week), indicating the economic burden of unproductive goods. Meanwhile the staple foods such as grains, consumed in large quantities, only absorb USD 1.17/capita/week, which is relatively cheap compared to processed products.

The ratio between consumption and expenditure shows that staple foods (grains) are economically efficient. In contrast, processed foods and cigarettes have high expenditures even though their carbohydrate content is relatively small. Dependence on processed products shown by high expenditure on processed foods reflects changes in household lifestyles, which may shift from home cooking to ready-to-eat foods due to business or taste preferences. Processed foods and sweetened beverages are the most significant contributors to calories, but do not support nutritional adequacy, the trend of increasing consumption of processed foods in big cities (Nurhasanah et al., 2024). Consumption of meat and fish is susceptible to price change, decreasing when food inflation rises

Meanwhile, animal consumption such as meat (0.3 grams/capita/week) and fish (7.6 grams/capita/week) is very low. Indonesia faces a triple burden of malnutrition: micronutrient deficiencies, overweight, and chronic energy deficiency (Andriani et al., 2023). Low animal protein consumption is a significant challenge in many households. This shows the problem of economic accessibility, low consumption preferences for animal protein, and the potential for malnutrition, especially in low-income families.

Table 5. Household food consumption expenditure and consumption intake by type of food

Type of Food	Consumption (gram/capita/week)	Expenditure (USD/capita/week)
Rice	1,264.8	1.17
Tubers	71.9	0.13
Fish/shrimp/squid/shellfish	7.6	0.85
Meat	0.3	0.52
Eggs and milk	23.6	0.55
Vegetables	51.4	0.84
Nuts	20.6	0.22
Fruits	84.0	0.48
Oil and coconut	4.2	0.27
Drink ingredients	146.9	0.30
Spices	8.8	0.22
Other food ingredients	57.3	0.20
Prepared food and drinks	376.5	3.33
Cigarettes and tobacco	0.0	1.33
Total	2,118.0	10.42

Source: Susenas (2023)

Based on the total expenditure for food consumption by generation, Gen-X has the highest food expenditure (USD11.15/capita/week), followed by Millennials (USD10.68/capita/week) and Baby Boomers (USD10.61/capita/week). Gen Alpha and Silent Generation spend the least, USD9.41/capita/week and USD9.30/capita/week,

respectively. Gen Alpha is low because they still depend on their parents' household. Silent Gen may show conservative consumption patterns or simpler food preferences.

Prepared food and beverages are the most significant expenditure components across generations. Gen X expenditure: USD3.54/capita/week; Millennials: USD3.48/capita/week; Baby Boomers: USD3.07/capita/week. This shows a strong consumption trend towards prepared food across all age groups, especially the productive and urban generations. The second highest expenditure occurs on cigarettes and tobacco, especially among Gen X: USD1.50/capita/week; Baby Boomers: USD1.26/capita/week; Millennials: USD1.39/capita/week. This consumption shows that the expenditure burden on non-productive goods is quite large.

Spending on meat and fish increases among younger generations, with the highest spending among Gen X and Millennials. Eggs and milk are pretty high among Gen Alpha (USD 0.67/capita/week), indicating households' focus on children's nutritional needs. Older generations (Baby Boomers) tend to spend more on vegetables (USD 0.96/capita/week) and fruits (USD 0.55/capita/week) than younger generations.

Table 6. Household expenditure for food consumption by generation and type of food (USD/capita/week)

Type of food	Silent Gen	Baby boomers	Gen X	Millennials	Gen Z	Alpha Gen
Rice	1.19	1.29	1.25	1.14	1.17	1.06
Tubers	0.13	0.15	0.14	0.13	0.13	0.11
Fish/shrimp/squid/shellfish	0.75	0.91	0.93	0.85	0.83	0.75
Meat	0.46	0.53	0.56	0.54	0.51	0.48
Eggs and milk	0.49	0.50	0.48	0.63	0.46	0.67
Vegetables	0.84	0.96	0.91	0.83	0.80	0.72
Nuts	0.25	0.27	0.24	0.21	0.20	0.18
Fruits	0.51	0.55	0.52	0.49	0.44	0.42
Oil and coconut	0.29	0.32	0.30	0.27	0.26	0.24
Drink ingredients	0.32	0.36	0.33	0.30	0.28	0.25
Spices	0.22	0.25	0.24	0.22	0.21	0.19
Other food ingredients	0.17	0.20	0.22	0.21	0.21	0.18
Prepared food and drinks	2.82	3.07	3.54	3.48	3.38	3.04
Cigarettes and tobacco	0.84	1.26	1.50	1.39	1.36	1.11
Total	9.30	10.61	11.15	10.68	10.24	9.41

Source: Susenas (2023)

According to the average carbohydrate intake from its main sources, total carbohydrate consumption is dominated by rice at 1,203.3 grams/capita/week, making it the primary source of carbohydrates. It is followed by Instant noodles: 42.5 grams/capita/week; meatball noodles/boiled/fried: 37.5 grams/capita/week; sweet bread/other bread: 26.8

grams/capita/week; and cassava consumption is relatively small (33.6 grams/capita/week). The next discussion is analysis of carbohydrate consumption patterns across quintile groups, generations, locations (rural/urban), and gender.

Rice remains dominant in all quintiles, but peaks in quintiles 3–4 (around 1,233 grams/capita/week). Quintile 5 (the richest) has the lowest rice consumption (1,153.1 grams/capita/week) but much higher instant noodles and bread consumption, indicating food diversification and preferences for instant foods. Instant noodles rose dramatically from 29.6 grams/capita/week (Q1) to 53.4 grams/capita/week (Q5). White and sweet bread increased sharply in the upper quintiles, reflecting urban and modern consumption patterns.

Boomers and the Silent Generation consume the highest amount of rice and cassava (more than 1,300 grams and 50 grams). The younger generation (Alpha, Z, and Millennial) show lower consumption of rice and cassava, but high in instant noodles and fried noodles, such as: Gen Z: instant noodles 44.3 grams/capita/week; fried/boiled noodles 40.7 grams/capita/week; Alpha: fried/boiled noodles 34.4 grams/capita/week; Bread consumption is relatively stable across generations, although slightly higher in Gen Alpha.

Villagers consume more rice (1,313.4 grams/capita/week) and cassava (41.4 grams/capita/week), indicating a dependence on traditional carbohydrate sources. Urban residents consume more instant noodles (45.3 grams/capita/week), white bread (21.1 grams/capita/week), and fried noodles (42.4 grams/capita/week), indicating a preference for practical and processed foods. Meanwhile, based on Gender, it shows that Men are slightly higher in consuming instant noodles (43.2 grams/capita/week) and rice (1,209.5 grams/capita/week). Women consume more white bread (16.3 grams/capita/week) and boiled/fried noodles (37.7 grams/capita/week), but the differences are slight.

Table 7. Carbohydrate Intake (grams/capita/week)

Categories		Rice	Cassava	Instant noodles	White bread	Sweet bread, other breads	Meatball noodles, boiled noodles, fried noodles
AGGREGATE		1,203.3	33.6	42.5	15.8	26.8	37.5
Quintile	1	1,172.2	32.0	29.6	4.2	20.1	22.5
	2	1,226.6	33.5	37.6	6.9	24.6	31.3
	3	1,233.8	34.1	42.8	10.1	27.0	37.6
	4	1,233.7	34.9	48.7	16.5	29.3	43.9
	5	1,153.1	33.7	53.4	40.1	32.5	51.8
Generation	Alpha	1,111.6	26.7	39.5	15.1	27.4	34.4
	Z	1,205.9	31.4	44.3	14.6	26.3	40.7
	Millennials	1,161.5	29.4	43.2	16.5	27.0	38.4
	X	1,261.7	36.6	44.3	15.7	26.2	40.2

Categories		Rice	Cassava	Instant noodles	White bread	Sweet bread, other breads	Meatball noodles, boiled noodles, fried noodles
	Boomer	1,314.8	50.9	39.3	17.9	27.0	30.3
	Silent	1,265.4	52.1	34.8	18.5	29.3	25.0
Rural/urban	Rural	1,313.4	41.4	38.7	8.4	27.1	30.9
	Urban	1,124.0	28.1	45.3	21.1	26.5	42.4
Gender	Male	1,209.5	33.6	43.2	15.3	26.7	37.4
	Female	1,197.0	33.7	41.9	16.3	26.8	37.7

Source: Susenas (2023)

Conclusion

Based on the previous discussion, it can be concluded that:

1. Household food and non-food expenditure patterns:
 - a. Urban areas show more modern and complex consumption patterns, especially in non-food components. Generational differences affect consumption priorities: from basic needs (food) to lifestyle and technology needs.
 - b. Female-headed households tend to allocate higher expenditures to essential non-food sectors such as education and health. Differences in patterns across generations reflect shifts in lifestyles and consumption priorities, which must be considered when formulating social and economic policies.
 - c. The increase in non-food expenditures aligns with the increase in welfare and productive age, supporting Engel's Law.
2. Household food consumption diversification patterns:
 - a. Grains and processed foods dominate household carbohydrate intake and expenditure. Consumption of animal protein is still very low, potentially impacting nutritional quality. High expenditure on ready-to-eat foods and cigarettes indicates the need for educational interventions on healthy consumption and strengthening household food security.
 - b. The productive generation (Gen X and Millennials) has the highest purchasing power and spending, especially on processed foods and cigarettes.
 - c. Changes in consumption patterns are visible: from staple foods to consumption of practical foods and recreational goods (cigarettes).
 - d. The older generation (Silent Boomers) maintains more conservative food consumption and a relatively even allocation.
 - e. Rice is still the primary source of carbohydrates. Still, there is a shift in consumption to processed foods (instant noodles, bread, fried noodles) in the younger generation, upper quintile (high income), and urban areas. This indicates a change in lifestyle consumption and potential future nutritional challenges (high in calories but low in nutrients).

Some policy recommendations from the analysis results in this study are:

1. For the government:
 - a. The government can adjust social assistance and subsidies based on regional and age consumption patterns.
 - b. Public services (education, transportation) should be provided in villages to make non-food expenditure more productive.
 - c. Age-based approach to cross-generational financial education or subsidies.
 - d. Developing generation-based policies for family economic planning and poverty alleviation.
 - e. Social intervention programs such as food or education subsidies should target the lower quintile of the younger generation (Millennials and Gen Z) and families with children (Gen Alpha).
 - f. Nutrition and healthy food intervention programs can focus more on households with children (Gen Alpha) to strengthen the nutritional resilience of future generations.
 - g. Future food policies need to balance the availability of staple foods and education on healthy consumption of processed products.
2. For household:
 - a. Support for women's households through education and health programs.
 - b. Healthy consumption education is needed, especially for the younger generation, to balance food spending between ready-to-eat food and nutritious raw materials.
 - c. Smoking control policies are still very relevant because the proportion of cigarette spending remains high across generations.

References

- Andriani, H., Friska, E., Arsyi, M., Sutrisno, A. E., Waits, A., Rahmawati, N. D. (2023). A multilevel analysis of the triple burden of malnutrition in Indonesia: trends and determinants from repeated cross-sectional surveys. *BMC Public Health*, 23, 1836. <https://doi.org/10.1186/s12889-023-16728-y>.
- BPS, B. (2022). *Expenditure for Indonesian Population Consumption, March 2022*. <https://www.bps.go.id/id/publication/2022/10/20/b9e45d7c9aeb2112005aaf53/pengeluaran-untuk-konsumsi-penduduk-indonesia--maret-2022.html>
- Diponegoro, U., & Fatmasari, AE (2024). Predicting Sustainable Consumption Behavior among Generation Z: Role of Nature Relatedness and Environmental Concern. *Psychological Research on Urban Society*, 7 (1). <https://doi.org/10.7454/proust.v7i1.1154>
- FAO, F. (2017). *The Future of Food and Agriculture – Trends and Challenges*.
- Grunert, K. G. (2006). How changes in consumer behavior and retailing affect competency requirements for food producers and processors. *Economía Agraria y Recursos Naturales (Agricultural and Resource Economics)* , 6 (February 2006), 3–22. <http://recyt.fecyt.es/index.php/ECAGRN/article/view/14334>
- Liang, J., Li, J., Cao, X., & Zhang, Z. (2024). Generational Differences in Sustainable

- Consumption Behavior among Chinese Residents: Implications Based on Perceptions of Sustainable Consumption and Lifestyle. *Sustainability (Switzerland)*, 16 (10). <https://doi.org/10.3390/su16103976>
- Makowska, M., Boguszewski, R., & Hrehorowicz, A. (2024). Generational Differences in Food Choices and Consumer Behaviors in the Context of Sustainable Development. *Foods*, 13(4), 521. <https://doi.org/10.3390/foods13040521>
- Maulida R, Nanishi K, Green J, Shibanuma A, Jimba M. (2016). Food-choice motives of adolescents in Jakarta, Indonesia: the roles of gender and family income. *Public Health Nutrition*, 19(15):2760-2768. doi: 10.1017/S136898001600094X.
- Nurhasan, M., Ariesta, D.L., Utami, M.M.H., Fahim, M., Aprillyana, N., Maulana, A. M., Ickowitz, A. (2024). Dietary transitions in Indonesia: the case of urban, rural, and forested areas. *Food Security*, 16, 1313–1331. <https://doi.org/10.1007/s12571-024-01488-3>
- OECD, O. (2019a). *Household Consumption across Generations*.
- OECD, O. (2019b). *The Heavy Burden of Obesity: The Economics of Prevention*.
- Popkin, B. M. (2006). Global nutrition dynamics: The world is shifting rapidly toward a diet linked to noncommunicable diseases. *American Journal of Clinical Nutrition*, 84 (2), 289–298. <https://doi.org/10.1093/ajcn/84.2.289>
- Pradanimas, A., & Julaihah, U. (2023). Generation Z Consumptive Online Behavior Patterns Based on Consumption Theory in an Islamic Economic Perspective. *Business and Accounting Research (IJEBAR) Peer Reviewed-International Journal*, 7 (4), 1–13. <https://jurnal.stie-aas.ac.id/index.php/IJEBAR>
- Putri, AD, & Yeshika, A. (2024). The Moderating Role of Generation Differences Determinant Factors of Sustainable Apparel Behavior Intention. *Indonesian Journal of Business and Entrepreneurship*, 10 (1), 154–167. <https://doi.org/10.17358/ijbe.10.1.154>
- Rachmawati, L., Cahyono, H., Hanifa, N., Vansyah, LRR, & Yanuarti, WA (2024). Factors Affecting Indonesian Women's Spending During the Covid-19 Pandemic. *KnE Social Sciences*, 814–826. <https://kneopen.com/KnE-Social/article/view/15123/>
- Savin, P.-S., Rusu, G., Miu, C.-M., Ciocodeica, D.-F., & Kasem, EIFT (2024). Generational Perspectives on Sustainable Consumption: Exploring Consumer Behavior of Millennials and Generation Z. *Proceedings of the 7th International Conference on Economics and Social Sciences*, 380–391. <https://doi.org/10.24818/ices/2024/038>
- Wibowo, FS, Hurdawaty, R., & Sulistiyowaty, R. (2023). Studying the Consumption Behavior of Generations Y and Z towards Ready-To-Drink Coffee. *International Journal of Travel, Hospitality and Events*, 2 (1), 285–300. <https://doi.org/10.56743/ijothe.v2i1.220>
- World Bank, WB (2019). Indonesia Economic Quarterly – Investing in People. In *World Bank* (Vols. 1–76, Issue 8969).

Performance and SWOT Analysis of Food Micro, Small, and Medium Enterprises in Nay Pyi Taw

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Abstract

Food Micro, Small, and Medium Enterprises (Food MSMEs) play a crucial role in the value-added chain, linking agricultural raw materials to industrial development. They are a significant source of job creation, export earnings, and the initiation of industrial growth. Given the notable advancements made by Myanmar's MSMEs in the food sector, it is necessary to examine the current status of food MSMEs. This study evaluates the profiles, current performance, strengths, weaknesses, opportunities, and threats of Food MSMEs in Nay Pyi Taw Union Council. The institutional, business, and demographic characteristics of 158 Food MSMEs, selected from all registered Food MSMEs, were interviewed from April to October 2024 using a purposive sampling method. The findings highlighted distinct circumstances among three categories of Food MSMEs, insights into their unique challenges and advantages, as well as the perspectives of their owners and managers regarding these characteristics. Micro enterprises benefited from a strong domestic market, availability of raw materials, and higher value-added production, but faced workforce shortages, high production costs, and limited financial literacy. Small enterprises excelled in leveraging domestic demand, raw materials, and government support for loans and training, although they encountered challenges with machinery and equipment. Medium enterprises struggled with machinery requirements and obtaining government permissions and licenses. Micro enterprises had opportunities for technology access and job creation, while small and medium enterprises could explore export markets and adapt to government regulations. Threats included lack of transparency, stringent collateral requirements, regulatory challenges, and other external business factors.

Keywords: food MSMEs, performance, perspectives, SWOT analysis

JEL code: A13, C10, C83, D22

SDG classification: SDG 9, SDG 12, SDG 16

Introduction

Micro, Small, and Medium Enterprises (MSMEs) play a crucial role in the economy for several reasons. According to statistics from the Central Statistical Organization (CSO), Food MSMEs contributed significantly to the overall manufacture of goods and services in Myanmar in 2023. They also play a crucial role in the value-added chain, linking agricultural raw materials to industrial development. Food MSMEs refer specifically to enterprises or firms operating within the food production sector in the current study. The sector encompasses a diverse range of businesses, including small-scale farms, local processors, and artisanal food producers. One significant aspect of Food MSMEs in Myanmar is their reliance on local ingredients. The role of Food MSMEs in enhancing food security in Myanmar is immensely important. Supporting these businesses not only strengthens the local economy but also boosts community resilience.

The 2018 survey on Myanmar Micro, Small, and Medium Enterprises (CSO) identified key challenges facing MSMEs, including limited access to credit, labor instability, unreliable electricity, and raw material shortages. Similarly, Phyu (2020) highlighted capital constraints, lack of technological know-how, and raw material scarcity as major barriers to MSME growth in Kayah State. Despite these challenges, significant opportunities exist for Food MSMEs. UN ESCAP (2021) highlights that while micro enterprises are key job creators, medium enterprises have greater potential for export-led market expansion. Public-private partnerships have shown mixed effectiveness, offering some advantages to micro enterprises but not translating into broader benefits for small and medium businesses (World Economic Forum, 2021).

Food MSMEs face several challenges and receive supporting opportunities that impact their growth and sustainability. The challenges, opportunities, and measurements associated with MSMEs are vital for assessing their performance. Therefore, these factors are crucial in the decision-making process and are closely linked to the enterprises' existing conditions and characteristics. For the sustainable development of Food MSMEs, a constructive analysis of strengths, weaknesses, opportunities, and threats in current conditions can effectively identify the complementary requirements needed for success. The primary objectives of this paper are to identify the demographic, business, and institutional characteristics of Food MSMEs in Nay Pyi Taw and to assess the strengths, weaknesses, opportunities, and threats of them in the study area.

Methodology

For this study, the total population was identified using secondary data sources of registered MSMEs from the year 2023 of the Department of Small-Scale Industries (SSID) and the Directorate of Industrial Supervision and Inspection (DISI). From this data, Food MSMEs in the food production sector were purposively selected. A sample of 158 enterprises was drawn from a total of 263 registered Food MSMEs. The study was conducted from Pyinmana, Lewe, and Tatkon townships in Nay Pyi Taw Union Council, the capital region of Myanmar with convenient connections to other states and regions. Data collection took place from April to October 2024.

MSME classifications vary across countries and sectors, using both quantitative and qualitative criteria (Kaczmarek et al., 2011). For this study, a structured questionnaire was designed to collect both quantitative and qualitative data, including demographic

information about owners or managers, as well as the operational and institutional aspects of the enterprises. To assess respondents' perspectives, a 5-point Likert scale (1=strongly disagree, 2= disagree, 3= neutral, 4= agree, 5=strongly agree) was employed for qualitative responses. The study also examined the rationale behind participants' selections on this scale.

The study further identified and evaluated their strengths, areas for improvement, opportunities, and threats related to the business and institutional characteristics, linking these dimensions to the previously outlined characteristics. Data analysis was conducted using one-way ANOVA and SWOT analysis. The findings will reveal distinct conditions across the three categories of Food MSMEs (micro, small, medium enterprises), offering insights into their unique challenges, strengths, and the perceptions of their owners or managers.

Results and Discussions

Demographic characteristics of the respondents

The demographic characteristics of Food MSMEs, such as the age, education, and experience of respondents, are crucial for sustainable development. The average age of owners or managers was 43 years for micro-enterprises, 48 years for small enterprises, and 47 years for medium enterprises, with significant differences across sizes shown in Table 1. In terms of education, a significant difference among Food MSMEs was noted, with average schooling years of education ranging from 9.56 years to 12.03 years.

Table 1. Age, education, and experience of the respondents

Items	Micro (n=73)	Small (n=47)	Medium (n=38)	F stat
Age (years)				
Average	43.60	48.11	47.11	3.029 ^{ns}
Range	25-80	32-76	25-70	
Standard deviation	9.79	9.77	12.50	
Education (years)				
Average	9.56	10.09	12.03	7.533 ^{***}
Range	3-14	4-16	6-15	
Standard deviation	3.53	3.32	2.28	
Working Experience (years)				
Average	12.07	14.55	17.50	4.427 ^{**}
Range	1-40	2-30	2-45	
Standard deviation	7.73	8.79	11.95	

Note: ***represents significance at the 1% level, ** at the 5% level, and ns represents "insignificant".

Working experience also varied significantly, with an average experience of owners or managers at 12.07 years for micro enterprises, 14.55 years for small enterprises, and 17.50 years for medium enterprises, indicating that larger MSMEs generally have owners or managers with more education and experience.

Business characteristics of food MSMEs

Business characteristics categorize Food MSMEs by employee count (firm size), operational years (firm age), raw material sources, equipment, and owners or managers' perspectives on marketing strategy and business performance.

The firm age and size are significant differences among Food MSMEs, as shown in Table 2. Small enterprises have the highest average age (19.45 years), while micro enterprises are the youngest (14.48 years). The F-statistic for firm age is 2.693, significant at the 10% level, indicating notable mean age differences across MSME categories. The mean number of employees varied significantly, with a F-statistic of 11.179, significant at the 1% level. Medium enterprises have the largest average employee count (18.32), followed by small (7.57) and micro (6.62) enterprises. Micro and small enterprises primarily targeted local markets, employing fewer people, while medium enterprises had greater potential for scaling and hiring more staff.

Table 2. Age and size of food MSMEs

Items	Micro (n=73)	Small (n=47)	Medium (n=38)	F stat.
Firm Age (years)				
Average	14.48	19.45	18.29	2.693*
Range	2-50	2-60	3-50	
Standard deviation	11.19	13.64	12.32	
Firm Size (Number)				
Average	6.62	7.57	18.32	11.179***
Range	1-50	2-25	1-100	
Standard deviation	7.97	6.16	22.97	

Note: *** represents significance at the 1% level and * at the 10% level.

Food MSMEs sourced raw materials not only from Nay Pyi Taw but also from other states and regions across Myanmar, as well as from international suppliers. As shown in Table 3, more than half of the Food MSMEs relied on local sources only from Nay Pyi Taw, with medium enterprises sourcing the least (52.63%). Medium enterprises were more likely to diversify their supply chains, sourcing from both local and other regions (47.37%). However, medium enterprises faced challenges such as high raw material prices and supply chain disruptions, including transportation issues, border trade complications, and regulatory constraints.

Table 3. Source of raw materials for food MSMEs

Items	Micro (n=73)	Small (n=47)	Medium (n=38)	P value
	No. (Percent)	No. (Percent)	No. (Percent)	
Only from Nay Pyi Taw	48 (65.75)	34 (72.34)	20 (52.63)	0.16 ^{ns}
Nay Pyi Taw and others	25 (34.25)	13 (27.66)	18 (47.37)	

Food MSMEs in Nay Pyi Taw used a combination of hand tools and power-driven machinery, shaped by their size and investment capabilities, as shown in Figure 1. The equipment was categorized into four types: (1) hand tools only, (2) power-driven machinery only, (3) manual and power-driven, and (4) hand tools and power-driven. Micro enterprises primarily used hand tools. In contrast, small and medium enterprises commonly benefited from power-driven machinery, followed by the combined use of manual and power-driven options.

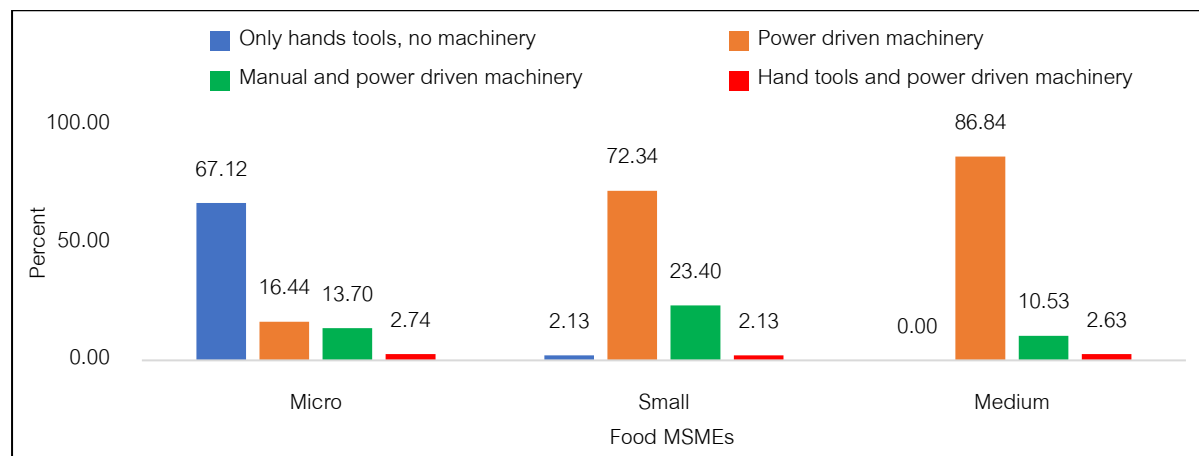


Figure 1. Equipment used for business operations in food MSMEs

The study evaluated market strategy (MS) applications in Food MSMEs using a Likert scale for mean and standard deviation calculations in Table 4. Findings indicated that micro enterprises scored a mean of 3.59 for product promotion (MS₁), reflecting agreement, while small (2.36) and medium enterprises (2.68) disagreed. For price reduction (MS₂), micro enterprises agreed (3.51), whereas small (2.57) and medium (2.79) remained neutral as a mean. In product diversification (MS₃) and new product/service introduction (MS₄), micro enterprises were neutral (3.07) and (3.18), while small and medium enterprises disagreed. All strategies were significant at the 1% level, indicating differences in strategy utilization for sales growth among micro, small, and medium enterprises. Micro enterprises showed higher average performance and greater variability than small and medium enterprises, indicating stronger marketing strategies and competitive pricing. In contrast, small and medium-sized enterprises were limited in product innovation and commonly produced products from local raw materials.

Table 4. Market strategy for sales in food MSMEs

Statement	Micro (n=73)	Small (n=47)	Medium (n=38)	F stat.
	Mean (SD)	Mean (SD)	Mean (SD)	
MS ₁ -The business often promotes products.	3.59 (0.85)	2.36 (0.76)	2.68 (0.90)	10.87**
MS ₂ -The business often lowers the price of products.	3.51 (0.87)	2.57 (0.95)	2.79 (0.91)	6.56***
MS ₃ -The business often diversifies products.	3.07 (1.05)	2.36 (0.76)	2.55 (0.80)	5.21***
MS ₄ -The business often introduces new products and services to the existing market	3.18 (1.02)	2.19 (0.77)	2.55 (0.76)	7.90***

Note: SD represents the standard deviation. *** represents significance at the 1% level

The study found that as sales increased, medium enterprises generally experienced growth in investment and profit, with statistically significant differences in performance metrics (BP₁, BP₄, BP₆) compared to micro and small enterprises. Notably, medium enterprises excelled in translating sales growth into tangible improvements. If enterprises did not find corresponding growth in products, customers, employees, or investments, it indicates stagnation, often due to insufficient capital reinvestment or limited innovation. Thus, while increased sales enhanced business performance, ongoing growth in these areas was crucial for long-term sustainability and competitiveness.

Table 5. Business performance in Food MSMEs

Statement	Micro (n=73)	Small (n=47)	Medium (n=38)	F stat.
	Mean (SD)	Mean (SD)	Mean (SD)	
BP ₁ -Business improves <i>substantially</i> .	3.71 (0.74)	3.79 (0.72)	4.21 (0.70)	13.81***
BP ₂ -Business profits improve to <i>a great extent</i> .	2.67 (1.09)	2.64 (1.07)	2.97 (1.13)	0.88 ^{ns}
BP ₃ -The business recovers all initial costs of investment.	3.49 (0.88)	3.64 (0.82)	3.58 (0.95)	1.06 ^{ns}
BP ₄ -The number of products on the market improves.	3.07 (1.00)	3.02 (1.01)	3.50 (0.95)	3.21**
BP ₅ -The business attracts a large number of customers.	3.03 (1.03)	3.02 (1.01)	3.16 (1.08)	0.75 ^{ns}
BP ₆ -The business's investment and profit increase yearly.	3.08 (1.00)	3.02 (0.99)	3.61 (0.86)	2.39*
BP ₇ -The number of employees increases.	2.59 (0.91)	2.49 (0.86)	2.53 (1.01)	1.88 ^{ns}

Note: SD represents the standard deviation

*** represents significance at the 1 % level, ** at the 5 % level, * at the 10 % level, and ns represents "insignificant".

Institutional characteristics of food MSME

The SSID under the Ministry of Cooperatives and Rural Development promotes rural small industries through registration, training, technology support, microfinance, and market linkage. The DISI, under the Ministry of Industry, oversees industrial registration, inspection, and compliance to ensure safe, standardizations, loan recommendation, and efficient industrial operations. The institutional characteristics of Food MSMEs are illustrated in the registration and association membership status and the perspectives on enacted rules and regulations shown in Table 6. The finding highlighted the registration and association membership status of Food MSMEs. Among micro enterprises, 89.04% were registered with SSID, while 97.87% of small and 97.37% of medium enterprises registered with the DISI. However, 82.19% of micro enterprises reported having no membership in any business association, with only 10.37% affiliated specifically with MSME associations. Membership rates increased with firm size, rising to 31.58% among medium enterprises engaged in business associations. Low membership rates reflected challenges such as limited awareness, perceived low value, geographical barriers, and weak collaboration. This indicates a need for targeted initiatives like awareness campaigns and tailored associations to improve engagement.

In Myanmar, fragmented registration requirements by enterprise size and sector create unequal access to financial services, subsidies, and training while also complicating data collection and policy-making. Though burdensome, these processes also offer businesses access to support, infrastructure, and standardized compliance.

Table 6. Registration and Membership of food MSMEs

Items	Micro (n=73)	Small (n=47)	Medium (n=38)
	No. (Percent)	No. (Percent)	No. (Percent)
Firm's registration			
• SSID	65 (89.04)	-	-
• DISI	-	46 (97.87)	37 (97.37)
• SSID and DISI	8 (10.96)	1 (2.13)	1 (2.63)
Membership			
• Business associations	2 (2.74)	7 (14.89)	12 (31.58)
• MSME associations	10 (13.70)	7 (14.89)	4 (10.53)
• Business associations and MSME	1 (1.37)	2 (4.26)	5 (13.16)
• None	60 (82.19)	31 (65.93)	17 (44.74)

Differing perceptions among Food MSMEs regarding enacted rules and regulations (RNR) based on business size are showcased in Table 7. RNR₁ found mean scores for technology and product protection ranged from 2.96 to 3.26, while RNR₂ revealed mean scores for business safety regulations between 3.14 and 3.34. RNR₃ indicated Food and Drug Administration (FDA) food safety regulations had mean scores from 2.97 to 3.49, with a significant difference, indicating that micro businesses tend to favor relaxed FDA regulations.

RNR₄ showed tax payment mean scores declining with size (3.63 to 2.95), indicating micro enterprises favor lower taxes. Many new enterprises were hesitant to pay taxes despite available exemptions, expressing a strong desire for greater transparency in the tax system and diverse needs for financial loans. RNR₅ on loan specifications displayed mean scores from 2.53 to 3.25 and significant differences. RNR₆ examined currency exchange rate regulations, showing rising mean scores from 2.77 to 3.66, with medium MSMEs feeling a greater impact. While opinions on safety regulations were consistent, significant differences emerged in FDA regulations, taxes, loans, and currency exchange. Understanding these perspectives is essential for developing policies that support Food MSMEs, optimize tax structures, and facilitate trade.

Table 7. Perspectives on enacted rules and regulations in food MSMEs

Statement	Micro (n=73)	Small (n=47)	Medium (n=38)	F stat.
	Mean (SD)	Mean (SD)	Mean (SD)	
RNR ₁ - The existing rules and regulations are needed to protect technology or product.	3.10 (1.02)	2.96 (0.93)	3.26 (0.89)	2.90**
RNR ₂ - Rules and regulations are needed for the safety of business.	3.14 (1.00)	3.17 (0.92)	3.34 (0.85)	2.54*
RNR ₃ - FDA regulations on food safety should be reduced because the business is a Food MSME.	3.49 (0.82)	3.17 (0.60)	2.97 (0.72)	10.55***
RNR ₄ - Tax payments should be reduced because the business is a Food MSME production.	3.63 (0.66)	3.19 (0.71)	2.95 (0.80)	12.67***
RNR ₅ - The rules and regulations in loan and type specifications for MSME are inconsistent with business.	3.25 (0.85)	2.60 (0.83)	2.53 (0.69)	12.43***
RNR ₆ - Rules and regulations on currency exchange rates affect business.	2.77 (0.89)	3.28 (0.85)	3.66 (0.67)	7.57***

Note: SD represents the standard deviation.

*** represents significance at the 1% level, ** at the 5% level, and * at the 10% level

Strengths, weaknesses, opportunities, and threats of food MSMEs

A SWOT analysis helps Food MSMEs identify internal strengths and weaknesses, and external opportunities and threats, supporting better planning, resource use, and strategic decisions. The strengths include domestic demand, raw material availability, government support, value-added products, packaging, health standards, a growing number of food entrepreneurs, and migrant demand, as shown in Figure 2. The analysis showed that strong domestic market demand is vital for Food MSMEs, with small enterprises at 80.85% and medium at 81.58%, while micro enterprises stand at 65.75%. When consumers show a willingness to spend on local food products, businesses are empowered to expand their operations, invest in new technologies, and hire more employees. Additionally, 73.97% of micro enterprises and 93.62% of small businesses had adequate access to raw materials, indicating a strong domestic production capacity.

As other strengths, the micro enterprises received training assistance, and small and medium enterprises received loan support. Micro enterprises excelled in producing value-added products (52.05%), ready-to-eat food items with high health standards (54.79%), and locally sourced foods with modern packaging (38.36%). Despite being the smallest enterprise category, they demonstrated significant potential for infrastructure and industrial investment, driven by rising entrepreneurship in the food sector and increased purchases by out-migrants. Among the three categories, micro businesses stand out in nearly all strengths, except in the area of edible oil regulations.

Government regulations on the importation of edible oils and credit assistance were significant concerns for Food MSMEs. The government had issued of the list of goods required to apply import license including edible oils since 2020 (MoC, 2020) and the Ministry of Agriculture, Livestock and Irrigation had planned to cultivate oil crops in specific zones during the 2024-2025 financial year to ensure an adequate supply of edible oil (The Global New Light of Myanmar, 2024). After that, the government introduced measures to support local producers through low-interest loans, subsidies for processing facilities, and research grants aimed at sustainable practices, all to enhance local production in the last year. Micro enterprises faced different challenges compared to small and medium enterprises, as edible oil was vital for their production processes. Medium enterprises, which accounted for about 12.33% of edible oil mills and producers, benefited from government assistance.

Food MSMEs were found to be facing eleven distinct business-related weaknesses, as illustrated in Figure 3. One of the major issues was the requirements of machinery, equipment, and mechanics. It revealed critical weaknesses among Food MSMEs, particularly small (63.83%) and medium-sized enterprises (55.26%). Larger businesses struggled with outdated equipment, while micro enterprises (31.51%) managed with simpler tools. A shortage of qualified mechanics further hindered operations. Next, workforce shortages and rising wages significantly impacted small (59.57%) and medium enterprises (60.53%), while micro businesses (43.84%) faced labor migration. Continuously, another weakness is high production costs, especially in medium enterprises (55.26%), which were linked to unreliable energy supply and frequent power outages. Obtaining government permissions was a major hurdle for small (53.19%) and medium enterprises (47.37%), with the FDA registration processes cited as time-consuming and costly. Compliance with water sanitation and infrastructure standards added to the burden. Following the FDA process, the consequent weaknesses of access to quality raw materials and limited knowledge of international food standards further restricted global competitiveness. In particular, 32.88% of micro enterprises faced insufficient marketing strategies and often incurred higher marketing costs than larger firms.

Financial literacy was a widespread issue of weakness, with slightly different rates among micro businesses (35.62%) compared to small (38.30%) and medium enterprises (44.74%). The complexity of loan processes, inadequate documentation, and stringent banking requirements limited access to capital, fueling underinvestment and reduced innovation. Continuously, limited business information sharing among MSME associations was another hurdle, particularly for small businesses (51.06%), highlighting the need for improved collaboration and access to industry insights.

Food MSMEs encounter various opportunities that contribute to their growth in Figure 4. On the opportunities front, employment creation was identified as a significant prospect across all sizes, with micro-enterprises leading at 57.53%, followed by small enterprises at 46.81% and medium enterprises at 36.84%. This showed that micro enterprises played a vital role in local job creation.

Market export potential increased with business size: medium enterprises (36.84%) benefited the most, followed by small (34.04%) and micro (21.92%) businesses. This trend highlighted the scalability of larger enterprises and their self-reliance. Targeted export incentives for micro enterprises were needed. Public-private partnerships (PPPs) had notably aided micro enterprises (21.92%) by introducing products in trade fairs, while small and medium enterprises saw limited benefits at 4.26% and 10.53%, respectively.

Micro enterprises showed greater easy access to technology and opportunities to work at home (64.38%) compared to small (23.40%) and medium (31.58%) businesses. However, government-backed technical training was 12.33% for micro and absent for others due to lack of interest and relevance for their needs. Tailored training and collaboration with institutions are crucial, especially in the food sector. Micro enterprises' stronger ties to SSID highlight a key channel for delivering these resources.

On the other hand, credit support programs from public and private banks had aided businesses of all sizes, with 28.77% of micro, 23.40% of small, and 21.05% of medium enterprises benefiting. Microfinance initiatives had improved loans to make micro enterprises more accessible. All stakeholders involved in the food sector, from agriculture to processing, should be engaged in targeted credit programs coordinated with government and financial institutions. Government regulation and policy adjustments were more beneficial for medium enterprises (39.47%), followed by small (34.04%) and micro enterprises (23.29%). Larger businesses gained better access to regulatory support and engaged more in policy advocacy. Timely government support was critical for small (42.55%), medium (34.21%), and micro (28.77%) enterprises. Continued dialogue between businesses and policymakers is essential to align regulations with industry needs. Support permission for raw material storage benefited small and medium enterprises, while micro enterprises gained from raw material and oil quotas, underscoring the role of government intervention in ensuring business sustainability.

Food MSMEs faced several threats, including limited access to export markets, financial constraints, regulatory burdens, and economic volatility, as shown in Figure 5. A key concern was the lack of transparency in business operations, affecting 53.19% of small and 47.37% of medium-sized enterprises, compared to 31.51% of micro businesses. In this context, transparency issues referred to concealed financial resources such as hidden revenues, unreported expenses, unclear financial reporting, undisclosed liabilities, opaque owners or managership or investments, etc. Moreover, the presence of "dominant large firms" impacted small (44.68%) and medium (28.95%) enterprises than micro counterparts (26.03%), highlighting the competitive pressures faced by these scaling businesses against established market players.

Importing equipment and essential raw materials has become a major challenge for Food MSMEs in today's competitive market. Medium enterprises were hit hardest, with 36.84% reporting difficulties, compared to 14.89% of small and 9.59% of micro enterprises. Unstable trade regulations and installment-based machinery purchases were impacted by

currency volatility and increasing costs. Key raw materials importing like wheat, food chemicals, and packaging accessories posed further concerns with limited tariffs and quotas. Regulatory barriers, such as lengthy government approvals, posed significant challenges, especially for businesses that rely on imported materials (OECD, 2019).

Climate change posed a significant threat to the production and quality of raw materials, particularly impacting medium-sized enterprises (31.58%), followed by small (17.02%) and micro enterprises (10.96%). It was disrupting agriculture and forestry, leading to reduced yields and lower-quality produce, especially for sensitive crops. The re-emergence of government regulations on edible oil imports and credit assistance as a threat (24.66%) in micro enterprises reflected their complex impact on Food MSMEs. Micro enterprises favored imported oil for its lower cost and neutral odor, underscoring the need for clear communication with all stakeholders to balance benefits and challenges.

The subsequent challenge was the inadequacy of market connections and the limitations within export markets. Micro (15.07%), small (17.02%), and medium (34.21%) enterprises were disproportionately affected by this issue, with reporting difficulties in entering international markets. Contributing factors included weak market linkages, poor marketing strategies, and limited knowledge of export procedures and international demand trends.

The limited market linkage among Food MSMEs posed another issue, especially for micro-enterprises, which faced a 23.29% barrier compared to 18.42% for medium enterprises and only 4.26% for small enterprises. Across the supply chain, weak collaboration among stakeholders—on pricing, quality standards, and information sharing—hinders growth. Medium enterprises struggled with financial constraints and lack of knowledge, often acting only as intermediaries. Meanwhile, micro enterprises struggled with high retailer profit margins, issues with returnable goods, and delayed payments. Lastly, collateral or third-party guarantees in obtaining loans also presented a significant hurdle for these MSMEs, which was most pronounced for 38.30% of small enterprises. Micro-enterprises were also heavily impacted (36.99%), followed closely by medium enterprises (31.58%).

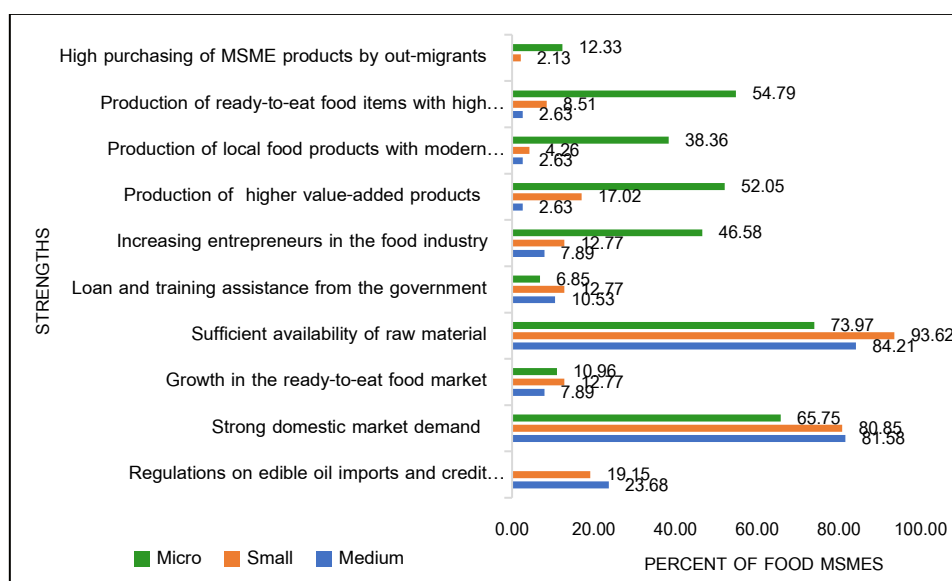


Figure 2. Strengths of food MSMEs in Nay Pyi Taw

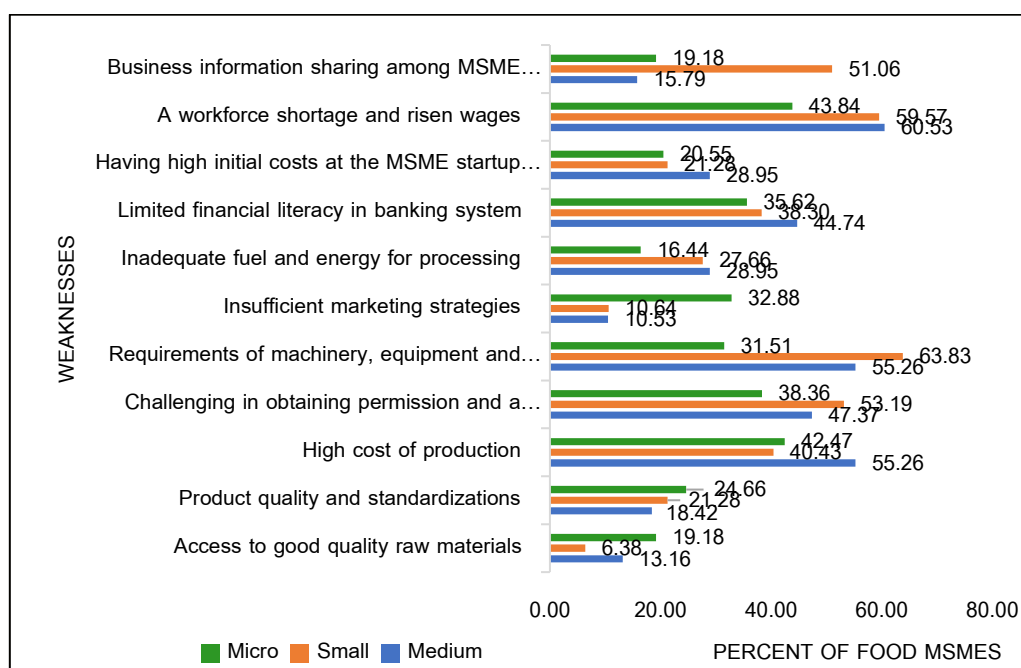


Figure 3. Weaknesses of Food MSMEs in Nay Pyi Taw

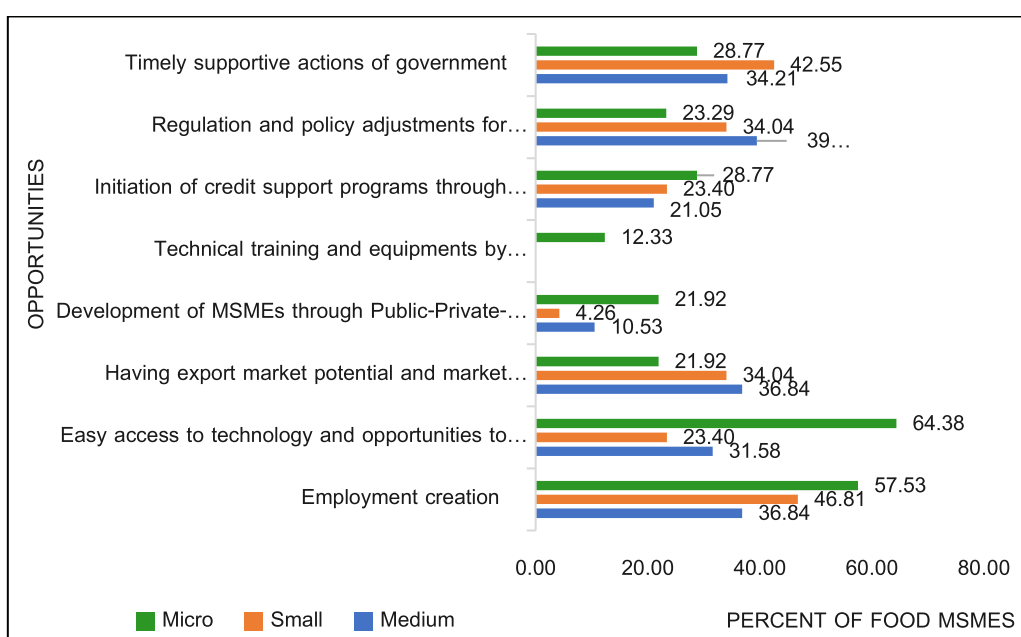


Figure 4. Opportunities for Food MSMEs in Nay Pyi Taw

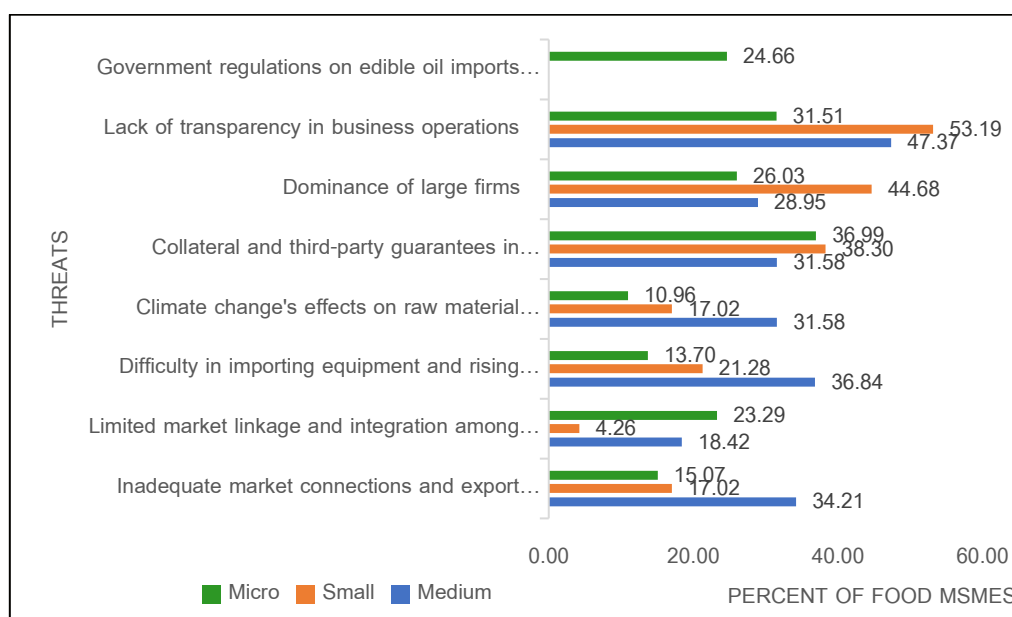


Figure 5. Threats of Food MSMEs in Nay Pyi Taw

Conclusion

The demographic profile of Food MSME owners or managers highlights the importance of human capital in enterprise growth. The age differences were significant at the 10% level across owners of Food MSMEs, with medium enterprises' owners or managers having significantly higher education (12.03 years) at 1% level and work experience (17.5 years) at 5 % level than those in small and micro enterprises. These results suggest that higher age, education, and experience contribute to managing and sustaining larger MSMEs.

The analysis of the business characteristics of food MSMEs in Nay Pyi Taw reveals significant variations across firm size categories. Medium enterprises demonstrate greater operational maturity, broader supply chain networks, and more sophisticated equipment use, along with stronger performance in areas such as business improvement, product availability, and annual investment growth. However, product diversification in medium enterprises, without corresponding increases in customer base and employment, especially in micro and small enterprises, suggests potential growth stagnation. To address this, continuous innovation, capital reinvestments, strategic marketing, and tailored policies should be extended.

Institutional characteristics show notable disparities in registration and association membership by size. Association membership is low, especially among micro enterprises, due to limited awareness and perceived benefits. Perceptions of regulations on FDA rules, taxation, loans, and currency policies also differ by size, and tailored policy support is needed.

The SWOT analysis of Myanmar's Food MSMEs highlights several key challenges and opportunities. Micro enterprises exhibit adaptability through marketing and value chain strategies that align with evolving consumer trends. However, they face growth stagnation and limited access to resources. Small enterprises struggle with sustainability

due to limited access to information and resources, hindering their ability to innovate and expand. Medium enterprises often limited innovation and value-added product development, while medium-sized MSMEs encounter fewer operational risks affecting their competitiveness.

Despite these challenges, strong domestic demand remains a significant advantage, particularly for micro and small enterprises. This demand drives innovation, strengthens local supply chains, and enhances overall economic resilience. However, disparities exist in how MSMEs perceive and navigate regulations, especially concerning FDA food safety standards and tax compliance. Smaller enterprises face greater difficulties due to regulatory complexity and limited resources. Inconsistent loan terms highlight the need for tailored financial products and supportive policies. Financial concealment hampers accurate growth assessments, requiring government-private sector collaboration to streamline import regulations, enhance infrastructure, and expand financial support. Therefore, fostering sustainable development in the Food MSME sector requires differentiated, size-specific interventions that enhance human capital, promote innovation, improve institutional access, and strengthen adaptive capacity across enterprise categories to meet sustainable development.

References

- Association of Southeast Asian Nations (ASEAN). 2015. ASEAN Strategic Action Plan for SME Development 2016–2025. *Jakarta: ASEAN Secretariat*. 338.6459
- Chong, H. G. 2008. Measuring the performance of small-and-medium sized enterprises: The grounded theory approach. *Journal of Business & Public Affairs*.
- Central Statistical Organization (CSO). 2018. Myanmar Micro, Small, and Medium Enterprise Survey, Ministry of Planning and Finance and United Nations University-WIDER, Myanmar.
- Central Statistical Organization (CSO). 2023. Myanmar Statistical Year Book. Ministry of Planning and Finance, Nay Pyi Taw.
- Department of Small Scale Industrial (SSID). 2023. Data record. Ministry of Cooperative and Rural Development, Nay Pyi Taw, Myanmar.
- Directorate of Industrial Supervision and Inspection (DISI). 2023. Data record. Ministry of Industry. Nay Pyi Taw, Myanmar.
- The Global New Light of Myanmar, 2024. <https://www.gnlm.com.mm/moali-plans-zone-wise-oil-crop-cultivation-to-ensure-edible-oil-sufficiency>
- Han, T. 2019. *Challenges for Micro, Small and Medium Enterprises Development in Yangon East District (A Case Study of Food and Beverage Enterprises)* (Doctoral dissertation, MERAL Portal).
- International Finance Corporation (IFC). (2021). *Unlocking the Potential of MSMEs for Sustainable Development*.

- Kaczmarek, A., Byczkowska, M., & Czyrka, K. 2016. Quantitative and qualitative criteria to determine the size of enterprises and specificity of SMEs' operations. *Globalization, the State and the Individual Journal*, 1(9).
- Ministry of Commerce. 2020. The Export Import Law.
- Mpasa, A. 2016. Examining the performance of small and medium enterprises (SMEs) in Shinyanga municipality (Doctoral dissertation, Mzumbe University).
- Organization for Economic Cooperation and Development (OECD). (2019). *SME and Entrepreneurship Policy in Myanmar*.
- Phyu, Z. P. (2020). *A Study on the challenges and opportunities of Micro, Small and Medium Enterprises (MSMEs) in Kayan States* (Doctoral dissertation, MERAL Portal).
- UN Economic and Social Commission for Asia and the Pacific (UN ESCAP). (2021). *The Future of MSMEs in Asia and the Pacific: A Policy Perspective*.
- World Economic Forum. (2021). *Public-private cooperation for inclusive development: Accelerating the development impact of public-private partnerships*. <https://www.weforum.org/reports/public-private-cooperation-for-inclusive-development/>

Street Food and Urban Food Security in Thailand: Policy Alignment and Prospects

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Abstract

Street food, defined as “ready-to-eat foods and beverages prepared and/or sold by vendors, especially in streets and other similar public places” by the Food and Agricultural Organization, plays a critical role as an affordable food source, especially for low-income populations, in urban food security. This study examines the alignment of Thai street food policies with key food security domains: availability, access, utilization, and stability. Based on documentary analysis, complemented by 25 in-depth interviews with stakeholders from governmental, academic, civil society, and food service associations, findings indicate that Thailand’s street food policies and actions inadequately address the availability, access, utilization, and stability of street food, resulting in a discrepancy between policy formulation and implementation. While street food is endorsed as a national policy priority, the availability of affordable street food is vulnerable to economic shocks; vendors are restricted from economic activity in pursuit of city orderliness and urban development; compliance to hygienic standards remains insufficiently monitored; and many interventions aimed at improving street food conditions are short-term. To better align street food governance with food security objectives, this study proposes a comprehensive street food policy framework that addresses key urban food security domains to ensure that Thailand’s street food sector contributes to urban food resilience and public health outcomes.

Keywords: street food, food security, urban food policy

JEL code: R58, I38, O17

SDG classification: SDG 2, SDG 11

Introduction

Street food is an integral component of the urban food environment. Previous literature has explored the roles of street food in urban food security, especially in providing affordable and accessible food options for populations in lower-income groups (Salamandane, Malfeito-Ferreira, & Brito, 2023; Tacoli, 2020). Street food vending was conventionally represented as a potentially unhygienic food source distributed through fixed or mobile establishments operated by vendors with lower socioeconomic backgrounds (Rane, 2011). The convergence of demographic, nutritional, and epidemiological transitions has fundamentally transformed the street food landscape, as evident in the increasing diversity of vendors, the presence of compact mobile food operations (food trucks and cloud kitchens), and the policy focus shifting towards non-communicable diseases (Nonato, Minussi, Pascoal, & De-Souza, 2016). These transitions pose both challenges and opportunities for urban street food management.

Despite the significance of street food for urban food security, urban food policy might not incorporate street food as an integral component. While numerous programs aimed at improving the quality of street food vending and nutritional outcomes exist, public authorities frequently implement restrictive regulatory measures in street food management, prioritizing city orderliness and food safety standards over the consumers' demands (Pulliat et al., 2024). However, a restrictive regulatory approach might potentially lead to adverse outcomes, not only causing the loss of income and compromised livelihoods of vendors but also resulting in widespread non-conformity with municipal standards and escalated tensions between vendors and urban authorities (Carroll, Basinski, & Morales, 2016). The juxtaposition between the evolving policy environment and the need for street food vending in urban centers creates tension in aligning the street food policy agenda with broader urban development goals. In Thailand, urban policies often prioritize city orderliness and pedestrian rights to promote tourism and uphold the city's global image rather than explicitly addressing food security concerns, which creates gaps in sustainable urban food systems.

The Food and Agriculture Organization's (FAO) basic concepts of food security provide a framework for understanding how street food policy can align with broader urban development goals (Practical, 2008). The four dimensions of food security include (1) the physical availability of food, (2) economic and physical access to food, (3) food utilization, and (4) stability of the other three dimensions over time (Practical, 2008). In order to conduct an analysis of food security, the FAO also published the "Right to food: guide to conducting a right to food assessment" as one of the guidelines that offers insights into a human rights-based approach to examine the legal structures, policies, institutions, and budgets that are essential contributors to food security (Mischler, 2009).

Thailand serves as an exemplary case to illustrate the attempts to align street food urban policy with food security. At the city level, the Bangkok Metropolitan Administration (BMA) has prioritized urban space management concerns over food security considerations. Recently, however, the BMA has begun implementing the Bangkok Food Policy 2023-2027, which represents a more comprehensive framework addressing multiple dimensions including food safety, equity, food waste, and vendor support.

Underpinned by the Food and Agriculture Organization's (FAO) "Right to Food" Assessment Framework, this study aims to examine the alignment of Thai street food policies with key food security domains: availability, access, utilization, and stability

(Practical, 2008). The outcomes of this research can help inform public policy on urban food security for countries with similar contexts, particularly in Southeast Asia.

Methodology

Underpinned by the FAO's Guide to Conducting a Right to Food Assessment, this study employed qualitative research methods (documentary review and in-depth interviews) to examine how Thai street food policies align with the four domains of food security (availability, access, utilization, and stability).

Data collection for this study was carried out using two complementary qualitative approaches: documentary review and in-depth interviews. The sources for documentary review involved a systematic search of academic databases, governmental websites, official publications, policy reports, and relevant media sources. The documents were selected based on their relevance to the study's focus on street food policies and their alignment with the FAO's definitions of food security dimensions.

The criteria for stakeholder recruitment were the direct involvement or a deep understanding of street food policy, urban planning, public health, and food security. In total, 25 stakeholders participated in the study. The stakeholders' identities were anonymized with the labels GO1-11 for governmental (national, local, and international governmental actors); AC1-8 for academics from various specializations, notably nutrition, food science, urban design, and social work; CS1-2 represented civil society organizations specializing in food safety, nutrition and dietetics, and public health; and FS1-4 for representatives of the food service and food industry sectors. Each interview was recorded and transcribed verbatim.

Data analysis was based on a thematic analysis protocol and guided by the FAO's Guide to Conducting a Right to Food Assessment (Mischler, 2009). WS coded and categorized the data based on the four domains of food security: availability, access, utilization, and stability (Practical, 2008). The descriptions of the four domains were slightly adjusted to suit the context of street food. Discussions among authors (WS and SP) were initiated to ensure that the key concepts were internally consistent and distinct from one another. The descriptions for the four domains of food security are indicated in Table 1.

Table 1. Key concepts

Key concepts	Descriptions
Availability	Availability refers to the physical availability of food and its sufficiency for consumption (Makombe, 2023; Practical, 2008). While the conventional definition of availability focuses on the "supply" side of food security, particularly food production, stock levels, and net trade (Practical, 2008), availability in the context of street food focuses on the adequate presence and distribution of street food vendors throughout urban spaces to meet population needs.
Access	Access refers to economic and physical access (affordability and proximity) to food (Makombe, 2023; Practical, 2008). While the conventional definition of food access focuses on household-level food security as represented by household income, household expenditure, and prices (Practical, 2008), access in the context of

Key concepts	Descriptions
	street food focuses on consumers' ability to acquire affordable street food and population density in an urban space.
Utilization	Utilization refers to the effective use of food for nutrition and health (Makombe, 2023; Practical, 2008). While the conventional definition of utilization focuses on the way the body makes the most of various nutrients, which results in the nutritional status of individuals (Practical, 2008), particularly through feeding practices, food preparation, and diversity of the diet, utilization in the context of street food focuses on food safety and nutritional aspects of food that contribute to foodborne diseases and non-communicable diseases.
Stability	Stability refers to the stability of the other three dimensions over time (Makombe, 2023; Practical, 2008). While the conventional definition of stability focuses on food security during certain situations, such as unemployment, rising food prices, or other crises (Practical, 2008), stability in the context of street food focuses on the resilience and consistency of the street food ecosystem despite external pressures. This includes vendors' ability to maintain operations during economic downturns or regulatory shifts.

Ethical considerations were carefully observed throughout the study. This study was reviewed by the Institutional Review Board of the Institute for Population and Social Research (COA No. 2024/05-045). All participants were informed about the objectives of the study through a Participant Information Sheet and a verbal explanation prior to the interview. All participants consented to the study and were anonymized throughout the presentation of this study.

Results and Discussion

Overview of Bangkok street food laws and perceived challenges in street food management

While the Public Health Act B.E. 2535 (1992) and the Act on the Maintenance of the Cleanliness and Orderliness of the Country (1992) provide the foundation for the control of city orderliness and hygiene at the national level, street food vending in Bangkok is regulated based on BMA city laws: (1) Bangkok Metropolitan Administration Ordinance on the Hawkers B.E. 2519 (1976) (Government Gazette, 1976b), (2) Bangkok Metropolitan Administration Ordinance on the Control of Street Stalls B.E. 2519 (1976) (Government Gazette, 1976a), (3) Bangkok Metropolitan Administration Ordinance on the Sale of Goods in Public Places or Pathways B.E. 2545 (2002) (Government Gazette, 2002), (4) Bangkok Metropolitan Administration Regulation on Criteria for Selling Goods in Public Places or Pathways B.E. 2546 (2003) (Government Gazette, 2003), and (5) Bangkok Metropolitan Administration Regulation on Criteria for Selling Goods in Public Places or Pathways (Second Edition) B.E. 2551 (2008) (Government Gazette, 2008). The details of the laws and the alignment to food security domains (FSD) are indicated in Table 2.

Table 2. Bangkok street food laws

Laws, policies, and actions	Main objective	Targetted beneficiaries	Weakness	Alignment with FSD			
				A	B	C	D
Bangkok Metropolitan Administration Ordinance on the Hawkers B.E. 2519 (1976)	To regulate and control mobile food vendors through a licensing system, operating hours restrictions, and establishing hygiene standards for vendors.	Mobile vendors are regulated for the benefit of the general public.	Only addresses mobile vendors, creating regulatory gaps for evolving vending formats.	✓	✓	✓	
Bangkok Metropolitan Administration Ordinance on the Control of Street Stalls B.E. 2519 (1976)	To establish a licensing system for fixed vendors in public spaces and standardize hygiene practices.	Fixed vendors are regulated for the benefit of the general public.	Only addresses fixed vendors, creating regulatory gaps for evolving vending formats.	✓	✓	✓	
Bangkok Metropolitan Administration Ordinance on the Sale of Goods in Public Places or Pathways B.E. 2545 (2002)	To establish comprehensive regulations for the sale of goods in public places or pathways.	All vendor types in public places or pathways.	Unified urban space management approach does not sufficiently address the diversity of vending formats and locations.	✓		✓	
Bangkok Metropolitan Administration Regulation on Criteria for Selling Goods in Public Places or	To provide specific requirements for food stall heights, food display and protection, vendor identification,	Registered vendors for the benefits of the general public.	Closed registration system and relocation policies disrupt the traditional street food	✓		✓	

Laws, policies, and actions	Main objective	Targetted beneficiaries	Weakness	Alignment with FSD			
				A	B	C	D
Pathways B.E. 2546 (2003)	and the application process.		vending landscape.				
Bangkok Metropolitan Administration Regulation on Criteria for Selling Goods in Public Places or Pathways (Second Edition) B.E. 2551 (2008)	To reinforce the rights of existing vendors and prohibit the transfer of vending permits or the granting of new permits in vacant spaces.	Registered vendors for the benefits of the general public.	Closed registration system and relocation policies disrupt the traditional street food vending landscape.	✓		✓	

Note: A = Availability, B = Access, C = Utilization, D = Stability

The evolution of Bangkok's street food laws demonstrated a shift from an open registration system to a closed registration system. Grounded in the Public Health Act B.E. 2484 (1941), the 1976 laws indicated two types of street food vendors (fixed vendors and mobile vendors) as the target groups. In 2002, however, BMA introduced a unified urban space management in accordance with the amended Public Health Act B.E. 2535 (1992). As a result of the urban space management, a semi-closed system that prioritized existing registered vendors was introduced in 2003, which led to a fully closed system that prohibited new vendors from occupying vacant spaces and the transfer of vending permits.

The availability of street food vendors in Bangkok faces significant challenges due to the city's increasingly restrictive regulatory environment. The shift of the regulatory landscape from a semi-closed system to a closed system in the early 2000s should, in theory, create an urban food system where the number of vendors, both registered and unregistered, could only decrease over time. In practice, however, the decrease in the number of registered vendors and the prohibition of new registrants enlarged the parallel informal street food sector alongside the formal counterpart. City officials are hesitant to impose strict regulations on vendors as crackdowns would result in a public backlash that has an impact on future political outcomes, as one national-level government official specializing in food hygiene reported:

"The political dimension was also important in determining measures related to controlling food sold in public places. It seems to be a violation of the pedestrian rights. [...] Across different eras and periods, there have been both abolishment and establishment [of concession points]. When political parties want votes, they tend to promote and open up more spots for vendors to sell." (GO1)

Urban food access is threatened by restrictive urban food policy directions. The 2008 Amendment (BMA Regulation B.E. 2551), combined with relocation policies, moved vendors from high-traffic public spaces to designated centers that may not attract the same customer flow. In the relocation process, vendors would face additional challenges from financial burdens and reduced consumer traffic, ultimately reducing accessible food options. A representative from the food service sector explained the burden on vendors in the following manner:

“Rental costs aren't reduced, and some locations are extremely harsh... And there are various landscape improvement projects [...] involving road construction, all of which impact street food and sidewalk food vendors” (FS1).

Food utilization components, especially food safety and nutritional quality of street food, remain insufficiently monitored due to fragmented regulatory oversight. The limited cooperation on food safety and nutritional quality of street food has resulted in inconsistent enforcement patterns where no single entity is fully in charge of the urban food system, as one government official on food, nutrition, and public health explained:

“Our street food spaces are managed in a disorganized manner. This single issue of space management doesn't only involve the Ministry of Public Health, but potentially the Ministry of Interior, and special administrative areas like Bangkok Metropolitan Administration” (GO2)

The stability of Bangkok's street food ecosystem faces significant challenges due to regulatory shifts. The legal shift from an open registration system to a closed registration system, together with new initiatives focused on Singaporean's “hawker center” model, does not sufficiently embrace the mobility of vendors, the demands of consumers, and the organic variety of Bangkok's street food landscape that have historically contributed to Bangkok's renowned street food culture. One specialist on urban design commented on how this model had an impact on Bangkok's street food landscape:

“About two years ago, we started hearing the term 'hawker' more frequently... I understand that they don't want to have too many stalls on the sidewalks, so the hawker centers would be spaces that aren't public, but rather private property or land belonging to government agencies or private entities that open those spaces for vendors who previously operated on sidewalks.” (AC1)

Prospects on aligning street food policy agenda with urban food security

To address the challenges in availability, an inclusive urban street food policy framework could ensure both the sufficiency and quality of street food. Bangkok's Food Policy 2023-2027 represents a promising step toward a more comprehensive approach that recognizes diverse vending formats while creating legal pathways for vendors. As noted by a governmental actor on food hygiene:

“Bangkok Food Policy doesn't just focus on food safety alone. It addresses food equity, food banks, food waste, and upgrading food establishments. It has multiple dimensions, with various departments and divisions within the BMA working on these initiatives” (GO3)

To balance pedestrian rights with street food vending practices in ensuring access, a more inclusive approach can be adopted. While the Public Health Act provides a framework for interagency cooperation between local officials and traffic police, it does

not prohibit broader stakeholder engagement. Cities can engage both vendors and consumers in decision-making processes regarding street food vending locations. This approach transforms a restrictive regulatory framework into a more sustainable governance model, as a government official on food safety explained:

"Under the Public Health Act, there are measures and conditions specifying that for each public space to be used, there must be public hearings or discussions with local authorities [...] Without going through public hearings and without permission from the responsible agencies, vendor-initiated arrangements in public spaces usually aren't sustainable" (GO1)

Enhancing food utilization requires establishing coordinated monitoring systems that engage multiple stakeholders – city officials, vendors, and consumers. By supporting vendors with training on safe, healthy, and nutritious food preparation, street food could contribute to better public health outcomes. One urban development specialist stated:

"Street food can be made healthier while maintaining quality and affordability. [...] We need to help vendors balance nutrition with food costs. If these can be balanced without significant trade-offs, I think this would be a good direction to initiate nutritional improvements" (AC2).

The stability of the urban food system requires sustainable policies that build on successful models and encourage knowledge sharing. The integration of Bangkok into international food policy networks has already yielded results, as explained by a city official:

"The key point is that after BMA joined this network, we brought knowledge and best practices from Milan to create Bangkok's first food policy in ASEAN, the Bangkok Food Policy 2023-2027, which has already been launched. The policy has seven dimensions for driving food system change" (GO4).

The challenges and prospects in aligning street food policy agenda with urban food security are presented in Table 3.

Table 3. Challenges and prospects in aligning street food policy agenda with urban food security

Key concepts	Challenges	Prospects
Availability	Closed registration system restricts legal vendor numbers, threatening the availability of street food.	Develop inclusive policy framework recognizing diverse vending formats and creating legal pathways for new vendors.
Access	Perceived priorities on orderliness and relocation policies limit vendors' economic opportunities and result in limited food accessibility.	Implement a balanced zoning approach that designates concession points through collaborations with vendors and consumers.
Utilization	Food safety oversight across multiple agencies results in inconsistent food safety monitoring and enforcement.	Establish coordinated monitoring systems that engage multiple stakeholders while supporting vendors with nutrition and food safety training.

Key concepts	Challenges	Prospects
Stability	Regulatory shifts create uncertainty for the street food ecosystem.	Develop sustainable policies building on successful models and incorporate knowledge sharing from international best practices.

The findings of this study show that the priorities on city orderliness and pedestrian rights have overshadowed food security domains in Bangkok's food policies and actions, undermining the roles of street food vending as a food distribution point (availability), a source of accessible and affordable food options (access), a potential channel to deliver safe and nutritious meal options (utilization), and a resilient food supply system for urban populations across socio-economic groups (stability).

This study demonstrates that Thai street food policies inadequately address the four dimensions of food security: availability, access, utilization, and stability. The shift from an open registration system to a closed registration system, perceived priorities on orderliness over food security considerations, a restrictive regulatory model, and fragmented regulatory oversight pose significant challenges in aligning street food management with food security goals.

The Bangkok Food Policy 2023-2027 represents a promising step toward a more comprehensive approach to street food management that recognizes its contribution to urban food security (Ahmad & Seng, 2023). To better align street food policies with food security goals, policymakers should consider: (1) developing inclusive policy frameworks that recognize diverse vending formats and create legal pathways for new vendors; (2) implementing balanced zoning approaches that engage both vendors and consumers in decision-making processes; (3) establishing coordinated monitoring systems that support vendors with nutrition and food safety training; and (4) developing sustainable policies built on successful models while incorporating knowledge sharing from international best practices.

Lessons learned from other countries have demonstrated that comprehensive and inclusive street food policies can fulfill food security objectives while maintaining city orderliness. In Asia, while Singapore's hawker center model has proven to improve hygienic standards and preserve cultural heritage, there are many other models from other countries that allow for more flexibility in regulating traditional street food vending practices without sacrificing city ambience, notably in Japan, Singapore, South Korea, and Taiwan (Magluntong & Khotcharee, 2024). Beyond traditional street food management, California is an exemplary case of a supportive legal system where street food is decriminalized, and "compact mobile food operations" are recognized as new forms of street food vending (California Legislative Information, 2018, 2022)

To better align street food governance with food security objectives, this study recommends a comprehensive street food policy framework that addresses key urban food security domains to ensure that Thailand's street food sector contributes to urban food resilience and public health outcomes. The role of the traditional street food sector needs to be taken into consideration in urban design to ensure food security objectives are addressed. Emerging forms of street food vending, such as compact mobile food

operations, also need to be recognized and integrated into regulatory frameworks to ensure that they serve food security objectives.

This study was one of the earliest attempts to explore how these contributive roles of street food align with food security goals. Previous literature has explored the role of street food in urban food security, especially in its role in providing a nutritious and affordable food source among lower-income households, as well as other contributions to poverty reduction, social inclusion, and urban cultural heritage (Misiko & Kisiang'ani, 2024; Stutter, 2017; Tacardon, Ong, & Gumasing, 2023). The strength of this study lies in its application of the FAO's Guide to Conducting a Right to Food Assessment (Mischler, 2009) to the complex relationship between urban food management and food security. However, the limitation of this study is in its scope in Bangkok. Other comparative studies should be conducted to identify how different regulatory scenarios in different settings have an impact on street food vendors.

Conclusion

This study examined the alignment of Thai street food policies with key food security domains: availability, access, utilization, and stability. Findings indicated that Bangkok street food policies and actions inadequately address key food security domains, resulting in a discrepancy between policy formulation and implementation, as evident in a challenging situation regarding street food availability; restrictions on vendors' economic activity in pursuit of city orderliness and urban development; insufficient monitoring of compliance with hygienic and nutritional initiatives; and short-term interventions and regulatory shifts that have an impact on improving street food conditions. To better align street food governance with food security objectives, this study proposes developing inclusive policy frameworks that recognize diverse vending formats; implementing balanced zoning approaches through collaborations with vendors and consumers; establishing coordinated monitoring systems that support vendors with food safety training; and developing sustainable policies built on successful models. The Bangkok Food Policy 2023-2027 represents a promising step toward a more comprehensive approach that recognizes street food's contribution to urban food resilience and public health outcomes in Thailand.

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References

- Ahmad, F. H. B., & Seng, C. E. (2023). The launch of Bangkok Food Policy 2023 - 2027. Retrieved from <https://www.mbsp.gov.my/la21v2/images/visit/2023/bangkok.pdf>
- California Legislative Information. (2018). Senate Bill No. 946 Sidewalk vendors.
- California Legislative Information. (2022). Senate Bill No. 972 California Retail Food Code.
- Carroll, K. A., Basinski, S., & Morales, A. (2016). Fining the hand that feeds you: Situational and violation-specific factors influencing New York City street vendor default in payment. *Cityscape*, 18(1), 89-108.
- Government Gazette. (1976a). *Bangkok Metropolitan Administration Ordinance on the Control of Street Stalls B.E. 2519 (1976)*.
- Government Gazette. (1976b). *Bangkok Metropolitan Administration Ordinance on the Hawkers B.E. 2519 (1976)*.
- Government Gazette. (2002). *Bangkok Metropolitan Administration Ordinance on the Sale of Goods in Public Places or Pathways B.E. 2545 (2002)*.
- Government Gazette. (2003). *Bangkok Metropolitan Administration Regulation on Criteria for Selling Goods in Public Places or Pathways B.E. 2546 (2003)*.
- Government Gazette. (2008). *Bangkok Metropolitan Administration Regulation on Criteria for Selling Goods in Public Places or Pathways (Second Edition) B.E. 2551 (2008)*.
- Maglumtong, M., & Khotcharee, Q. (2024). Evolution of street food management in Asian metropolises. *Asian Creative Architecture, Art and Design*, 37(2).
- Makombe, G. (2023). The food security concept. *Africa Development/Afrique et Développement*, 48(4), 53-80.
- Mischler, F. (2009). Guide to Conducting a Right to Food Assessment.
- Misiko, A. J., & Kisiang'ani, R. I. (2024). Effects of the informal street food vendors' operations on the socio-cultural and economic wellbeing of Nyeri Town Public. *African Journal of Tourism and Hospitality Management*, 3(1), 30-55.
- Nonato, I. L., Minussi, L. d. A., Pascoal, G. B., & De-Souza, D. A. (2016). Nutritional issues concerning street foods. *J Clin Nutr Diet*, 2(1), 1-7.
- Practical, G. (2008). An introduction to the basic concepts of food security. *FAO: Rome, Italy*.
- Pulliat, G., Block, D., Bruckert, M., Nussbaum-Barberena, L., Dreysse, C., Dupé, P., & Perrin, C. (2024). Governing the nurturing city: the uneven enforcement of street food vending regulations. *Urban Geography*, 45(7), 1148-1172.
- Rane, S. (2011). Street vended food in developing world: hazard analyses. *Indian journal of microbiology*, 51(1), 100-106.
- Salamandane, A., Malfeito-Ferreira, M., & Brito, L. (2023). The socioeconomic factors of street food vending in developing countries and its implications for public health: a systematic review. *Foods*, 12(20), 3774.

- Stutter, N. (2017). *The social life of street food: exploring the social sustainability of street food in Hanoi, Vietnam*. Cardiff University,
- Tacardon, E. R., Ong, A. K. S., & Gumasing, M. J. J. (2023). Why are street foods consumed? A machine learning ensemble approach to assess consumption intention of street foods. *Future Foods*, 8, 100261.
- Tacoli, C. (2020). Food (in) security in rapidly urbanizing, low-income contexts. In *Handbook on Urban food security in the global south* (pp. 23-33): Edward Elgar Publishing.

Food Consumption Across Ecological Zones: A Systematic Literature Review on Dietary Patterns and Determinants

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Abstract

Food and nutrition insecurity remains a critical issue, with significant variations observed across the population. Given the substantial dietary differences, addressing these challenges requires an understanding of consumption patterns in various ecological zones. This systematic literature review analyzes existing research on household food consumption across upland, lowland, and coastal areas, highlighting geographic constraints, socioeconomic factors, and gaps in the literature that shape dietary patterns. The review follows a structured approach, utilizing reputable publishers and databases. Altogether, 151 references were identified, of which 52 were excluded after reading the title or abstract and 62 after reading the article, leaving 37 articles for detailed analysis. Findings indicate that upland areas experience food insecurity due to limited market access and low production diversity, while lowland communities benefit from better food access but experience diet shifts toward processed foods. Coastal households exhibit high food insecurity and nutritional deficiencies due to poor infrastructure and storage conditions. Demographic, economic, education, awareness, perception, markets and infrastructure, culture and religion, and price variables influence food consumption with varying effects. Significant gaps remain, which include limited studies disaggregating data by ecological zones, assessing the effectiveness of food-based dietary guidelines, and exploring how gender roles and decision-making influence household food consumption. Hence, there is a pressing need for comprehensive studies and targeted interventions to improve dietary diversity and food security across ecological zones.

Keywords: consumer behavior, diet, food security, nutrition

JEL code: Q18, D12, I32

SDG classification: SDG 2, SDG 3, SDG 10

Introduction

The United Nations (2024) has highlighted that adequate food and freedom from malnutrition are basic human rights and are key to human and national development. Therefore, a healthy and nutritious diet remains crucial to human and national development. The 2030 Agenda for Sustainable Development further states, "...no one will be left behind, and we are determined to ensure that every human being can fulfill their potential in dignity and equality in a healthy environment."

The economic burden of food insecurity and undernutrition emphasizes the urgency of addressing the existing challenges. Estimates from Galasso and Wagstaff (2019) show that the per capita income penalty for developing countries due to childhood stunting ranges between 5-7 percent, while nutritional interventions are estimated to have a 5-7 percent higher rate of return. Furthermore, UNICEF (2019) states that inadequate access to nutritious food heightens the risk of chronic diseases, suggesting that increasing the consumption of healthy food items could help mitigate the burden of diseases.

Geographic location contributes to variations in food intake, representing unique challenges and opportunities (Shmidt & Mukerjee, 2024). Given the significant dietary differences across the population, improving nutrition and food distribution systems requires a deeper understanding of consumption patterns in diverse geographic contexts. To our knowledge, no systematic review has synthesized household food consumption across different ecological zones, particularly upland, lowland, and coastal areas.

This systematic literature review (SLR) integrates existing studies to understand food consumption patterns and their determinants across different contexts. This study aims to answer the following key questions: (i) How do geographic constraints influence food security, dietary diversity, and nutritional outcomes across upland, lowland, and coastal areas? (ii) What are the key determinants of household food consumption across ecological zones? and (iii) What are the gaps in the literature regarding food security in upland, lowland, and coastal areas?

The contribution of this paper is threefold. First, by analyzing prior studies, this SLR provides a comprehensive understanding of food consumption across ecological zones. Second, it highlights inconsistencies, unexplored areas, and gaps in the literature, establishing a foundation for future research. Lastly, it offers insights and recommendations based on empirical findings, supporting evidence-based decision-making among researchers and policymakers.

To achieve these objectives, we review existing literature, following a structured methodology outlined in the next section. We then present the results and discussion before concluding with final remarks.

Methodology

This study employed SLR to synthesize existing research on food consumption in upland, lowland, and coastal areas. It focused on the determinants of food consumption across and gaps in the literature on food and nutrition security. Literature from reputable publishers and databases was sourced, including Cambridge University Press, ScienceDirect, SpringerLink, Wiley Online Library, SAGE Publications, Oxford University Press, and Taylor & Francis. The search included combinations of the following main

keywords: “Household Food Consumption” AND “Ecological Zones,” “Food Security and Nutrition” AND “Upland, Lowland, Coastal Areas,” and “Determinants of Food Consumption” AND “Socioeconomic Factors.”

This review included studies published between 1998 and 2025 that captured trends in household food consumption patterns and examined the role of socioeconomic, geographic, and market factors in influencing food choices. Studies focusing on individual dietary behaviors and those lacking empirical evidence or methodological clarity were excluded. While this SLR provided valuable insights, it is subject to several limitations, including the overrepresentation of studies with significant findings.

Results and Discussion

From the 151 articles in the literature search, we identified 99 abstracts potentially related to our research questions. After reading all available articles in full text, we selected 37 studies. The studies focused mainly on the socioeconomic attributes (n=18) affecting food consumption. Figure 1 displays the detailed selection process.

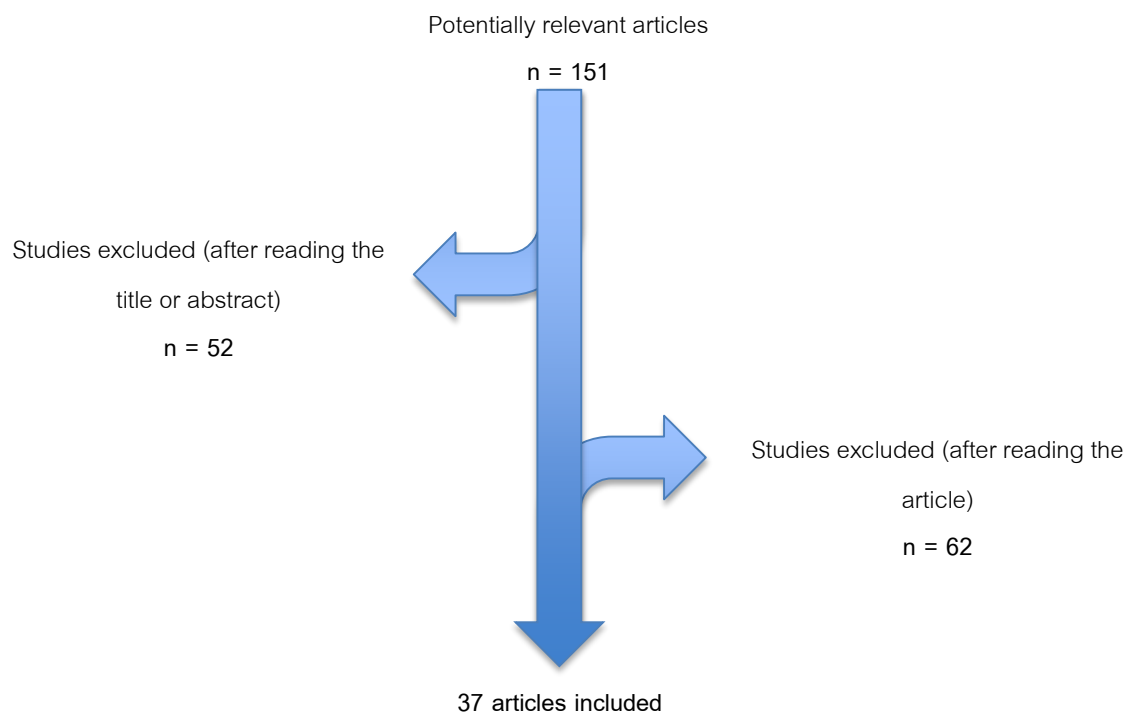


Figure 1. Flowchart of the study selection process.

Geographic constraints that influence food security, dietary diversity, and nutritional outcomes

Food and nutrition security challenges varied across upland, lowland, and coastal areas in different countries, shaped by market access, dietary diversity, gender dynamics, and spatial inequalities (Table 1). The countries included Indonesia, Ethiopia, Lao PDR, Papua New Guinea, the Philippines, and Lesotho, where most primary authors were from.

Upland regions faced food insecurity due to limited market access and low production diversity, leading to inadequate dietary diversity and shortages of essential food items (Boulom et al., 2020). While energy intake was sufficient in some upland communities, protein deficiency and malnutrition persisted (Antriyandarti et al., 2023). Lower dietary diversity among lactating women in highland areas suggests that food security does not necessarily equate to nutritional security (Sitotaw, Haileslasie, & Adama, 2017). In Papua New Guinea, subsistence agriculture was prevalent, but food value chain challenges limited access to diverse food sources (Schmidt & Mukerjee, 2024). In the Philippines, upland indigenous groups, particularly in conflict areas, relied more on locally available food but still exhibited inadequate nutrient consumption (Ricalde et al., 2019). Market inaccessibility constrained food choices, leading to monotonous diets and severe malnutrition (Viloria & Barrion, 2018).

Lowland communities generally had better access to food and essential services, promoting diet diversity (Viloria & Barrion, 2018). However, proximity to fast-food establishments limited healthy food choices. Additionally, gender disparities affected food security. Women in Lesotho's lowlands faced exclusion from decision-making, land ownership, and economic resources, leading to higher food insecurity (Mokati, Ncube, & Bahta, 2022).

Table 1. Geographic constraints and their impact on food security and nutrition

Ecological Zone	Key Challenges	Countries	Supporting Studies
Upland	Limited market access, low production diversity, inadequate dietary diversity, protein deficiency, malnutrition, armed conflict	Lao PDR, Indonesia, Ethiopia, Papua New Guinea, Philippines	Sitotaw et al. (2017), Viloria and Barrion (2018), Ricalde et al. (2019), Boulom et al. (2020), Antriyandarti et al. (2023), Schmidt and Mukerjee (2024)
Lowland	Better food access, but fast-food proximity limits healthy choices; gender disparities in food security	Philippines, Lesotho	Viloria & Barrion (2018), Mokati et al. (2022)
Coastal	High food insecurity, malnutrition, poor transport, high stunting rates, deficiencies in protein, calcium, and iron	Indonesia, Philippines	Sumarmi et al. (2018), De Guzman (2019), Yuliantini et al. (2022)

Source: Own elaboration.

Coastal communities experienced severe food insecurity and malnutrition compared to agricultural regions (Sumarmi, Mahmudiono, & Melaniani, 2018). Limited fruit consumption, particularly among men, was linked to spatial inequalities, including poor transportation infrastructure. Stunting rates in coastal Indonesia exceeded global levels, highlighting the long-term consequences of poor nutrition (Yuliantini et al., 2022). In the Philippines, despite higher per capita food intake due to rice and seafood consumption,

coastal households still faced deficiencies in protein, calcium, and iron (De Guzman, 2019).

Overall, the findings emphasize the critical role of geographic location, infrastructure, and socioeconomic factors in shaping food security and nutrition outcomes. Addressing these disparities requires targeted interventions to improve food access, dietary diversity, and nutrition awareness in each ecological zone.

Key determinants of household food consumption across ecological zones

The SLR highlights multiple factors influencing household food consumption in upland, lowland, and coastal areas. These determinants are related to demographics, economic factors, education, awareness and perception, markets and infrastructure, culture and religion, and prices, with varying effects (Table 2).

Household composition and demographics were the most studied (n=12). Some studies found a positive relationship between household size and food consumption (Laorden & Bangcaya, 2013; Fujii, 2016; Terin et al., 2019; Onumah et al., 2020), while others revealed a negative relationship (Gustavsen & Rickertsen, 2006; Aepli & Finger, 2013; Antriandarti et al., 2023). Sex positively influenced food consumption, with females prioritizing healthy food choices (Lantican et al., 2013; Ogundele, 2014; Amo-Adjei & Kumi-Kyereme, 2015; Fujii, 2016; Terin et al., 2019; Dizon, Josephson, & Wang, 2022). Older individuals tended to consume more fruits, vegetables, dairy, and fish while being more conscious of dietary health (Gustavsen & Rickertsen, 2006; Amo-Adjei & Kumi-Kyereme, 2015; Fujii, 2016; Terin et al., 2019), but they spent less on rice, protein-rich foods, and high-calorie meals (Lantican et al., 2013; Ogundele, 2014; Fujii, 2016; Adeleke & Owoye, 2022). Married individuals were found to consume more fish, fruits, and vegetables due to the increased household size and associated food expenditures (Terin et al., 2019; Onumah et al., 2020). Household characteristics positively influenced fruit and vegetable consumption (Terin et al., 2019).

A total of 11 studies explored economic factors. Those with higher income generally had improved diet quality, increased protein and calorie intake, and boosted fruit and vegetable consumption, although the effects varied by region and food type (Laorden & Bangcaya, 2013; Terin et al., 2019; Onumah et al., 2020; Bairagi et al., 2022; Antriandarti et al., 2023; Comstock, Ecker, & Jones, 2024). However, lower-income households in some regions, such as Cebu City, Philippines, exhibited greater dietary diversity and higher consumption of certain food items like meat and fruits, while higher-income groups allocated less expenditure to fish and reduced consumption of some food items when income declined (Amo-Adjei & Kumi-Kyereme, 2015; Dai et al., 2021; Valera et al., 2022; Howard & Labuzon, 2024). Having a formal job or off-farm income enhanced food consumption, increasing spending on fish, beef, chicken, fruits, and vegetables (Laorden & Bangcaya, 2013; Amo-Adjei & Kumi-Kyereme, 2015; Onumah et al., 2020; Ma & Zheng, 2021). However, time constraints from employment limited fruit and vegetable intake (Terin et al., 2019). Retirement pensions positively influenced fruit consumption, while financial aid recipients tended to consume fewer fruits and vegetables, potentially due to their lower income and quality of life (Terin et al., 2019).

Table 2. Factors influencing household food consumption in upland, lowland, and coastal areas

Category	Factors	Supporting Studies
Demographics	Household Size	Gustavsen and Rickertsen (2006); Aepli and Finger (2013); Laorden and Bangcaya (2013); Fujii (2016); Terin et al. (2019); Onumah et al. (2020); Antriyandarti et al. (2023)
	Sex	Lantican et al. (2013); Ogundele (2014); Amo-Adjei and Kumi-Kyereme (2015); Fujii (2016); Terin et al. (2019); Dizon et al. (2022)
	Age	Gustavsen and Rickertsen (2006); Lantican et al. (2013); Ogundele (2014); Amo-Adjei and Kumi-Kyereme (2015); Fujii (2016); Terin et al. (2019); Onumah et al. (2020); Adeleke and Owoeye (2022)
	Marital Status	Terin et al. (2019)
Economic	Income	Laorden and Bangcaya (2013); Amo-Adjei and Kumi-Kyereme (2015); Terin et al. (2019); Onumah et al. (2020); Dai et al. (2021); Bairagi et al. (2022); Valera et al. (2022); Antriyandarti et al. (2023); Comstock et al. (2024); Howard and Labuzon (2024)
	Employment	Laorden and Bangcaya (2013); Amo-Adjei and Kumi-Kyereme (2015); Terin et al. (2019); Onumah et al. (2020); Ma and Zheng (2021)
	Financial Aid	Terin et al. (2019)
Education, Awareness, and Perception	Nutrition Awareness	Amo-Adjei and Kumi-Kyereme (2015); Terin et al. (2019); Boulom et al. (2020); Onumah et al. (2020); Dai et al. (2021); Yuliantini et al. (2022)
	Policies and education Programs	Lantican et al. (2013); Ogundele (2014); Fujii (2016); Darfour-Oduro, Andrade, and Grigsby-Toussaint (2020); Dai et al. (2021)
	Food security perceptions	Onumah et al. (2020); Seligman et al. (2023)
Markets and Infrastructure	Market proximity	Onumah et al. (2020); Dai et al. (2021); Nguyen and Qaim (2024)
	Retail sector	Farrell et al. (2021)
	Vehicle ownership	Terin et al. (2019)
Culture and religion	Ethnicity	Maxwell et al. (2012); Ricalde et al. (2019); Duante et al. (2022)
	Religion	Laorden and Bangcaya (2013); Amo-Adjei and Kumi-Kyereme (2015); Onumah et al. (2020)

Category	Factors	Supporting Studies
Prices	Own-price and Cross-price	Aepli and Finger (2013); Sanusi, Ashaolu, and Ogundipe (2017); Dai et al. (2021); Bairagi et al. (2022); Valera et al. (2022); Comstock et al. (2024)

Source: Own elaboration.

Education, awareness, and perception were also found to influence food consumption. Higher education and nutrition awareness promoted healthier diets, increasing fruit, vegetable, fish, and protein intake (Amo-Adjei & Kumi-Kyereme, 2014; Terin et al., 2019; Boulom et al., 2020; Onumah et al., 2020; Dai et al., 2021; Yuliantini et al., 2022). Policies and combined educational strategies enhanced nutritional knowledge and dietary habits (Darfour-Oduro et al., 2020; Dai et al., 2021). However, higher education reduced rice and cereal consumption, shifting spending toward meat and fruits (Lantican et al., 2013; Ogundele, 2014; Fujii, 2016). A major gap in nutrition education remains, especially in early childhood (Schmidt & Mukerjee, 2024). Food security perceptions affected dietary patterns beyond income levels. Seligman et al. (2023) linked food insecurity to lower fruit and vegetable intake. Onumah et al. (2020) found that low-income mountain households in Ghana adapted to food price fluctuations, with most having year-round access to fish.

Access to markets and infrastructure shaped food consumption and dietary diversity. Market proximity improved dietary diversity and food consumption, particularly for fish, fruits, and vegetables, while better infrastructure enhanced market access (Onumah et al., 2020; Dai et al., 2021; Nguyen & Qaim, 2024). Supermarkets and grocery retail sectors provided diverse and safe food options while increasing access to processed foods (Farrell et al., 2021). In contrast, vehicle ownership and home internet access correlated with lower fruit and vegetable consumption, possibly due to misconceptions about food accessibility and the appeal of diverse online food options (Terin et al., 2019).

Cultural and religious factors shaped dietary patterns by influencing food preferences, accessibility, and restrictions. Ethnicity impacted food consumption, with Asian Americans consuming fewer fruits and vegetables than non-Hispanic whites (Maxwell et al., 2012), while indigenous populations in the Philippines experienced lower diet diversity and higher undernutrition due to socioeconomic and political disadvantages (Ricalde et al., 2019; Duante et al., 2022). Religious beliefs also affected dietary choices, as Christians tended to spend more on fish (Onumah et al., 2020), traditional spiritualists consumed fewer fruits and vegetables (Amo-Adjei & Kumi-Kyereme, 2015), and Muslim dietary laws limited pork consumption (Laorden & Bangcaya, 2013).

Food prices, income, and consumption patterns interacted in complex ways. Rice was essential for rural households but an inferior good for wealthier groups (Bairagi et al., 2022). Filipinos have been shifting to high-value foods (Valera et al., 2022). Grain price shocks impacted food security differently across countries (Comstock et al., 2024). Higher prices of healthy foods reduced fruit and vegetable consumption (Dai et al., 2021). Cross-price effects showed that rising pork prices increased demand for sheep and goat meat (Aepli & Finger, 2013), while beef prices affected chicken demand (Sanusi et al., 2017).

Gaps in the literature regarding food security across ecological zones

Despite the available studies, several gaps remain in understanding food consumption and food security across upland, lowland, and coastal households. Most research has focused on national and regional trends, with limited studies disaggregating data by ecological zones (e.g., within a single city or municipality). The role of food-based dietary guidelines and the assessment of their effectiveness in changing household dietary behavior and improving nutritional outcomes remain lacking. While gender disparities are mentioned, there is a need for more studies that explore how gender roles and decision-making influence household food consumption, particularly in fishing communities. Lastly, research has focused on food security, but nutrition security, or the accessibility to a diverse and nutrient-rich diet, remains underexplored.

Conclusion

This SLR has highlighted the critical role of geographic constraints in shaping food security, dietary diversity, and nutritional outcomes across upland, lowland, and coastal areas. Findings indicate that upland regions experience food insecurity due to limited market access, low production diversity, and inadequate dietary variety, leading to malnutrition. Lowland areas generally benefit from better food access but are increasingly influenced by urbanization and the consumption of processed foods, raising concerns about diet quality. Coastal communities exhibit high food insecurity and nutritional deficiencies, aggravated by poor food storage, limited transport infrastructure, and reliance on unstable food sources. These disparities highlight the need for localized interventions to improve food availability and nutrition across ecological zones.

Socioeconomic factors, market accessibility, cultural preferences, and nutrition awareness influence household food consumption. Income and employment play a crucial role, with wealthier households consuming more nutrient-dense foods while lower-income groups struggle with food access and diversity. Education and nutrition awareness significantly influence dietary choices, with better-educated individuals more likely to consume fruits, vegetables, and proteins. However, economic constraints, gender disparities, and physical market accessibility limit food security across different regions.

While existing studies have provided valuable insights, significant gaps remain. There is limited research on behavioral drivers of food consumption across ecological zones. Additionally, few studies have examined the effectiveness of food-based dietary guidelines in improving household nutrition and dietary diversity. Gender studies and nutrition security remain underexplored. Addressing these gaps through comprehensive studies and targeted policy interventions will be essential in advancing food security and nutrition outcomes.

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References

- Adeleke, O., & Owoeye, R. S. (2022). *Demand Analysis of Fruits and Vegetables on Consumers' Behaviour in Ekiti State, Nigeria*. *International Journal of Agriculture Innovations and Research*, 11(2).
- Aeppli, M., & Finger, R. (2013). Determinants of sheep and goat meat consumption in Switzerland. *Agricultural and Food Economics*, 1(1), 11. <https://doi.org/10.1186/2193-7532-1-11>
- Amo-Adjei, J., & Kumi-Kyereme, A. (2015). FRUIT AND VEGETABLE CONSUMPTION BY ECOLOGICAL ZONE AND SOCIOECONOMIC STATUS IN GHANA. *Journal of Biosocial Science*, 47(5), 613–631. <https://doi.org/10.1017/S002193201400025X>
- Antriandarti, E., Barokah, U., Rahayu, W., Laia, D. H., & Asami, A. (2023). Factors Associated with Food Security of Dryland Farm Households in the Karst Mountains of Gunungkidul Indonesia. *Sustainability*, 15(11), 8782. <https://doi.org/10.3390/su15118782>
- Bairagi, S., Mohanty, S., Baruah, S., & Thi, H. T. (2020). Changing food consumption patterns in rural and urban Vietnam: Implications for a future food supply system. *Australian Journal of Agricultural and Resource Economics*, 64(3), 750–775. <https://doi.org/10.1111/1467-8489.12363>
- Boulom, S., Essink, D. R., Kang, M.-H., Kounnavong, S., & Broerse, J. E. W. (2020). Factors associated with child malnutrition in mountainous ethnic minority communities in Lao PDR. *Global Health Action*, 13(sup2), 1785736. <https://doi.org/10.1080/16549716.2020.1785736>
- Comstock, A., Ecker, O., & Jones, E. (2024). *A shock to the (food) system: Using new IFPRI tools to evaluate household food security outcomes*. <https://www.ifpri.org/blog/a-shock-to-the-food-system-using-new-ifpri-tools-to-evaluate-household-food-security-outcomes/>
- Dai, C.-L., Sharma, M., Haider, T., & Sunchu, H. (2021). Fruit and Vegetable Consumption Behavior Among Asian Americans: A Thematic Analysis. *Journal of Primary Care & Community Health*, 12, 2150132720984776. <https://doi.org/10.1177/2150132720984776>
- Darfour-Oduro, S. A., Andrade, J. E., & Grigsby-Toussaint, D. S. (2020). Do fruit and vegetable policies, socio-environmental factors, and physical activity influence fruit and vegetable intake among adolescents? *Journal of Adolescent Health*, 66(2), 172-180.
- De Guzman, A., Sumalde, Z., Rance, G. M., Colance, M. D., & Ponce, M. F. (2019). Contribution of gleaning fisheries to food security and nutrition of poor coastal communities in the Philippines. *Journal of Environmental Science and Management*, 22(1), 34-40.
- Dizon, F., Josephson, A., & Wang, Z. (2022). *Intra-Household Inequality in Food Consumption and Diets in the Philippines*. *The World Bank*. <https://doi.org/10.1596/1813-9450-10170>
- Duante, C., Austria, R. E., Ducay, A. J., Acuin, C. C., & Capanzana, M. (2022). Nutrition and Health Status of Indigenous Peoples (IPs) in the Philippines: Results of the 2013

- National Nutrition Survey and 2015 Updating Survey. *Philippine Journal of Science*, 151(1). <https://doi.org/10.56899/151.01.39>
- Farrell, P., Rachmi, C. N., Mulcahy, G., Helble, M., & Thow, A. M. (2021). Food environment research is needed to improve nutrition and well-being in Asia and the Pacific. *Public Health Nutrition*, 24(14), 4706–4710. <https://doi.org/10.1017/S136898002100241X>
- Fujii, T. (2016). *Is urban food demand in the Philippines different from China?* In Chinese Global Production Networks in ASEAN (pp. 97–117). Springer International Publishing.
- Galasso, E., & Wagstaff, A. (2019). The aggregate income losses from childhood stunting and the returns to a nutrition intervention aimed at reducing stunting. *Economics & Human Biology*, 34, 225–238. <https://doi.org/10.1016/j.ehb.2019.01.010>
- Gustavsen, G. W., & Rickertsen, K. (2006). A Censored Quantile Regression Analysis of Vegetable Demand: The Effects of Changes in Prices and Total Expenditure. *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie*, 54(4), 631–645. <https://doi.org/10.1111/j.1744-7976.2006.00070.x>
- Howard, L. L., & Labuzon, C. (2024). The impact of urbanization on children's diets: Longitudinal evidence from Cebu. *Journal of Social and Economic Development*, 26(2), 603–618. <https://doi.org/10.1007/s40847-023-00284-7>
- Lantican, F.A., Sombilla, M.A., & Quilloy, K.P. (2013). Estimating the demand elasticities of rice in the Philippines. *SEARCA*.
- Laorden, N. L., & Bangcaya, A. M. P. (2013). *Consumers' Purchasing Behavior Towards Fresh Meat in Davao City, Philippines*. *BANWA*, 10(1), 50-64.
- Ma, W., & Zheng, H. (2021). Promoting fruit and vegetable consumption in rural China: Does off-farm work play a role? *Q Open*, 1(2), qoab010. <https://doi.org/10.1093/qopen/qoab010>
- Maxwell, A. E., Crespi, C. M., Alano, R. E., Sudan, M., & Bastani, R. (2012). Health Risk Behaviors Among Five Asian American Subgroups in California: Identifying Intervention Priorities. *Journal of Immigrant and Minority Health*, 14(5), 890–894. <https://doi.org/10.1007/s10903-011-9552-8>
- Mokati, J. T. W., Ncube, A., & Bahta, Y. T. (2024). Is It Really Feminization of Agriculture? The Issue of Household Food Security in Lesotho's Southern Lowland District. *Journal of Asian and African Studies*, 59(2), 411–424. <https://doi.org/10.1177/00219096221111359>
- Nguyen, T.-T., & Qaim, M. (2025). Local and regional food production diversity are positively associated with household dietary diversity in rural Africa. *Nature Food*. <https://doi.org/10.1038/s43016-024-01096-6>
- Ogundele, O. (2014). Factors influencing consumers' preference for local rice in Nigeria. *African Journal of Marketing Management*, 6(4), 49-55.
- Onumah, E. E., Quaye, E. A., Ahwireng, A. K., & Campion, B. B. (2020). Fish Consumption Behaviour and Perception of Food Security of Low-Income Households in Urban Areas of Ghana. *Sustainability*, 12(19), 7932. <https://doi.org/10.3390/su12197932>

- Ricalde, R. G. J., Libranza, A. K. P., Alviola, P. A., Sarmiento, J. M. P., Obsioma, V. P., Limpoco, M. A. A. A., & Laorden, N. L. (2018). Diet constraints of indigenous children in conflict and non-conflict areas of Davao del Norte, Philippines. *Journal of Economics, Management & Agricultural Development*, 4(1), 19-37.
- Sanusi, M. M., Ashaolu, O. F., & Ogundipe, J. B. (2017). ANALYSIS OF HOUSEHOLD CONSUMPTION OF CHICKEN IN IDO LOCAL GOVERNMENT AREA, OYO STATE. *Ife Journal of Agriculture*, 29(1), 74-83.
- Schmidt, E., & Mukerjee, R. (2024). *Survey: Rural Papua New Guinea faces an array of food security challenges*. IFPRI Blog: Research Post | Development Strategies and Governance.
- Seligman, H. K., Levi, R., Adebisi, V. O., Coleman-Jensen, A., Guthrie, J. F., & Frongillo, E. A. (2023). Assessing and Monitoring Nutrition Security to Promote Healthy Dietary Intake and Outcomes in the United States. *Annual Review of Nutrition*, 43(1), 409–429. <https://doi.org/10.1146/annurev-nutr-062222-023359>
- Sitotaw, I. K., Haileslasie, K., & Adama, Y. (2017). Comparison of nutritional status and associated factors of lactating women between lowland and highland communities of District Raya, Alamata, Southern Tigray, Ethiopia. *BMC nutrition*, 3, 1-12.
- Sumarmi, S., Mahmudiono, T., & Melaniani, S. (2018). *Household food insecurity and undernutrition in children below 5 years living in different geographical areas in East Java, Indonesia*.
- Terin, M., Birinci, A., Bilgic, A., & Urak, F. (2019). Determinants of Fresh and Frozen Fruit and Vegetable Expenditures in Turkish Households: A Bivariate Tobit Model Approach. *Journal of Food Products Marketing*, 25(2), 137–158. <https://doi.org/10.1080/10454446.2018.1500327>
- [UNICEF] The United Nations International Children's Emergency Fund. (2019). Stunting and malnutrition pose health and economic burden in Bangsamoro. *UNICEF Philippines*. <https://www.unicef.org/philippines/stories/stunting-and-malnutrition-pose-health-and-economic-burden-bangsamoro>
- [UN] United Nations. (2024). OHCHR and the right to food. *United Nations Human Rights Office*. <https://www.ohchr.org/en/food>
- Valera, H. G., Mayorga, J., Pede, V. O., & Mishra, A. K. (2022). Estimating food demand and the impact of market shocks on food expenditures: The case for the Philippines and missing price data. *Q Open*, 2(2), qoac030. <https://doi.org/10.1093/qopen/qoac030>
- Viloria, A. L. S., & Barrion, A. S. A. (2018). *Diet Diversity and Nutritional Status of Children 2 to 5 Years Old Situated in different Ecological Settings*.
- Yuliantini, E., Sukiyono, K., Yuliarso, M. Z., & Sulisty, B. (2022). Food Security and Stunting Incidences in the Coastal Areas of Indonesia. *Open Access Macedonian Journal of Medical Sciences*, 10(F), 454–461. <https://doi.org/10.3889/oamjms.2022.9335>

Unlocking Sustainability in Corn Farming: Enablers and Barriers to the Shift from Linear to Circular Economy in Lucena City, Quezon

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Abstract

The shift from a linear to a circular economy in agriculture offers a promising pathway to sustainability and resource efficiency. This study examines the adoption of circular economy practices in corn farms in Lucena City, Quezon Province, discovering the factors that enable or hinder this transition. As Quezon remains the leading corn producer in CALABARZON, understanding how sustainability principles are integrated into its farming systems is crucial. Using a qualitative research approach, the study collects data through semi-structured interviews and field observations with local farmers and stakeholders. Thematic analysis uncovers key trends in circular economy adoption, including existing practices, challenges, and critical success factors. Findings indicate that while some farmers engage in sustainable practices such as organic fertilization and crop residue repurposing, the persistence of traditional linear methods stems from financial limitations, knowledge gaps, and inconsistent policy support. Key enablers for circular economy adoption include economic incentives, access to training, improved infrastructure, and stronger policy frameworks. The study concludes that circular economy practices can enhance agricultural sustainability by reducing costs, improving soil health, and strengthening community resilience. However, addressing structural and institutional challenges is essential for widespread implementation. Based on these insights, the study provides strategic recommendations to facilitate the transition toward circular economy principles in corn farming, contributing to broader efforts in sustainable agriculture.

Keywords: agricultural resilience, circular economy practices, corn farms, resource efficiency, sustainable farming

JEL code: Q01, Q12, Q57

SDG classification: SDG 2; SDG 12, SDG 13

Introduction

The increasing global demand for food production presents significant challenges for agricultural systems, necessitating the adoption of sustainable practices to mitigate environmental degradation while ensuring long-term productivity. Agriculture is a major contributor to land degradation, greenhouse gas emissions, and excessive resource consumption, prompting the need for innovative approaches that balance productivity with sustainability (Aznar-Sánchez et al., 2019; Circle Economy, 2021). One such approach is the Circular Economy (CE), which emphasizes resource efficiency, waste reduction, and regenerative agricultural practices as an alternative to the traditional linear model of production and consumption (Velasco-Muñoz et al., 2021). CE principles have demonstrated potential in mitigating climate change, conserving biodiversity, and enhancing food security by closing material loops through recycling, reusing, and repurposing agricultural inputs (EMF, 2019). However, despite its global adoption, CE integration into small-scale farming, particularly in developing countries, remains underexplored.

In the Philippines, small-scale farmers constitute the backbone of the agricultural sector, yet they face persistent challenges such as resource scarcity, financial constraints, and limited access to sustainable inputs (PSA, 2022). Quezon Province, a leading producer of corn in the CALABARZON region, plays a vital role in ensuring food security, livestock feed supply, and industrial raw materials (PSA, 2024; Exconde, 2023). However, research on sustainable corn farming practices, particularly the application of CE principles, is limited. This study aims to bridge this gap by investigating CE adoption in small-scale corn farms in Lucena City, Quezon Province. It seeks to evaluate how CE practices are implemented, the challenges faced by farmers, and the factors influencing successful adoption.

This research is particularly important as it addresses sustainability concerns in small-scale farming while providing practical insights into integrating CE principles into Philippine agriculture. The study's objectives include characterizing the profiles of small-scale corn farms in Lucena City, identifying existing CE practices and associated challenges, assessing the impact of CE adoption on agricultural sustainability, determining the key success factors in transitioning to circular farming models, and developing recommendations for wider CE implementation. The findings will benefit policymakers, agricultural stakeholders, and farmers by offering evidence-based strategies for sustainable farming, contributing to improved resource management and economic viability.

Previous studies on CE have primarily focused on large-scale agricultural systems, leaving a gap in understanding how small-scale farms can adopt and benefit from circular approaches. This research adds value by examining the localized context of corn farming in the Philippines, addressing the practical barriers to CE adoption, and offering solutions tailored to smallholder farmers.

Methodology

This study was conducted in Lucena City, Quezon Province, a significant agricultural hub in the CALABARZON region known for its corn production. The research employed a qualitative approach to examine the adoption of circular economy (CE) practices among

small-scale corn farmers. Given the complexity of agricultural sustainability and the integration of CE principles, a qualitative design was deemed appropriate to explore the lived experiences, challenges, and factors influencing CE adoption in corn farming. The study is grounded in the principles of the circular economy, which emphasize sustainability through waste reduction, resource efficiency, and regenerative agricultural practices. This framework provides the foundation for analysing farming methods that transition from a linear production model to a circular one. The study also incorporates elements of socio-ecological systems theory, considering the interconnectedness of farmers, environmental factors, and external stakeholders in influencing CE adoption.

Primary data were collected using semi-structured interviews and direct field observations. The interviews consisted of open-ended questions designed to explore CE practices, adoption challenges, and their perceived impacts on sustainability. Field observations complemented these interviews by providing empirical evidence of farming activities, waste management, and recycling practices. A non-probability snowball sampling technique was used to identify respondents. Initial participants, members of three prominent corn growers' associations—Isabang Corn Growers Association, Ibatas Corn Growers Association, and Bocoohan-Domoit Corn Growers Association—were asked to refer other farmers engaged in CE practices. This approach ensured that respondents had relevant experiences and insights on the topic.

The study employed thematic analysis to identify and interpret patterns within the qualitative data. This approach allowed for an in-depth examination of CE adoption in the context of small-scale farming. Thematic coding was performed inductively, allowing themes to emerge organically. The process followed Braun and Clarke's (2006) framework, beginning with familiarization, coding, theme identification, and refinement. Themes were then categorized into broader areas related to internal farming systems, external stakeholder relations, and sustainability impacts. Several instruments were utilized to ensure systematic data collection, including a participant consent form that ensured voluntary participation, confidentiality, and ethical compliance, a semi-structured interview guide focused on farm profiles, CE practices, adoption challenges, sustainability impacts, and success factors, and a demographic information form that collected data on farmers' age, experience, farm size, and association memberships.

While this study is qualitative in nature, validation of findings was achieved through triangulation, wherein interview responses were cross verified with field observations and secondary data sources such as government reports and agricultural statistics. This ensured credibility and reliability in identifying the key drivers and barriers to CE adoption in corn farming. By employing a comprehensive methodological approach, this study provides a structured analysis of CE practices in small-scale corn farming, contributing to a deeper understanding of sustainable agricultural transitions.

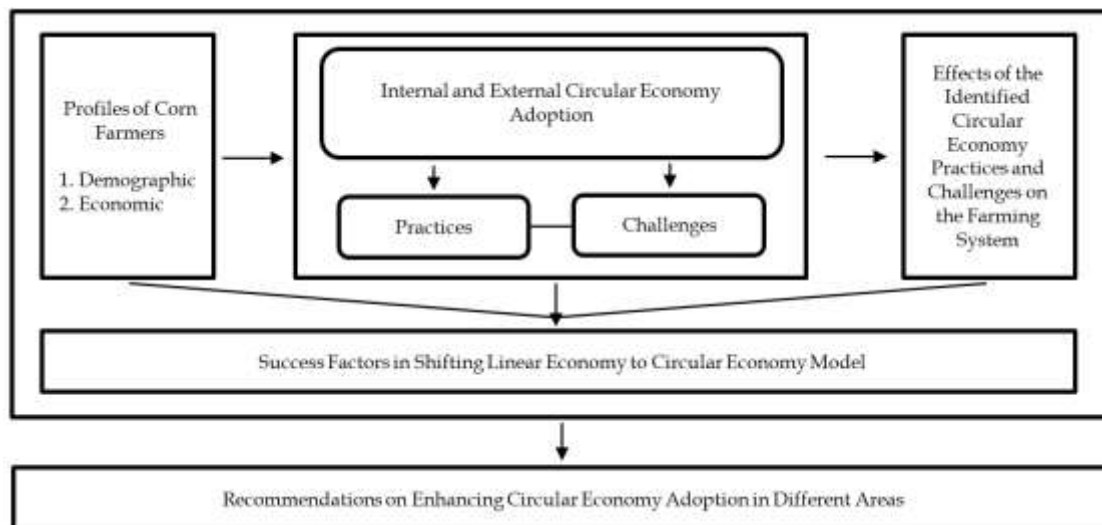


Figure 1: Conceptual framework of the study

The conceptual framework presents a structured overview of the various interconnected components influencing the adoption of circular economy (CE) practices in corn farms in Lucena, Quezon Province. It aligns closely with the study's objectives, providing a systematic pathway from farmer profiling to actionable recommendations for advancing sustainable agriculture.

At the foundation of the framework, the profiles of corn farmers are examined, focusing on two key dimensions: demographic and economic factors. These include attributes such as age, gender, educational background, average harvest yields, and income per harvest. These variables provide a basis for understanding how personal and economic conditions shape farming practices and the willingness to adopt CE strategies.

The second layer of the framework addresses both internal and external factors impacting CE adoption. Internal practices refer to on-farm strategies, such as composting, using organic fertilizers, and efficient land use. External relations, on the other hand, encompass interactions with stakeholders like government agencies, markets, and local cooperatives, which can either facilitate or hinder the integration of CE principles. The interplay between internal and external factors shapes the farmer's ability to effectively adopt and sustain CE practices.

The next component of the framework examines the effects of CE practices and associated challenges on farming systems. These effects are analyzed in terms of their positive and negative impacts, offering insights into how CE adoption influences operational efficiency, yield sustainability, and environmental outcomes. This analysis is aligned with the study's definition of "effects," focusing on tangible and measurable changes.

The penultimate layer of the framework synthesizes findings from earlier sections to identify key success factors for transitioning from a linear economy (LE) to a circular economy (CE) model. This includes identifying enablers, such as government subsidies, farmer knowledge, and access to sustainable inputs, as well as obstacles like high costs and labor demands that affect the successful integration of CE practices.

At the bottom of the framework, the study concludes with recommendations designed to promote the adoption of CE in corn farming. These recommendations are tailored to the specific context of Lucena City, while also aiming to be adaptable to other agricultural regions, ensuring a broader impact on sustainability.

Results and Discussion

The study on circular economy (CE) adoption in small-scale corn farming in Lucena City, Quezon Province, reveals both emerging sustainable practices and persistent challenges. While some farmers have started integrating CE principles, such as using organic fertilizers, repurposing crop residues, and implementing natural pest management, widespread adoption remains hindered by financial, technical, and structural constraints. High costs and limited availability of sustainable inputs, labor-intensive processes, and inconsistent government support pose significant barriers. Despite these challenges, CE practices have demonstrated potential economic, environmental, and social benefits. Economically, they help reduce costs through resource efficiency, although financial instability and market fluctuations hinder their long-term viability. Environmentally, practices like organic fertilizers and crop residue repurposing contribute to improved soil fertility and waste reduction, yet unsustainable methods, such as burning residues, persist. Socially, CE adoption creates employment opportunities and fosters skill development, but a lack of strong institutional support limits its impact.

These findings underscore the importance of CE in promoting agricultural sustainability. By minimizing waste, optimizing resource use, and enhancing farm resilience, CE practices contribute to the long-term viability of small-scale farming. However, systemic challenges, including inadequate infrastructure, financial constraints, and the absence of market incentives, must be addressed for successful implementation. The study emphasizes the crucial role of consistent policy support, farmer education, and improved market mechanisms in facilitating the transition toward circular farming systems.

Additionally, this research fills a critical gap in CE studies by focusing on small-scale corn farming in the Philippine context, an area that has received limited attention compared to industrial applications of CE. While existing literature primarily explores CE implementation in larger agricultural and industrial sectors, this study provides empirical evidence on the challenges and opportunities within smallholder farming. By highlighting the specific constraints faced by corn farmers in Lucena City and the factors influencing CE adoption, the study contributes valuable insights that can inform national agricultural policies and sustainability strategies. It also lays the groundwork for future research on scaling CE adoption in other regions, helping to drive more sustainable and resilient agricultural practices in the Philippines.

Profile of Corn Farmers

Key demographic characteristics

The age distribution of corn farmers in Lucena City shows an aging workforce, with the majority (46-55 years old) making up the largest group. A smaller portion consists of younger farmers aged 25-35, indicating limited generational renewal in the industry. This trend poses a sustainability challenge, as older farmers near retirement, and there are insufficient younger successors to continue farming.

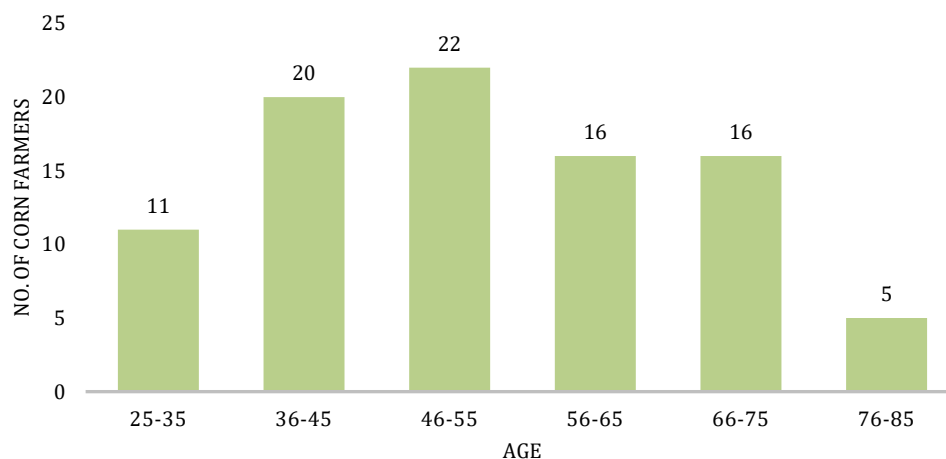


Figure 2. Age of corn growers in Lucena City

The gender composition of corn farming in Lucena City is predominantly male, with 78% of farmers being men and only 22% being women. This disparity reflects long-standing perceptions of agriculture as physically demanding work, limiting female participation. Despite the challenges, female farmers contribute significantly to the industry, highlighting the need for targeted support programs to encourage gender inclusivity in farming.

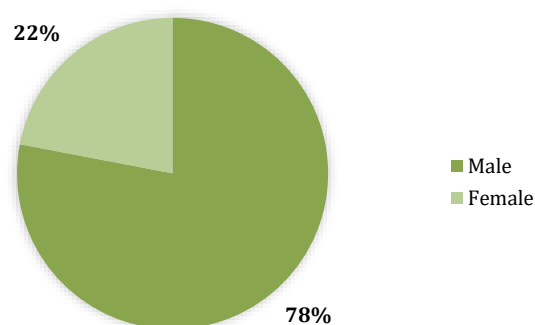


Figure 3. Gender of corn growers in Lucena City

Educational attainment among corn farmers is relatively low, with 61.9% having only an elementary education, 23.8% reaching high school, and just 14.3% attaining college education. Limited education may restrict farmers' ability to adopt innovative and sustainable agricultural techniques, such as circular economy (CE) practices. Farmers with higher education levels may be more open to adopting sustainable solutions, emphasizing the importance of targeted agricultural training programs.

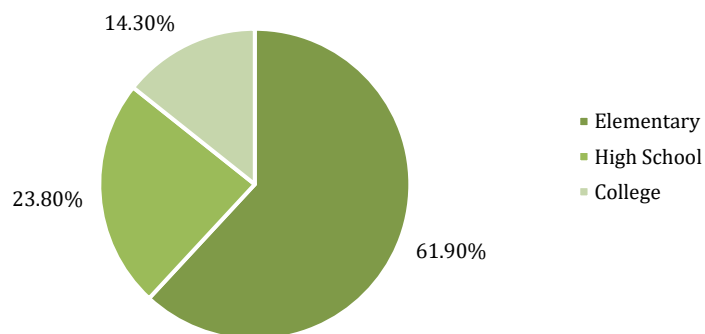


Figure 4. Educational attainment of corn growers in Lucena City

Economic characteristics of farmers

Corn farmers in Lucena City operate predominantly on small-scale farms, with most managing land areas between 0-3 hectares. This small-scale nature influences their productivity and ability to invest in CE practices. Farm ownership patterns reveal that a significant portion of farmers do not own their land but instead rent it. This affects long-term sustainability investments, as tenant farmers may be hesitant to adopt long-term soil conservation or infrastructure improvements due to uncertain land tenure.

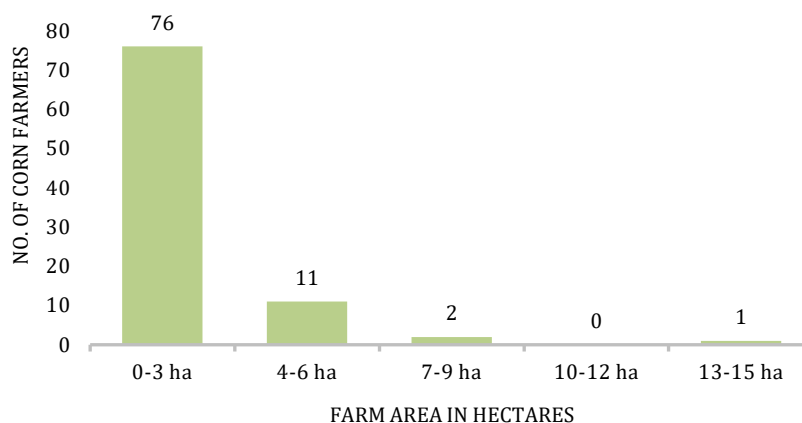


Figure 5. Average farm area of corn growers in Lucena City

The financial stability of corn farmers is affected by various economic challenges, including low income per harvest, pest infestations such as fall armyworm, and fluctuating market prices. These financial constraints limit farmers' ability to invest in sustainable

inputs, mechanization, and CE practices. Without stable income sources or financial support mechanisms, the transition to sustainable farming remains difficult.

Adoption of Circular Economy Practices

Sustainable farming practices currently in use

Several sustainable practices are being implemented in small-scale corn farming in Lucena City, including the use of organic fertilizers, crop residue recycling, and water conservation techniques. Farmers have started using organic fertilizers such as compost and animal manure, which improve soil fertility while reducing dependence on chemical inputs. Crop residues, such as corn husks and stalks, are repurposed for soil enrichment instead of being burned, minimizing waste and carbon emissions. Water conservation techniques, though less widely adopted, include rainwater harvesting and improved irrigation management to reduce water waste.

These practices align with CE principles by promoting resource efficiency, reducing waste, and regenerating natural systems. Unlike the traditional "take-make-waste" farming model, CE encourages closed-loop systems where resources are continuously reused. For example, composting organic waste returns nutrients to the soil rather than allowing them to be lost. Compared to conventional methods, sustainable practices offer long-term benefits, but farmers often perceive them as slower in delivering immediate results. While chemical fertilizers provide rapid crop growth, organic alternatives improve soil health over time, requiring greater patience and commitment. Similarly, traditional burning of crop residues is viewed as convenient but environmentally harmful, whereas recycling residues into compost enhances sustainability.



Figure 6. Mind map of circular economy practices and challenges identified in the study

Factors influencing CE adoption

One of the primary barriers to CE adoption is the knowledge gap among farmers. Many lack awareness of CE principles and their long-term benefits. Without sufficient training or access to agricultural extension services, farmers may struggle to implement sustainable techniques effectively.

Another significant factor is the accessibility and affordability of sustainable inputs. Organic fertilizers and eco-friendly pest management solutions are often more expensive or difficult to source compared to traditional chemical inputs. Many small-scale farmers rely on supplier credit systems or government subsidies, which do not always prioritize CE-based alternatives. The lack of affordable and readily available sustainable inputs discourages farmers from transitioning fully to circular practices.

Social and cultural attitudes also play a role in CE adoption. Farming communities have long relied on conventional methods, and shifting toward sustainability requires overcoming deeply ingrained practices. Some farmers perceive CE strategies as labor-intensive and risky, particularly if they have not seen clear financial returns. Additionally, peer influence and generational farming traditions shape attitudes toward innovation, making it essential to involve local farmer associations and cooperatives in promoting CE adoption.

Barriers to Circular Economy Adoption

Major obstacles faced by farmers

One of the primary challenges in adopting Circular Economy (CE) practices in corn farming is the high cost of sustainable inputs. Organic fertilizers, biofertilizers, and alternative pest management solutions are significantly more expensive than conventional chemical-based options. Farmers with limited financial resources often prioritize short-term affordability over long-term sustainability. Additionally, the availability of CE-friendly inputs is inconsistent, making it difficult for farmers to transition fully.

Another critical issue is the limited government and institutional support. While some subsidy programs and training initiatives exist, they are often irregular, insufficient, or inaccessible to small-scale farmers. Many farmers rely on government-provided fertilizers or grants, but these programs do not always promote circular economy solutions. Additionally, a lack of policy enforcement and institutional backing leaves farmers without clear guidance on implementing sustainable methods.

Logistical challenges further hinder CE adoption. Many sustainable practices, such as composting or crop residue repurposing, require additional labor, equipment, or storage facilities that small-scale farmers do not have. Limited access to irrigation infrastructure and transportation networks also makes it difficult to implement efficient water conservation strategies and market CE-based products effectively.

Lastly, farmers' resistance to change due to traditional methods and a lack of immediate incentives poses a significant barrier. Many farmers prefer conventional techniques because they provide predictable yields and require less initial investment. Sustainable methods, while beneficial in the long run, often take time to show results, discouraging farmers who need immediate returns. Social and cultural influences also play a role, as

generational farming traditions often dictate agricultural practices. Without financial rewards or strong community-driven advocacy, adoption remains slow.

Effects of circular economy practices on corn farming

Adopting circular economy practices has clear economic implications, particularly in reducing costs and increasing revenue. Farmers observed substantial savings over time due to the long-lasting effects of organic inputs, such as chicken manure, which required less frequent application. These practices also reduced dependence on chemical fertilizers and pesticides, further lowering costs. Additionally, the enhanced quality of produce—such as larger, heavier corn kernels—translated to higher market value and increased revenue. However, economic challenges remain significant. Many farmers rely solely on crop sales as their income source, with limited exploration of by-products or crop residues as alternative revenue streams. For instance, opportunities to sell corn stalks or leaves as animal feed or other by-products were often underutilized, resulting in missed income opportunities and added waste disposal costs. Moreover, while resource sharing was practiced, it fell short of fully embracing circular economy principles, as shared resources like machinery were often still paid services rather than collaborative, cost-saving solutions. These findings suggest that while economic benefits are achievable, fostering innovation in income diversification and resource utilization is essential for long-term sustainability.

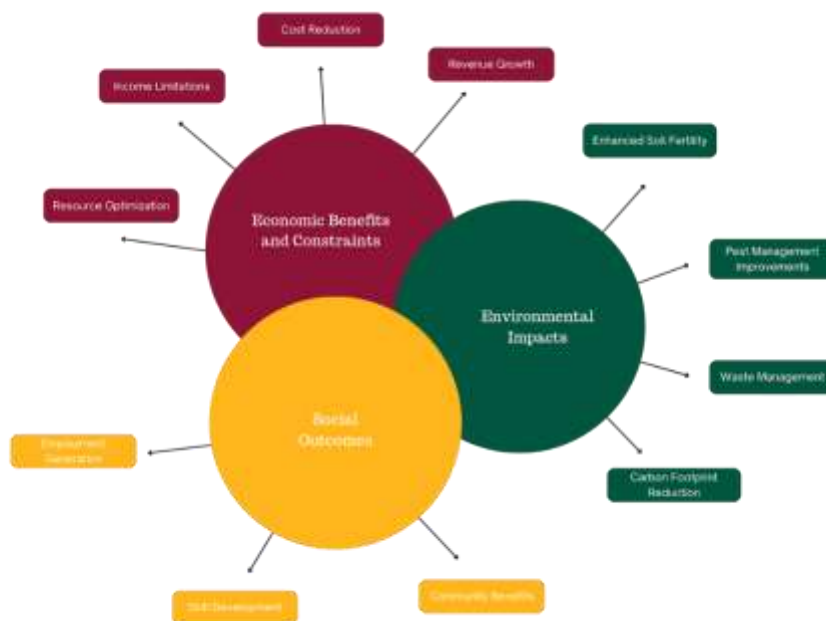


Figure 7. Conceptual framework of effects of circular economy practices on corn farming

The environmental benefits of circular economy practices are evident in improved soil health, enhanced waste management, and reduced greenhouse gas emissions. Farmers noted that organic fertilizers led to healthier, less acidic soil and decreased pest infestations, promoting a more balanced ecosystem. These outcomes reduce the reliance

on chemical inputs, mitigating the risks of water contamination and soil degradation. Waste management also emerged as a critical component, with practices such as using chicken manure from the poultry industry as fertilizer or repurposing corn residues as livestock feed serving as prime examples of circular resource use. These practices not only reduced waste but also fostered inter-industry collaboration, embodying the principles of the circular economy. However, the lack of formal systems and long-term studies to evaluate these practices extended environmental impacts indicates the need for structured implementation strategies. By formalizing waste repurposing and continuing to minimize chemical inputs, the environmental sustainability of corn farming can be further amplified.

Beyond economic and environmental dimensions, the societal impacts of circular economy practices reveal their role in fostering employment, skill development, and community cohesion. The labor-intensive nature of sustainable practices created job opportunities for landless farmers and seasonal workers, addressing local unemployment challenges. Training programs organized by government agencies further equipped farmers with the technical knowledge needed to adopt and sustain these practices, highlighting the importance of capacity-building initiatives. However, accessibility gaps, such as logistical barriers and financial limitations, restricted the full participation of farmers in these programs. On a community level, resource-sharing practices, such as distributing surplus inputs like chicken manure, strengthened relationships among farmers and promoted a sense of collective responsibility. While these efforts fostered collaboration, the informal nature of these initiatives suggests that more structured community-based programs could enhance their impact.

Success factors influencing the shift from linear economy to circular economy practices in corn farms

The fourth objective of this study evaluates the success factors that influence the shift from a linear economy to a circular economy (CE) model in corn farming. Success factors are operationally defined in this study as themes, links, or concepts that contribute to an effective and sustainable transition toward CE practices. These factors address financial, social, infrastructural, and policy-related barriers and enablers within the context of smallholder corn farming in Lucena City, Quezon. Four primary themes emerged as critical enablers of this transition: Economic Incentives and Market Forces, Knowledge, Education, and Awareness, Infrastructure and Resource Accessibility, and Policy and Institutional Support. These themes collectively emphasize the multidimensional nature of shifting to CE practices and highlight the interplay between economic viability, knowledge dissemination, resource accessibility, and institutional frameworks.

Economic incentives are fundamental in motivating farmers to adopt CE practices. Government subsidies, financial support, and local market demand for sustainably grown crops significantly reduce the barriers to entry for smallholder farmers. While cost reduction and revenue growth opportunities drive adoption, inconsistent subsidy distribution and the lack of explicit market premiums for sustainable products hinder long-term commitment. As Ghisellini et al. (2016) emphasize, financial viability is a cornerstone of successful CE transitions, and fostering strong economic incentives is crucial. The findings suggest that addressing these gaps, such as through consistent

subsidies and the introduction of market premiums, can enhance farmers' willingness and capacity to adopt CE principles.



Figure 8. Conceptual framework of success factors influencing the shift from linear to circular economy practices on corn farming

Knowledge dissemination is pivotal for empowering farmers to integrate CE practices. Training programs and workshops organized by government agencies serve as critical platforms for building farmers' technical capacity and understanding of CE principles. However, inconsistent access to these opportunities and the absence of follow-up mechanisms limits their effectiveness. As Kirchherr et al. (2018) highlight, sustained education and capacity-building initiatives are essential for fostering systemic shifts toward CE. Farmers require consistent, actionable knowledge to adopt and sustain practices like composting, mulching, and efficient resource use. Addressing these gaps through regular training and localized communication strategies is key to driving adoption at the grassroots level.

Agricultural infrastructure and the availability of sustainable inputs directly influence the feasibility of CE practices. Challenges such as limited access to organic fertilizers, irrigation systems, and storage facilities constrain farmers' ability to implement sustainable methods. As Pretty et al. (2018) argue, robust infrastructure supports productivity and resource efficiency, which are critical for transitioning to CE. Addressing these infrastructural gaps through targeted investments in irrigation, storage, and sustainable input can provide the physical and logistical means for farmers to shift toward circular farming systems.

Policy and institutional frameworks are indispensable for creating an enabling environment for CE adoption. Farmers rely on government subsidies, training programs, and clear policy guidelines to transition from linear practices. However, the study reveals significant gaps in the consistency and sufficiency of these interventions. Research by Garcia-Sanchez et al. (2021) underscores the importance of regular subsidies and institutional frameworks that incentivize CE practices. Additionally, the absence of organized cooperatives limits collective action and resource-sharing opportunities among farmers. Strengthening institutional support through consistent financial assistance,

organized farmer cooperatives, and regular training programs can address these barriers and foster a more sustainable agricultural system.

Conclusion

This study examined the adoption of circular economy (CE) practices among small-scale corn farmers in Lucena City, Quezon Province, focusing on their socio-demographic profiles, CE practices, challenges, and the success factors influencing their adoption. Findings highlight that most farmers operate small-scale farms, with an aging workforce and low educational attainment posing sustainability concerns. Gender disparity remains evident, with men dominating the sector, though female participation is gradually increasing.

Farmers primarily rely on traditional methods, with some integrating sustainable practices such as organic fertilization and crop residue reuse. However, financial constraints, limited access to sustainable inputs, and a lack of technical knowledge hinder full CE adoption. The study found that while some CE principles are practiced—such as using crop residues for mulching or livestock feed—these efforts remain inconsistent due to economic and logistical barriers. Farmers continue to engage in linear practices, such as burning crop residues and improper plastic disposal, indicating the need for stronger awareness campaigns and incentives for sustainability.

Key success factors for CE adoption include institutional support, farmers' openness to sustainable practices, community collaboration, and adaptability to external conditions. Government interventions, including financial assistance, training, and infrastructure improvements, are essential for overcoming systemic barriers to CE integration. Strengthening institutional support through enhanced farmer education, consistent training programs, and financial incentives can encourage greater CE adoption.

Policies should also promote better price stabilization for sustainably grown corn and establish stronger market linkages between farmers and buyers of CE-based products. Additionally, investments in sustainable farming infrastructure, such as composting facilities and waste management systems, are necessary to eliminate reliance on harmful linear practices. Programs targeting young farmers should be implemented to address the aging agricultural workforce and ensure the sector's long-term sustainability.

Furthermore, strengthening farmer associations and cooperative models will facilitate knowledge-sharing and resource efficiency, enabling a more effective transition toward circular farming systems. By addressing these challenges, Lucena City's corn farming sector can move toward more sustainable agricultural practices, ensuring economic resilience, environmental sustainability, and long-term viability for future generations. Further research on CE adoption in other crop sectors can provide broader insights for Philippine agriculture.

The study's findings highlight both the opportunities and barriers in transitioning from linear to circular economy (CE) practices in corn farming. To ensure effective implementation, recommendations focus on economic incentives, knowledge dissemination, infrastructure development, and policy support. Given the diverse demographic and economic profiles of farmers, tailored training programs using localized materials and practical demonstrations should be developed. Additionally, financial

assistance must prioritize small-scale farmers, particularly those without land ownership, to encourage long-term investments in sustainable practices.

The study also identifies key CE practices, such as organic fertilizers and crop residue repurposing, while recognizing challenges like high input costs and limited market incentives. To address these, government and private sector partnerships should improve the affordability of sustainable inputs, while mechanized solutions and cooperatives can ease labor-intensive processes. The economic benefits of CE, including cost reduction and improved yields, should be reinforced through price premiums and certifications for sustainably grown crops. Environmentally, the adoption of organic fertilizers and integrated pest management should be scaled up through targeted training. Socially, resource-sharing initiatives among farmers can reduce costs and strengthen community collaboration.

For long-term success, economic incentives such as subsidies and market-driven pricing must be institutionalized. Localized training programs should emphasize practical CE applications, and infrastructure investments should focus on irrigation and storage systems. Finally, strong policy frameworks, cooperatives, and public-private partnerships will be essential in providing consistent support for CE adoption. Strengthening these areas will enhance the sustainability and resilience of corn farming systems in Lucena City and beyond.

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References

- Barrett, C. B., Bellemare, M. F., & Hou, J. Y. (2019). Structural transformation and economic development: Insights from the agri-food value chain revolution. *World Development*, 117, 216-227. <https://doi.org/10.1016/j.worlddev.2018.08.015>
- Brief background on organic agriculture | Home. (n.d.). *National Organic Agriculture Program*. <https://noap.da.gov.ph/brief-background-on-organic-agriculture/>
- Brown, L., & Green, C. (2020). *Organic farming and sustainability: Economic and ecological benefits of reduced chemical use in agriculture*. *Agricultural Sciences*, 5(3), 12-25. <https://doi.org/10.1016/j.agrisci.2020.02.001>

- Burney, J. A., & Naylor, R. L. (2012). Smallholder irrigation as a poverty alleviation tool in sub-Saharan Africa. *World Development*, 40(1), 110-123. <https://doi.org/10.1016/j.worlddev.2011.05.007>
- Bui, S., Cardona, A., Lamine, C., & Cerf, M. (2020). Sustainability transitions: Insights on processes of niche-regime interaction and regime reconfiguration in agri-food systems. *Journal of Rural Studies*, 76, 99-111. <https://doi.org/10.1016/j.jrurstud.2020.04.011>
- Circular economy: Definition, importance, and benefits. (n.d.). *European Parliament*. <https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits>
- Circular economy in action: 9 examples of businesses and policymakers accelerating the transition. (2023, March 20). *World Economic Forum*. <https://www.weforum.org/agenda/2023/03/9-examples-circular-economy-accelerating-transition/>
- Circular economy introduction. (n.d.). *Ellen MacArthur Foundation*. <https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview>
- Circular Economy: Waste-to-Resource. (n.d.). *Food and Agriculture Organization of the United Nations*. <https://www.fao.org/land-water/overview/onehealth/circular/en/>
- Doss, C., Meinzen-Dick, R., & Bomuhangi, A. (2014). Who owns the land? Perspectives from rural Ugandans and implications for land acquisitions. *Feminist Economics*, 20(1), 76-100. <https://doi.org/10.1080/13545701.2014.897739>
- Figuerola, A. M. I., Pintor, L. L., Sapuay, G. P., Ancheta, A. A., Atienza, V. A., Hintural, W. P., Abris, M. I. V., & Ghosh, S. K. (2021). Circular economy strategies and implementation in the Philippines. In *Circular Economy* (pp. 219–257). https://doi.org/10.1007/978-981-16-0913-8_7
- Garcia-Sanchez, I. M., Zafra-Gomez, J. L., & Rodriguez-Dominguez, L. (2021). Barriers to implementing circular economy in agricultural sectors: Evidence from European regions. *Sustainability*, 13(2), 889. <https://doi.org/10.3390/su13020889>

Sustainability of Giant Freshwater Prawn (*Macrobrachium Rosenbergii*) Production in Brunei Darussalam

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Abstract

The importation of food items such as vegetables, meat, and others including Giant Freshwater Prawn surpasses local production. This situation raises concerns about sustainability and food security in Brunei Darussalam. Therefore, this study aims to evaluate the sustainability of Giant Freshwater Prawn production in the region. It emphasizes the integration of sustainable practices within the aquaculture supply chain to ensure long-term viability and resilience of aquatic resources. An in-depth qualitative interview methodology was employed, focusing on the operational strategies of various aquaculture companies. The study findings showed that aquaculture companies implement diverse strategies to enhance sustainability while addressing market demands and ecological impacts. Common practices include integrating aquaculture with agricultural practices to promote local broodstock and community involvement, utilizing advanced hatchery techniques to optimize growth and quality, and diversifying species offerings and fostering collaborations with educational institutions to drive innovation. Despite these efforts, challenges such as high input costs, fluctuating market demand, and environmental sustainability persist. The findings suggest that a collaborative approach among industry stakeholders is essential for enhancing the sustainability of Giant Freshwater Prawn production, ultimately benefiting local communities and ecosystems.

Keywords: giant freshwater prawn, production, aquaculture, Brunei Darussalam

JEL code: Q22, Q56, L66

SDG classification: SDG 2, SDG 12, SDG 14

Introduction

Ensuring national food security is an increasingly critical concern for Brunei Darussalam, especially as the country works to strengthen its domestic agricultural and aquacultural output in line with its long-term development goals under the Brunei Vision 2035 (Government of Brunei Darussalam, n.d.). One sector of strategic importance is aquaculture, particularly the cultivation of giant freshwater prawn (*Macrobrachium rosenbergii*), locally known as *udang galah*. This species is highly prized in both local and regional markets for its nutritional value, culinary appeal, and commercial potential (New, 2005). However, the current level of domestic production is significantly insufficient to meet growing consumer demand, resulting in a continued reliance on imports to fill the supply gap (Department of Fisheries, 2021). This imbalance not only impacts food sovereignty but also exposes the country to fluctuations in global supply chains and market prices (FAO, 2022).

Brunei Darussalam faces a critical challenge in ensuring food security as domestic production of giant freshwater prawn (*Macrobrachium Rosenbergii/Udang Galah*) falls significantly below market demand. Despite the deployment of advanced hatchery technologies and operational innovations in the aquaculture sector, conventional on-farm practices remain constrained by limited cultivation areas and suboptimal water management. Furthermore, high production costs, largely incurred due to dependency on imported inputs and infrastructural limitations, have compounded the challenges to achieving sustainable prawn production. These factors have triggered the present study, which aims to evaluate sustainability practices and identify central obstacles that hinder the scaling of local aquaculture.

In recent years, the Government of Brunei, along with private stakeholders, has invested in modernizing the aquaculture sector. The deployment of advanced hatchery technologies and the introduction of innovative operational systems mark significant progress toward improving productivity and efficiency (Ahmed, Thompson, & Glaser, 2019). Nevertheless, these advancements have yet to yield transformative results at the farm level. Conventional on-farm practices remain the dominant production model, and these are hampered by several persistent limitations. Among the most notable are the restricted availability of suitable cultivation areas and the challenges associated with maintaining optimal water quality (New, 2005). These factors directly impact growth rates, survival, and overall yield, thereby curbing the potential for large-scale, sustainable production (FAO, 2022).

Moreover, the economic sustainability of *udang galah* farming is constrained by high production costs. A substantial proportion of these costs stem from the sector's dependence on imported inputs, including feed, broodstock, and specialized equipment (Ahmed et al., 2019). In addition to input-related expenses, infrastructural shortcomings—such as inadequate storage facilities, limited access to technology, and inefficient farm-to-market logistics—further hinder productivity and profitability (FAO, 2022). These issues are compounded by the lack of tailored technical guidance and insufficient integration of environmentally sustainable farming practices, both of which are vital for long-term viability in aquaculture (Ahmed et al., 2019).

Given these challenges, there is a pressing need to assess the sustainability and scalability of current *udang galah* production systems in Brunei Darussalam. This study emerges in response to that need. It aims to systematically evaluate the existing

sustainability practices within the freshwater prawn aquaculture sector and to identify the central obstacles that are inhibiting its expansion. Through a critical analysis of production methods, input dependencies, and environmental management practices, the research seeks to offer actionable insights that can inform policy, support local farmers, and enhance the resilience and productivity of Brunei's aquaculture industry. Ultimately, the findings are expected to contribute toward building a more self-reliant and economically viable food production system aligned with national food security objectives (Government of Brunei Darussalam, n.d.).

Despite Brunei Darussalam's strategic efforts to modernize its aquaculture sector, the local production of giant freshwater prawn (*Macrobrachium rosenbergii*) remains critically low, failing to meet rising domestic demand (Department of Fisheries, 2021). This shortfall presents a significant threat to the country's broader food security objectives (Government of Brunei Darussalam, n.d.). Although technological advancements—particularly in hatchery systems—have improved aspects of seed production and early-stage rearing, the benefits of these innovations are not fully realized at the grow-out level, where conventional practices dominate (Ahmed et al., 2019). Farmers continue to face limitations in land accessibility, poor site management, and inconsistent water quality, all of which suppress production efficiency (New, 2005).

Moreover, the economic burden of prawn farming remains high, primarily due to the sector's reliance on imported feed, broodstock, and farming equipment (FAO, 2022). These dependencies not only inflate operational costs but also render local producers vulnerable to external supply shocks. Infrastructural deficits, such as insufficient cold storage, limited access to financing, and a lack of efficient distribution networks, further compound these issues (Ahmed et al., 2019). Consequently, the sector struggles to scale sustainably or attract broader private-sector participation. This situation underscores the urgent need to identify key bottlenecks in the system and to explore practical, sustainable solutions tailored to Brunei's unique aquaculture landscape.

The main aim of this study is to critically assess the sustainability practices and systemic constraints within Brunei Darussalam's giant freshwater prawn aquaculture sector. The specific objectives are:

- **To assess sustainability:** Evaluate the overall sustainability of udang galah production by examining operational strategies, water management practices, and economic constraints.
- **To identify key challenges:** Synthesize the major hurdles—ranging from technological innovations in hatchery practices to on-farm production limitations—that impede the sector's capacity to meet local demand.

A qualitative research design was employed to capture the detailed perspectives of key stakeholders in Brunei's aquaculture industry. In-depth interviews using semi-structured guides were conducted with representatives from three major aquaculture enterprises. Purposive sampling ensured that participants had extensive experience in various dimensions of production, including hatchery operations, water management, on-farm practices, and market distribution. The interviews focused on contrasting advanced production techniques with operational bottlenecks such as limited grow-out areas, variable water quality management, and high production costs.

The literature review details the existing knowledge on sustainability challenges in udang galah production, emphasizing hatchery innovations, water quality issues, and economic constraints. The result presents the integrated findings from the qualitative interviews, merging insights across the three enterprises. The discussion subsequently interprets these findings, highlighting the implications for sustainable aquaculture in Brunei and suggesting integrated approaches for innovation and policy reform. Finally, the conclusion summarizes the study's contributions and outlines future research directions.

Literature review on the sustainability of udang galah production

Sustainability in aquaculture production is receiving increasing attention globally given its implications for food security and environmental management (Nair & Salin, 2012). Studies from Southeast Asia—particularly in Malaysia, Thailand, and Indonesia—have demonstrated the viability of integrated and sustainable farming systems, where careful management of water quality, feed, and stocking density has led to increased yields and profitability (New, 2002; Tidwell et al., 2015).

However, literature also emphasizes the challenges that developing aquaculture sectors face, particularly in small-scale or emerging economies. According to FAO (2020), the main constraints include lack of access to affordable inputs, insufficient technical training, and inadequate policy support.

In Brunei, where domestic production of udang galah is significantly outpaced by imports, the literature identifies several interrelated challenges. The previous reports have highlighted underutilized aquaculture zones and weak integration between upstream (hatcheries) and downstream (processing and distribution) operations (Department of Fisheries, 2021). Furthermore, sustainability concerns—ranging from effluent discharge to inefficient resource use—remain pressing issues that have yet to be fully addressed in national strategies.

Recent studies have documented considerable advances in hatchery techniques, where modern systems can produce millions of post-larvae (PL) in short production cycles (Banu & Christianus, 2016). However, these technical innovations are not entirely mirrored at the on-farm production stage. Traditional pond management systems, typically characterized by low carrying capacities (approximately 0.2 kg of prawn biomass per square meter), restrict the scalability of production even when the hatchery output is high (Greasley, 2019). This disconnect between early-stage production and grow-out capacity is acknowledged as a central challenge in the sustainability literature.

Efficient water management is critical in mitigating mortality and enhancing production yields. Conventional water exchange methods, while effective under certain conditions, are increasingly being supplemented by advanced water treatment technologies such as Recirculating Aquaculture Systems (RAS) and biofloc systems (Yuan & Xue, 2023). These systems not only ensure consistent water quality but also facilitate nutrient recycling. Despite these innovations, practical challenges persist in reconciling regional regulatory recommendations with on-farm operational realities. For instance, the timing and method of water exchanges can significantly affect post-larval survival, highlighting the need for locally adapted best practices.

Economic viability in udang galah production is constrained by a heavy reliance on imported inputs including specialized feed, broodstock eggs, and equipment. Although premium pricing for live prawns offers partial compensation, the limited available cultivation space and high input costs dramatically curb the ability to scale production. Furthermore, infrastructural and regulatory constraints, such as complex licensing procedures, intensify the challenges and underscore the need for coordinated policy support (UTB, n.d.).

While substantial research has been conducted on the technical aspects of aquaculture sustainability, few studies have integrated the operational, economic, and regulatory dimensions specifically for the Bruneian context. This study aims to fill that gap by synthesizing firsthand insights and offering a context-specific discussion of sustainable udang galah production.

Results and Discussion

The findings of this study are derived from in-depth interviews with key stakeholders from three leading aquaculture operations in Brunei. Although each enterprise has its unique practices and challenges, several common themes emerged.

Integrated hatchery and grow-out practices

Respondents reported that advanced hatchery practices have enabled the production of large quantities of post-larvae. However, a consistent challenge noted was the disparity between hatchery capacity and the limited scale of on-farm production. Despite high hatchery outputs, the physical constraints of available farm areas—typically measured in modest hectares—impose a ceiling on the overall production yield. The practical implication is that even with technological innovation at the hatchery stage, the inability to expand or optimize pond utilization remains a significant hurdle.

Water management strategies

Efficient water quality management has emerged as a recurring concern. Interviewees described a blend of traditional water exchange methods and newer technologies such as RAS and multi-stage filtration systems. While these advanced methods have improved the stabilization of water parameters, local operational practices sometimes conflict with regulatory guidance. For example, debates over the optimum timing for transferring post-larvae reflect the need for locally adapted protocols that adequately consider environmental stressors and water quality fluctuations.

Economic and supply chain constraints

High production costs were cited as a critical limiting factor. The high dependence on imported inputs—notably specialized feed and broodstock—along with elevated operational expenses, directly impacts economic sustainability. Premium market pricing for live prawns helps mitigate some of these costs; however, the inability to scale production rapidly because of spatial and infrastructural limitations continues to restrict profitability. Additionally, supply chain bottlenecks, such as delays in feed deliveries and transportation challenges, further exacerbate economic hurdles.

Innovations and process integration

Despite the constraints, the interviewed stakeholders demonstrated significant innovation in integrating traditional practices with modern technological solutions. Examples include the use of high-powered pumping systems, advanced multi-layered water filtration, reservoir management techniques, and integrated supply chain strategies to maintain product freshness and adjust harvesting strategies according to market demand. These innovations indicate a willingness among industry players to adapt and improve operational efficiencies in pursuit of long-term sustainability.

The integrated analysis of interviews from leading aquaculture players in Brunei reveals a complex interplay of technological innovation, operational constraints, and economic challenges. Although contemporary hatchery systems can generate vast numbers of post-larvae, the subsequent growth and harvest phases are severely limited by physical production capacity. Water management remains a critical variable, with stakeholders employing advanced systems yet still grappling with regulatory versus practical considerations regarding water exchange timing and cost-effective salinity adjustments.

Furthermore, economic pressures—stemming largely from reliance on imported inputs and high production expenses—underline the difficulty of achieving economies of scale in local production. These challenges highlight the necessity for a holistic approach that combines technological advancements with process optimization, policy support, and enhanced infrastructure. Streamlined licensing procedures, local supply chain development, and targeted investments in scalable grow-out systems appear essential for improving the sustainability of udang galah production in Brunei.

Collectively, these insights suggest that while technological excellence exists on paper at the hatchery level, it must be coupled with innovative on-farm practices and supportive policy measures to bridge the gap between potential and actual production. Such an integrated strategy could significantly reduce Brunei's reliance on prawn imports, bolster local food security, and foster a more resilient aquaculture sector.

Conclusion

This study underscores that while advanced hatchery practices and innovative water management strategies play a crucial role in enhancing the sustainability of giant freshwater prawn production, on-farm operational limitations and high production costs continue to restrict the industry's ability to meet local demand. The findings reveal that integrating sustainable practices within the aquaculture supply chain—such as optimizing on-farm production techniques, improving resource utilization, and addressing economic and regulatory challenges—is imperative for reducing Brunei's reliance on prawn imports. A collaborative approach among industry stakeholders, government agencies, and research institutions is essential to drive innovations that not only overcome existing obstacles but also promote community involvement and environmental resilience. Ultimately, these combined efforts are critical for ensuring long-term food security and sustaining the viability of Brunei's aquaculture sector.

References

- Ahmed, N., Thompson, S., & Glaser, M. (2019). *Global aquaculture productivity, environmental sustainability, and climate change adaptability*. *Environment International*, 126, 112–123. <https://doi.org/10.1016/j.envint.2019.02.018>
- Banu, R., & Christianus, A. (2016). *Giant freshwater prawn Macrobrachium rosenbergii farming: A review on its current status and prospective in Malaysia*. [Publisher details].
- Department of Fisheries. (2021). *Annual Fisheries Statistics 2020*. Ministry of Primary Resources and Tourism, Brunei Darussalam. <https://www.fisheries.gov.bn>
- FAO. (2022). *Regional review on status and trends in aquaculture development in Asia-Pacific – 2020*. FAO Fisheries and Aquaculture Circular No. 1234. <http://www.fao.org>
- Government of Brunei Darussalam. (n.d.). *Brunei Vision 2035*. Prime Minister's Office. <https://www.pmo.gov.bn>
- Greasley, A. (2019). *Absolute essentials of operations management*. Routledge.
- Nair, C. M., & Salin, K. R. (2012). Current status and prospects of farming the giant river prawn *Macrobrachium rosenbergii* and the monsoon river prawn *Macrobrachium malcolmsonii* in India. *Aquaculture Research*, 43(7), 999–1014.
- New, M. B. (2005). *Freshwater prawn farming: Global status, recent research and a glance at the future*. *Aquaculture Research*, 36(3), 210–230. <https://doi.org/10.1111/j.1365-2109.2005.01240.x>
- UTB. (n.d.). *Future project collaborations | Universiti Teknologi Brunei*. Retrieved from <https://www.utb.edu.bn/research/research-centres/centre-for-research-on-agri-food-science-and-technology-craft/future-project-collaborations/>
- Yuan, X. M., & Xue, A. (2023). Supply chain 4.0: New generation of supply chain management. *Logistics*, 7(1), 9.

The Intention to Adopt Agriculture Digital Technology Among TKPM Farmers in Pahang, Malaysia

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Abstract

The adoption of digital technology in agriculture is increasingly vital for enhancing productivity, efficiency, and sustainability, yet uptake remains limited due to various barriers. This study investigates the factors influencing farmers' intention to adopt agricultural digital technology in Taman Kekal Pengeluaran Makanan (TKPM), Pahang, Malaysia. Using a structured questionnaire, data were collected from 181 farmers engaged in diverse agricultural activities. The study examines four main factors: socio-economic characteristics, digital literacy, government grants and subsidies, and agricultural extension services. Findings indicate that digital literacy and government support are the most significant drivers of adoption. Grants and subsidies reduce financial barriers, enabling investment in precision farming tools, automated irrigation, and farm management software. Socio-economic factors such as age, education, and income also play a role, while extension services provide critical training and technical support, though their reach and effectiveness remain uneven. The results highlight the importance of enhancing extension services, improving digital literacy through training programs, and expanding access to government support. The study recommends collaborative efforts among government bodies, private sector actors, and research institutions to develop and disseminate user-friendly technologies tailored to farmers' needs. By addressing these challenges through targeted policies and multi-stakeholder collaboration, Malaysia can accelerate digital transformation in agriculture, thereby improving productivity, sustainability, and farmers' livelihoods.

Keywords: intention, adoption, digitalization, agriculture digital technologies, TKPM

JEL code: Q12, Q16, Q18, O13, O33

SDG classification: SDG 2, SDG 8, SDG 9, SDG 12, SDG 17

Introduction

Modernization refers to the process of adopting modern technologies, ideas, and techniques with the purpose of bringing improvement and progress to various sectors of society. In agriculture, modernization signifies a major shift from traditional methods to more advanced approaches that encompass various aspects of farming. This transformation involves the use of improved seed varieties, modern agricultural machinery and tractors, harvesters and threshers, and the efficient use of chemical fertilizers and pesticides, often complemented by controlled water management. Modernizing agriculture is essential for increasing labor productivity, enabling the integration of technology, boosting agricultural surplus for capital accumulation, and enhancing foreign exchange through exports. By embracing advanced technology and new methods, the agricultural sector can become more productive, resilient, and sustainable, thereby contributing to global food security and economic growth. Numerous technologies have been developed to serve the agricultural sector, and in today's modern agriculture, sophisticated tools such as machinery, sensors, and Global Positioning System (GPS) have made farming more profitable, efficient, safe, and environmentally sustainable.

One of the most promising developments in agriculture is digitalization. It refers to a sociotechnical framework that integrates digital innovations and is expected to catalyze the future of agricultural transformation. In the field of agricultural production systems, various terms have emerged to indicate different types of digitalization, which include precision agriculture, digital agriculture and smart agriculture (Cui & Wang, 2023). The best opportunity to achieve sustainable agriculture lies in the emerging field of digital technologies that increase productivity while addressing the economic, environmental and social impacts associated with agricultural systems. Digitalization involves the methodological transformation of analog data into a digital format (Rolandi et al., 2021). Electronic devices and systems used to process and store data to increase productivity and efficiency fall under the category of digital technology. This includes smartphones, the internet, and devices that enable fast data transmission and digital processing.

In essence, the digitalization of agriculture refers to the use of digital technology in farming activities to increase productivity, efficiency, sustainability, and profitability. Such a transformation is crucial for collecting, analyzing, and applying data to make informed agricultural decisions. It offers access to comprehensive databases of information—from soil conditions to market prices—enabling better decision-making throughout the agricultural production and distribution process. Studies show that the adoption of digital technologies positively influences innovation performance, with knowledge base breadth and depth mediating this relationship, especially in environments experiencing digital changes (Zhou et al., 2024). Adoption also enhances economic and environmental performance, with digital technology capabilities and strategic alignment serving as key enablers of sustainable development. Furthermore, integrating digital technologies can lead to considerable changes in organizational strategies, with a study suggesting a strong correlation between the adoption of technology and the process of strategic renewal (Van Zeebroeck et al., 2023).

Although digital technology in agriculture promises to enhance productivity, sustainability and efficiency, farmers face various challenges that hinder their intentions to adopt digital technologies. One significant problem is financial constraints, considering how expensive digital technologies are. The initial investment required for advanced tools

is substantial, and the ongoing maintenance and operational expenses place a financial burden on farmers, particularly smallholders who struggle to afford such technologies. A 2023 study by the Malaysian Agricultural Research and Development Institute (MARDI) revealed that 70% of farmers cited financial constraints as a primary reason for not adopting digital tools (Cui & Wang, 2023).

The adoption of agriculture digital technology in rural areas is significantly lower compared to urban areas. Rural environments often lack critical infrastructure, such as reliable internet access and consistent electricity, which are both essential for the effective use of digital tools. According to a 2022 report by the Food and Agriculture Organization (FAO), rural regions in Malaysia suffer from poor internet connectivity, which hinders the use of real-time data transmission and cloud-based platforms essential for digital agriculture (Pangapanga-Phiri et al., 2024). Other challenges include the lack of local network coverage, insufficient logistics and sales systems, and a shortage of digital-skilled personnel, which prevent the widespread adoption of digital technology in rural agricultural settings (Chulwa et al., 2022). The complexity of digital technology means that individuals handling such a tool require adequate tutoring and technical support, which many farmers lack. Most farmers, especially older ones, are particularly disadvantaged, as they often lack the digital literacy needed to operate and maintain these advanced tools effectively. A survey conducted by Khazanah Research Institute in 2023 indicated that only 30% of Malaysian farmers had received formal training in digital agricultural technologies. Besides, aging farmers tend to use traditional methods in agriculture that are passed down through generations (Shaila & Begum, 2021). For them, the transition to digital technology can be intimidating, especially when it comes to learning new technologies, and they may find such digital tools hard and difficult to use. There may also be concerns about the new technology's usefulness and dependability, particularly if it has not been extensively embraced in their community where aging farmers value the eco-friendly nature of traditional practices.

Limited access to training and technical support further hinders farmers' ability to use digital tools. This lack of capacity contributes to a slower pace of technological adoption in rural areas, thereby widening the gap in agricultural productivity and efficiency between rural and urban farms. Further compounding this issue are challenges such as the complexity of digital technologies, the absence of standardized evaluation frameworks, and insufficient access to digital agricultural extension services, all of which create additional barriers to adoption (Wang & Dong, 2023). In the realm of agriculture, inadequate support and after-sales service can undermine the efficient use of these technologies. When farmers do not receive adequate assistance after purchasing digital tools, it erodes their trust in the technology and discourages future use (Finger, 2023). Cultural resistance further complicates the adoption of new technologies. Traditional farming practices are deeply ingrained in many farming communities, and farmers often resist change due to skepticism toward unfamiliar tools and a strong attachment to conventional methods. A survey conducted by Khazanah Research Institute in 2023 found that cultural resistance remains a significant barrier to the adoption of precision agriculture in Malaysia. Farmers were hesitant to abandon traditional practices in favor of digital tools, even when presented with evidence of their benefits (Pangapanga-Phiri et al., 2024).

According to Akudugu et al. (2023), the adoption of digital technology in agriculture is influenced by a variety of social factors, including age, gender, education, and social networks. For instance, younger farmers and those with higher levels of education are generally more receptive to digital technologies, as they tend to be more comfortable with new technologies and can better understand the potential benefits. Second, farmers' knowledge and skills in using digital tools play a significant role in shaping their intention to adopt such technologies. Digital literacy, defined as the ability to access, manage, and utilize digital tools, is crucial for implementing smart farming practices. A study shows that farmers with higher education levels and those who participate in agricultural extension activities are more likely to adopt digital tools due to their more positive attitudes toward technology use (Akudugu et al., 2023).

In addition, the level of digital literacy among farmers not only influences adoption rates but also affects broader agricultural practices and economic outcomes. Higher digital literacy enhances entrepreneurial performance and enables farmers to better identify and exploit new opportunities (Wang & Dong, 2023). To strengthen these capabilities, Fharaz et al. (2022) emphasize the importance of targeted education and training programs, as well as the role of internet platform enterprises in enhancing farmers' digital skills and the effectiveness of their technology use. Similarly, Wan Mokhtar et al. (2022) highlight the need for practical, hands-on skills in using digital platforms to contribute to greater food security and improved agricultural productivity. Therefore, enhancing farmers' digital literacy and providing necessary support and resources are critical for the successful adoption of digital technologies in agriculture (Marshall et al., 2021).

Third, government grants and subsidies play a pivotal role by reducing the economic burden of adopting new tools and technologies. By making digital tools more affordable and accessible, such financial support helps bridge the digital divide and promotes the shift toward sustainable agricultural practices (Samadder et al., 2023). Furthermore, subsidies not only alleviate financial barriers to adopting digital technologies but also create an enabling environment that supports technological innovation and long-term investment in digital agriculture (Guo et al., 2023).

Lastly, agricultural extension officers are crucial in promoting digital technology adoption among farmers by serving as intermediaries that bridge the divide between technological progress and practical farming applications. They facilitate the transfer of knowledge from research establishments to farmer communities, guaranteeing that advancements in agricultural techniques, crop management methodologies, and technological innovations reach remote and marginalized areas (Rai et al., 2023). According to Fabregas et al. (2023), extension services are especially vital in promoting climate-smart agricultural practices, highlighting the need for greater investment in these services to mitigate the consequences of climate change and support sustainable farming. By encouraging the use of mobile phones and other digital devices, extension officers provide farmers with timely and relevant information, such as crop management guidelines, market prices, and weather forecasts, that can considerably improve decision-making and productivity (Li, 2023). Overall, agricultural extension services are instrumental in reducing the digital gap and supporting farmers in developing countries to adopt and benefit from digital technologies (Anang, 2022).

Generally, the objective of this study is to identify the factors influencing the intention to adopt agricultural digital technology among farmers in *Taman Kekal Pengeluaran Makanan* (TKPM) Pahang, Malaysia. Specifically, the study aims to 1) determine the

influence of socio-economic factors, digital literacy, government grants and subsidies, and agricultural extension services on the intention to adopt agricultural digital technology among TKPM farmers and 2) assess the level of intention among TKPM farmers to adopt agricultural digital technology.

Methodology

TKPMs in Pahang were selected as the location of the study. *Taman Kekal Pengeluaran Makanan* (TKPM) represents a strategic initiative under the Third National Agricultural Policy (DPN3), designed to promote large-scale, commercial, and technology-driven agricultural ventures by entrepreneurs and the private sector stakeholders. It serves as a permanent food production zone aimed at enhancing sustainable and high-quality national food production. The key objectives of establishing TKPM include creating a permanent food crop production zone, increasing the quality and continuity of the national food supply, promoting entrepreneurial participation in commercial food crop production, increasing participants' net income, and encouraging private sector involvement in the agricultural sector.

In total, there are 19 TKPMs in Pahang, covering a total area of around 5,310 hectares. These zones are designated for the cultivation of leafy vegetables, fruit vegetables, cash crops and fruits. Prior to obtaining the sample, the total population of TKPM farmers in Pahang was first determined, which stands at 335 individuals. A structured questionnaire was used as the primary data collection instrument and was distributed to the identified farmers. The sample size was determined using the Krejcie and Morgan Table, which recommends a minimum of 181 respondents for a population of 335. This sample size is considered sufficient to meet the statistical analysis requirements using SPSS.

Results and Discussion

Mean level of socio-economic factors influencing the intention to adopt agricultural digital technology

According to Table 1, the socio-economic factor with the highest mean score of 4.24 corresponds to the statement: *"I will adopt digital technology because the experience I have gained over the years enhances my ability to understand and use it on my farm."* It suggests that many farmers perceive their accumulated agricultural experience as an advantage in adapting to and utilizing digital tools. The statement with the lowest mean score of 3.93 is the statement *"I will adopt digital technology because my income does not hinder my ability to adopt and use it in farming."* Although the score reflects a moderate level of agreement, it indicates that some respondents still see limited income as a barrier to technology adoption.

Table 1. Socio-economic factors (n = 181)

Statement	Scale					Mean	SD
Socio-economic Factor	1	2	3	4	5		
I will adopt digital technology because I am still at an age where I can learn and adopt new digital tools in agriculture.	0 (0.0)	2 (1.1)	21 (11.6)	95 (52.5)	63 (34.8)	4.21	0.683
I will adopt digital technology because the experience I have gained over the years enhances my ability to understand and use it on my farm.	0 (0.0)	0 (0.0)	21 (11.6)	96 (53.0)	64 (35.4)	4.24	0.645
I will adopt digital technology because I believe farmers of all genders can benefit from adopting it.	0 (0.0)	3 (1.7)	18 (9.9)	94 (51.9)	66 (36.5)	4.23	0.692
I will adopt digital technology because my income does not hinder my ability to adopt and use it in farming.	4 (2.2)	8 (4.4)	31 (17.1)	92 (50.8)	46 (25.4)	3.93	0.895
I will adopt digital technology because I am confident that my educational background enables me to learn and implement new digital tools in farming.	0 (0.0)	5 (2.8)	19 (10.5)	92 (50.8)	65 (35.9)	4.20	0.733
I will adopt digital technology because I believe the knowledge I gained from my education will help me use digital tools effectively on my farm.	0 (0.0)	3 (1.7)	21 (11.6)	91 (50.3)	66 (36.5)	4.22	0.709
I will adopt digital technology because I believe I can overcome financial constraints to enhance my farming practices.	4 (2.2)	3 (1.7)	29 (16.0)	94 (51.9)	51 (28.2)	4.02	0.843
I will adopt digital technology if I can find ways to manage the costs effectively despite potential financial barriers.	4 (2.2)	6 (3.3)	30 (16.6)	94 (51.9)	47 (26.0)	3.96	0.872
I will adopt digital technology because I believe it will benefit my farm, which influences my decision to use it.	0 (0.0)	5 (2.8)	23 (12.7)	100 (55.2)	53 (29.3)	4.11	0.722

Statement	Scale					Mean	SD
Socio-economic Factor	1	2	3	4	5		
I will adopt digital technology because the positive experiences of other farmers with digital technology motivate me to do the same.	0 (0.0)	5 (2.8)	22 (12.2)	101 (55.8)	53 (29.3)	4.12	0.717
Total Average Mean						4.123	0.619

Note: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree

The overall mean score for socio-economic factors is 4.123 with a standard deviation of 0.619, as shown in Table 2. It reflects a generally strong perception among respondents regarding the influence of socio-economic factors on the use of agricultural digital technology. A total of 33 respondents (18.2%) reported a medium level of agreement, indicating some variation in perception, while none (0%) demonstrate a low level of agreement, further reinforcing the positive or moderately positive view of socio-economic factors in influencing technology adoption among farmers.

Table 2. Mean level of socio-economic factors

Level	Frequency	Percentage (%)	Mean	SD
High (3.67–5.0)	148	81.8	4.123	0.619
Medium (2.34–3.66)	33	18.2		
Low (1–2.33)	0	0		
Total	181	100		

Mean level of digital literacy factors influencing the intention to adopt agricultural digital technology

Table 3 presents the mean scores related to the digital literacy factor among respondents. The highest mean score of 4.35 is associated with the statement “*I will adopt digital technology if I can easily learn how to use new digital technologies in farming.*” This finding suggests that respondents are more inclined to adopt digital technologies when they perceive them as user-friendly and easy to learn. This perception may also be linked to the educational background of the farmers, which influences their comfort level with learning new technologies. In contrast, the statement with the lowest mean score of 4.24 is “*I will adopt digital technology because my current level of digital literacy is sufficient for adopting digital technologies in farming.*” Although the score still reflects a positive perception, it indicates slightly low confidence among some farmers regarding existing digital literacy. Even though many farmers believe they have the necessary basic skills, there remains a segment that requires additional support or training to adopt technology more effectively.

Table 3. Mean of digital literacy factor (n = 181)

Statement	Scale					Mean	SD
	1	2	3	4	5		
Digital literacy							
I will adopt digital technology if I can use digital devices such as smartphones and computers for farming activities.	0 (0.0)	0 (0.0)	19 (10.5)	94 (51.9)	68 (37.6)	4.27	0.640
I will adopt digital technology if I am knowledgeable about the various digital tools available for agricultural purposes.	0 (0.0)	0 (0.0)	19 (10.5)	95 (52.5)	67 (37.0)	4.27	0.638
I will adopt digital technology if I can easily learn how to use new digital technologies in farming.	0 (0.0)	0 (0.0)	12 (6.6)	94 (51.9)	75 (41.4)	4.35	0.601
I will adopt digital technology because my current level of digital literacy is sufficient for adopting digital technologies in farming.	0 (0.0)	1 (0.6)	22 (12.2)	91 (50.3)	67 (37.0)	4.24	0.678
I will adopt digital technology because I regularly use the internet or other digital resources to gather information about farming practices.	0 (0.0)	1 (0.6)	18 (9.9)	84 (46.4)	78 (43.1)	4.32	0.673
I will adopt digital technology if I feel capable of keeping up with the rapid changes in digital technology.	0 (0.0)	0 (0.0)	14 (7.7)	91 (50.3)	76 (42.0)	4.34	0.618
I will adopt digital technology if I can manage the complexity of using digital tools in my farming operations.	0 (0.0)	0 (0.0)	22 (12.2)	89 (49.2)	70 (38.7)	4.27	0.664
I will adopt digital technology because I understand how to use digital tools to enhance my farming practices.	0 (0.0)	0 (0.0)	12 (6.6)	98 (54.1)	71 (39.2)	4.33	0.595
I will adopt digital technology because my digital literacy skills are sufficient for adopting digital technologies in farming.	0 (0.0)	1 (0.6)	13 (7.2)	96 (53.0)	71 (39.2)	4.31	0.627
I will adopt digital technology because I regularly use online resources to improve my knowledge of digital farming tools.	0 (0.0)	1 (0.6)	18 (9.9)	84 (46.4)	78 (43.1)	4.32	0.673
Total Average Mean						4.301	0.597

Note: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree

Analysis of digital literacy among TKPM farmers in Pahang, as shown in Table 4, indicates a generally high level of proficiency. Out of 181 respondents, 161 farmers (89%) were categorized as having a high level of digital literacy, suggesting that the majority possess the skills necessary to engage with digital agricultural technologies, which likely facilitated their willingness to adopt agricultural digital technologies. Meanwhile, 20 respondents (11%) were classified at a medium level, and none (0%) were classified as a low-level category. The overall mean score was 4.301 with a standard deviation of 0.597.

Table 4. Mean level of digital literacy factor

Level	Frequency	Percentage (%)	Mean	SD
High (3.67–5.0)	161	89	4.301	0.597
Medium (2.34–3.66)	20	11		
Low (1–2.33)	0	0		
Total	181	100		

Mean level of government grants and subsidies factors influencing the intention to adopt agricultural digital technology

Table 5 presents the analysis of government grants and subsidies as influencing factors in the adoption of digital technology among TKPM farmers. The statement with the highest mean score of 4.45 is “*I will adopt digital technology if applying for government grants and subsidies is a straightforward process.*” This finding suggests that farmers placed high importance on the ease and accessibility of the grant application process. Simplifying bureaucratic procedures can significantly improve uptake by reducing entry barriers and encouraging farmers to take advantage of available grants and subsidies. Meanwhile, the lowest mean score of 4.33 was recorded for the statement “*I will adopt digital technology because I believe government grants are a key factor in enabling farmers like me to adopt it.*” Although this score still reflects a positive perception, it suggests that farmers acknowledge the importance of financial assistance but may not regard it as the sole or most decisive factor in adopting technology. This lower score reflects the recognition that subsidies and grants are essential in reducing economic barriers, especially for farmers with limited financial resources.

Table 5. Government grants and subsidies factor (n = 181)

Statement	Scale					Mean	SD
	1	2	3	4	5		
Government Grants and Subsidies							
I will adopt digital technology if government grants and subsidies were available to support its adoption in farming.	0 (0.0)	4 (2.2)	14 (7.7)	65 (35.9)	98 (54.1)	4.42	0.731
I would invest in digital technology if the government's financial support encouraged me to adopt digital technology in my farming practices.	0 (0.0)	1 (0.6)	15 (8.3)	74 (40.9)	91 (50.3)	4.41	0.666

Statement	Scale					Mean	SD
	1	2	3	4	5		
Government Grants and Subsidies							
I will adopt digital technology if government grants and subsidies help reduce the cost of purchasing it.	0 (0.0)	4 (2.2)	14 (7.7)	65 (35.9)	98 (54.1)	4.42	0.731
I will invest in digital technology if I receive substantial financial support from various parties.	0 (0.0)	1 (0.6)	15 (8.3)	74 (40.9)	91 (50.3)	4.41	0.666
I will adopt digital technology if the government provides continuous financial support and subsidies.	0 (0.0)	4 (2.2)	14 (7.7)	66 (36.5)	97 (53.6)	4.41	0.730
I will adopt digital technology because I believe government grants are a key factor in enabling farmers like me to adopt it.	0 (0.0)	8 (4.4)	17 (9.4)	63 (34.8)	93 (51.4)	4.33	0.824
I will adopt digital technology if applying for government grants and subsidies is a straightforward process.	0 (0.0)	2 (1.1)	10 (5.5)	73 (40.3)	96 (53.0)	4.45	0.653
I will use digital technology if there is no bureaucratic process involved in applying for government grants and subsidies.	0 (0.0)	2 (1.1)	10 (5.5)	75 (41.4)	94 (51.9)	4.44	0.653
I will adopt digital technology if agricultural officials visit my farm to help me with the grant and subsidy application process.	0 (0.0)	2 (1.1)	10 (5.5)	75 (41.4)	94 (51.9)	4.44	0.653
I will adopt digital technology if the government provides grants that are specifically accessible to small farmers like me.	0 (0.0)	4 (2.2)	15 (8.3)	65 (35.9)	97 (53.6)	4.41	0.737
Total Average Mean						4.501	0.552

Note: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree

Table 6 presents the respondents' perceptions of government grants and subsidies as influencing factors, with the overall mean being 4.501 and a standard deviation of 0.552. Out of 181 respondents, 173 (95.6%) were categorized at the high perception level (mean range of 3.67–5.00). This indicates that most farmers strongly consider government grants and subsidies as critical enablers in their decision to adopt digital technologies. Only 8 respondents (4.4%) were classified at the medium level (mean range: 2.34–3.66), while none (0%) fell into the low-level category (1.00–2.33).

Table 6. Mean score and perception levels of government grants and subsidies as a factor

Level	Frequency	Percentage (%)	Mean	SD
High (3.67–5.0)	173	95.6	4.501	0.552
Medium (2.34–3.66)	8	4.4		
Low (1–2.33)	0	0		
Total	181	100		

Mean level of agriculture extension services factor toward the intention to adopt agriculture digital technology

According to Table 7, the statement with the highest mean score of 4.55 is “*I will adopt digital technology if agricultural extension continues to help me until I am proficient in using it.*” This highlights farmers’ strong expectations for sustained hands-on support from extension officers. Consistent and long-term guidance not only facilitates learning but also builds farmers’ confidence in using and mastering digital technologies independently. The statement with the lowest mean score of 4.47 is “*I would adopt digital technology if the training provided by agricultural extension services is effective in helping me use digital technology.*” This statement shows that farmers value the presence of extension officers and rely on their services, such as getting practical training.

Table 7. Agriculture extension services factor (n = 181)

Statement	Scale					Mean	SD
	1	2	3	4	5		
Agriculture Extension Services							
I will adopt digital technology if agricultural extension services provide me with the necessary information for it.	0 (0.0)	1 (0.6)	5 (2.8)	81 (44.8)	94 (51.9)	4.48	0.583
I will only adopt digital technology if I trust the advice given by agricultural extension officers regarding its use in farming.	0 (0.0)	0 (0.0)	8 (4.4)	77 (42.5)	96 (53.0)	4.49	0.583
I would adopt digital technology if the training provided by agricultural extension services is effective in helping me use digital technology.	0 (0.0)	1 (0.6)	6 (3.3)	81 (44.8)	93 (51.4)	4.47	0.592
I will adopt digital technology if agricultural extension services regularly update me on the latest digital technologies in agriculture.	0 (0.0)	1 (0.6)	6 (3.3)	80 (44.2)	94 (51.9)	4.48	0.592
I will adopt digital technology if agricultural extension services show evidence that farmers who have adopted it can achieve maximum profit.	0 (0.0)	1 (0.6)	7 (3.9)	72 (39.8)	101 (55.8)	4.51	0.602

Statement	Scale					Mean	SD
	1	2	3	4	5		
Agriculture Extension Services							
I will be more likely to adopt digital technology if I receive continuous support from agricultural extension services.	0 (0.0)	0 (0.0)	6 (3.3)	80 (44.2)	95 (52.5)	4.49	0.564
I will adopt digital technology if agricultural extension officers explain and demonstrate how to use it clearly.	0 (0.0)	0 (0.0)	8 (4.4)	74 (40.9)	99 (54.7)	4.50	0.583
I will adopt digital technology if agricultural extension services continue to help me until I am proficient in using it.	0 (0.0)	0 (0.0)	4 (2.2)	74 (40.9)	103 (56.9)	4.55	0.542
I will adopt digital technology if agricultural extension officers help me choose the most appropriate type of technology for my farm.	0 (0.0)	0 (0.0)	7 (3.9)	71 (39.2)	103 (56.9)	4.53	0.573
I will adopt digital technology if agricultural extension officers are friendly and use language that is easy for me to understand.	0 (0.0)	0 (0.0)	7 (3.9)	73 (40.3)	101 (55.8)	4.52	0.573
Total Average Mean						4.501	0.579

Note: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree

Table 8 shows the mean level of agricultural extension services as perceived by the respondents. The overall mean score was 4.501, with a standard deviation of 0.579, indicating a strong agreement among farmers regarding the importance of extension services in supporting digital technology adoption. Out of 181 respondents, 173 farmers (95.6%) were categorized at the high level, while 8 respondents (4.4%) exhibited a medium level, and none were classified at the low level (0%). These findings show the importance of agricultural extension services as a factor in supporting and guiding farmers through the adoption process.

Table 8. Mean level of agriculture extension services factor

Level	Frequency	Percentage (%)	Mean	SD
High (3.67–5.0)	173	95.6	4.501	0.579
Medium (2.34–3.66)	8	4.4		
Low (1.00–2.33)	0	0		
Total	181	100		

Mean level of intention to adopt agriculture digital technology

Table 9 presents the analysis of the dependent variable, namely farmers' intention to adopt agricultural digital technology. The statement with the highest mean score (4.38) was *"I will adopt digital technology if I believe it will improve my farming productivity"*. This shows that farmers in TKPM, Pahang, prioritize tangible, outcome-driven benefits, particularly the potential for increased productivity. Their intention to adopt is strongly tied to the perceived effectiveness of digital tools in enhancing agricultural yields, reinforcing the need to clearly demonstrate the advantages of such technologies to boost adoption rates. On the other hand, the statement with the lowest mean score (4.24) was *"I will adopt digital technology if I feel comfortable using it for my farming activities"*. Although still relatively high, it shows that while comfort and ease of use are important, they are slightly less influential than productivity outcomes. This shows that some farmers may still face challenges related to usability and comfort in handling new technologies.

Table 9. Intention to adopt agricultural digital technology (n=181)

Statement	Scale					Mean	SD
	1	2	3	4	5		
Intention							
I will adopt digital technology if I believe it will allow me to manage my farm more effectively.	0 (0.0)	0 (0.0)	17 (9.4)	80 (44.2)	84 (46.4)	4.37	0.651
I will adopt digital technology if I believe it will help me make better decisions in farming.	0 (0.0)	0 (0.0)	18 (9.9)	79 (43.6)	84 (46.4)	4.36	0.658
I will adopt digital technology if I believe it will improve my farming productivity.	0 (0.0)	0 (0.0)	17 (9.4)	79 (43.6)	84 (47.0)	4.38	0.652
I will adopt digital technology if I believe it will enhance the overall efficiency of my farm operations.	0 (0.0)	0 (0.0)	18 (9.9)	81 (44.8)	82 (45.3)	4.35	0.656
I will adopt digital technology if I feel comfortable using it in my farming activities.	0 (0.0)	4 (2.2)	23 (12.7)	79 (43.6)	75 (41.4)	4.24	0.758
I will adopt digital technology if I believe it requires minimal effort to use it.	0 (0.0)	4 (2.2)	21 (11.6)	81 (44.8)	75 (41.4)	4.25	0.747
I will adopt digital technology on my farm if I have the experience and skills to use it.	0 (0.0)	4 (2.2)	19 (10.5)	82 (45.3)	76 (42.0)	4.27	0.737
I will adopt digital technology if I believe it can help me achieve higher profits.	0 (0.0)	2 (1.1)	13 (7.2)	86 (47.5)	80 (44.2)	4.35	0.663
I will adopt digital technology on my farm if I receive support and encouragement from family, friends and extension agencies.	0 (0.0)	2 (1.1)	15 (8.3)	85 (47.0)	79 (43.6)	4.33	0.675
I will adopt digital technology if I can afford the purchase cost.	0 (0.0)	2 (1.1)	14 (7.7)	86 (47.5)	79 (43.6)	4.34	0.669
Total Average Mean						4.325	0.686

Note: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree

Table 10 presents the overall mean score for respondents' intention to adopt agricultural digital technology, which is 4.325, indicating a high level of intention. There were 161 respondents (89%) whose intentions were at a high level, while 20 respondents (11%) were at a medium level, and none (0%) exhibited a low level (1.00–2.33). These findings highlight a generally positive and encouraging outlook toward the adoption of digital technology in agriculture among TKPM farmers in Pahang, suggesting that the majority recognize its potential benefits and are inclined to incorporate it into their farming practices.

Table 10. Mean level of intention to adopt agricultural digital technology

Level	Frequency	Percentage (%)	Mean	SD
High (3.67–5.0)	161	89	4.325	0.686
Medium (2.34–3.66)	20	11		
Low (1.00–2.33)	0	0		
Total	181	100		

Conclusion and Recommendations

The first objective of this study was to determine the levels of socio-economic factors, digital literacy, government grants and subsidies, and agriculture extension services in relation to the intention to adopt agricultural digital technology among TKPM farmers in Pahang. Based on the descriptive analysis conducted, the findings indicate a high level of agreement among respondents across all four factors. The mean scores for each factor were as follows: socio-economic factors (4.123), digital literacy (4.301), government grants and subsidies (4.501), and agricultural extension services (4.501). These results suggest that all four variables exert a significant and positive influence on farmers' intention to adopt digital technology in agriculture. The study underscores the need for targeted policies to promote digital adoption among TKPM farmers. These policies should focus on increasing digital literacy through training programs and workshops, expanding access to financial support and streamlining the application process for government grants and subsidies, and strengthening agricultural extension services by equipping officers with digital tools and providing continuous training. Additionally, a multi-stakeholder collaboration among government agencies, private sector players, and research institutions can facilitate the development and dissemination of user-friendly agricultural technologies tailored to farmers' needs. Overall, the study affirms that improving socio-economic conditions, enhancing digital literacy, providing accessible financial incentives, and ensuring robust extension services are pivotal to driving digital transformation in agriculture, ultimately contributing to improved productivity and sustainability in the sector.

References

- Akudugu, M. A., Nkegbe, P. K., Wongnaa, C. A., & Millar, K. K. (2023). Technology adoption behaviors of farmers during crises: What are the key factors to consider? *Journal of Agriculture and Food Research*, 14, 100694. <https://doi.org/10.1016/j.jafr.2023.100694>
- Anang, B. T. (2022). Interceding Role of Agricultural Extension Services in Adoption of Climate-Smart Agricultural Technologies in Northern Ghana. *Asia Pacific Journal of Sustainable Agriculture, Food and Energy*, 10(2), 69–76. <https://doi.org/10.36782/apjsafe.v10i2.175>
- Chulwa, A. Z., Ibad, M. Z., & Tanjung, A. S. (2022). Dampak Digitalisasi Pertanian Terhadap Tingkat Ekonomi Masyarakat Petani di Kecamatan Adiluwih Dan Gadingrejo Pringsewu. *Jurnal Perencanaan Dan Pengembangan Kebijakan*, 2(3), 176. <https://doi.org/10.35472/jppk.v2i3.845>
- Cui, L., & Wang, W. (2023). Factors Affecting the Adoption of Digital Technology by Farmers in China: A Systematic Literature Review. *Sustainability*, 15(20), 14824. <https://doi.org/10.3390/su152014824>
- Fabregas, R., Harigaya, T., Kremer, M., & Ramrattan, R. (2023). Digital Agricultural Extension for Development. In *Introduction to Development Engineering* (pp. 187–219). Springer International Publishing. https://doi.org/10.1007/978-3-030-86065-3_8
- Fharaz, V. H., Kusnadi, N., & Rachmina, D. (2022). Pengaruh Literasi Digital Terhadap Literasi E-Marketing Pada Petani. *Jurnal Agribisnis Indonesia*, 10(1), 169–179. <https://doi.org/10.29244/jai.2022.10.1.169-179>
- Finger, R. (2023). Digital innovations for sustainable and resilient agricultural systems. *European Review of Agricultural Economics*, 50(4), 1277–1309. <https://doi.org/10.1093/erae/jbad021>
- Fuerst, S., Sanchez-Dominguez, O., & Rodriguez-Montes, M. A. (2023). The Role of Digital Technology within the Business Model of Sustainable Entrepreneurship. *Sustainability*, 15(14), 10923. <https://doi.org/10.3390/su151410923>
- Guo, F., Zhang, T., Huang, X., & Zhong, Y. (2023). Government Subsidy Strategies Considering Greenness on Agricultural Product E-Commerce Supply Chain. *Mathematics*, 11(7), 1662. <https://doi.org/10.3390/math11071662>
- Kolmykova, T. S., Obukhova, A. S., Klykova, S. V., Mashegov, P. N., Zaitsev, A. G., & Popova, O. V. (2021). Features and Benefits of Digital Technologies in Agricultural Enterprises. *E3S Web of Conferences*, 247, 01018. <https://doi.org/10.1051/e3sconf/202124701018>
- Li, L. (2023). Use Promote Inclusive Entrepreneurship Among Farmers? *Frontiers in Business, Economics and Management*, 7(2), 228–236. <https://doi.org/10.54097/fbem.v7i2.4925>
- Marshall, A., Turner, K., Richards, C., Foth, M., & Dezuanni, M. (2021). Rural Data Divides: Critical Factors of Digital Agtech Adoption on Australian Farms. *AoIR Selected Papers of Internet Research*. <https://doi.org/10.5210/spir.v2021i0.12206>

- Mokhtar, M. S. (2022). Peranan Jabatan Pertanian dan Diversiti Pertanian Kolonial di Tanah Melayu, 1920-1938 (Role of Agriculture Department and Colonial Agriculture Diversity In Malaya, 1920-1938). *Malaysian Journal of History, Politics and Strategic Studies*, 49(3). <https://doi.org/10.17576/jebat.2022.4903.01>
- Pangapanga-Phiri, I., Ngoma, H., & Thierfelder, C. (2024). Understanding sustained adoption of conservation agriculture among smallholder farmers: insights from a sentinel site in Malawi. *Renewable Agriculture and Food Systems*, 39, e10. <https://doi.org/10.1017/S1742170524000061>
- Puppala, V. K. (2021). Digital Technology – The 4th Industrial Revolution & Beyond. *International Journal of Engineering Applied Sciences and Technology*, 5(9). <https://doi.org/10.33564/IJEAST.2021.v05i09.017>
- Rai, A. K., Ranjan, A., Bharti, S. D., Saikanth, D. R. K., Surender, Rout, S., & Gautam, R. (2023). Agricultural Extension's Key Role in Modern Farming: A Review. *Asian Journal of Agricultural Extension, Economics & Sociology*, 41(9), 475–485. <https://doi.org/10.9734/ajaees/2023/v41i92066>
- Rolandi, S., Brunori, G., Bacco, M., & Scotti, I. (2021). The Digitalization of Agriculture and Rural Areas: Towards a Taxonomy of the Impacts. *Sustainability*, 13(9), 5172. <https://doi.org/10.3390/su13095172>
- Samadder, S., Pandya, S. P., & Lal, S. P. (2023). Bridging the Digital Divide in Agriculture: An Investigation to ICT Adoption for Sustainable Farming Practices in Banaskantha District of Gujarat, India. *International Journal of Environment and Climate Change*, 13(9), 1376–1384. <https://doi.org/10.9734/ijecc/2023/v13i92367>
- Shaila, M., & Begum, N. (2021). Ancient farming methods of seed storage and pest management practices in India – a Review. *Plant Archives*, 21(Suppliment–1), 499–509. <https://doi.org/10.51470/PLANTARCHIVES.2021.v21.S1.077>
- Van Zeebroeck, N., Kretschmer, T., & Bughin, J. (2023). Digital “is” Strategy: The Role of Digital Technology Adoption in Strategy Renewal. *IEEE Transactions on Engineering Management*, 70(9), 3183–3197. <https://doi.org/10.1109/TEM.2021.3079347>
- Wang, B., & Dong, H. (2023). Research on the farmers' agricultural digital service use behavior under the rural revitalization strategy—Based on the extended technology acceptance model. *Frontiers in Environmental Science*, 11. <https://doi.org/10.3389/fenvs.2023.1180072>
- Zhou, Y., Yang, C., Liu, Z., & Gong, L. (2024). Digital technology adoption and innovation performance: a moderated mediation model. *Technology Analysis & Strategic Management*, 36(11), 3341–3356. <https://doi.org/10.1080/09537325.2023.2209203>

Utilization of Poultry Manure as an Organic Amendment for Sustainable Soil Management in Brunei Darussalam

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Abstract

Brunei, which is located in Southeast Asia, has predominantly Ultisols and Oxisols, which are highly weathered, nutrient-deficient, and acidic soil posing challenges for agriculture. As a result, the country struggles to meet self-sufficiency targets with rice production covering only 8.14% of local demand, while most of the crops are imported to meet consumption needs. To improve crop production, initiatives such as liming to reduce soil acidity, introducing high-yield seed varieties, and opening new land for cultivation have been implemented, though they pose economic and environmental challenges. In addition to crop production, poultry farming plays a key role in food security, achieving near self-sufficiency in broiler and egg production. Nevertheless, increased poultry farming generates significant waste, such as manure, which requires proper management to prevent pollution. The rise in waste output has led to higher landfill demand and environmental degradation. However, repurposing poultry waste into organic amendments, fertilizers, and biogas promotes sustainable waste utilization. The use of organic amendment derived from poultry manure can enhance soil fertility by improving nutrient availability, microbial activity, and soil structure, supporting sustainable soil management, and reducing reliance on synthetic fertilizers. By integrating these practices, Brunei can adopt circular agriculture, reintegrating agriculture by-products into the production cycle to enhance sustainability and food security. Hence, the objective of the presented review enables an approach that not only enhances soil fertility but also contributes to long-term agricultural sustainability which includes sustainable soil management and food security in Brunei.

Keywords: acid soil, soil management, waste management, circular agriculture

JEL code: Q01, Q10, Q16

SDG classification: SDG 2, SDG 12

Introduction

A common environmental problem that can significantly decrease crop production is the occurrence of acid soil. Brunei is situated in South-East Asia, a region characterized by the widespread occurrence of acidic soil (von Uexküll & Mutert, 1995). Soil evaluation conducted in Brunei have shown that its soil properties closely resemble those of typical acid soil, and many of which are found in the inland low-lying area, which are key zones for agricultural activities (Grealish & Fitzpatrick, 2013). Acid soils can affect the growth of plant root development and yield through nutrient imbalance, toxicity, and inadequacy of essential nutrient elements in the soil (Osman, 2018; Sade et al., 2016). As a result, Brunei is unable to achieve a self-sufficiency rate for crop production, which includes rice (8.15%), tropical vegetables (72.7%), tropical fruits (43%), and miscellaneous crops (10.9%) (Department of Agriculture and Agri-food, 2023). These low self-sufficiency levels have necessitated the importation of these crops to meet domestic consumption demands.

In response to this challenge, various initiatives have been undertaken to improve the situation. A common agricultural practice adopted by local farmers is the application of lime to reduce soil acidity and improve crop production, however, the effectiveness of the current approach may lead to under- or over-liming, which will result in yield loss and increase costs (Ringrose-Voasde et al., 2008). Brunei also introduced high-yield variety crops to improve crop production. An example is rice variety *Sembada 188*, with a paddy production of more than 4000 metric tonnes (Mt) in 2021, has contributed to the growth of paddy production (Department of Agriculture and Agri-food, 2022). Another initiative made by the government is the opening of new agricultural land for paddy production. The new 500 hectares of agricultural land is located in Kandol, Belait, and is expected to generate 6000 - 8000 Mt of rice yearly by 2025 (Wong, 2020). These efforts demonstrate Brunei's commitment to improving agricultural productivity; however, these practices must be carefully managed to avoid negative impacts such as soil degradation and nutrient imbalance. Thus, sustainable soil management remains a critical foundation for improving crop yield and achieving national food security goals.

In Brunei, the poultry sector currently leads in achieving self-sufficiency among all livestock industries, playing a crucial role in the nation's food security (Department of Agriculture and Agri-food, 2023). It is expected from this sector to produce a high amount of waste. It was estimated that 82,055 Mt of chicken manure from both broiler and layer was produced in 2023 (personal communication, 2024). However, despite this significant output, Brunei lacks a proper waste classification system, aside from arrangements for the disposal of hazardous waste; most waste is either combined with household refuse and common landfill sites (Department of Environment Parks and Recreation, n.d.)

Waste generation is defined as discarded material including municipal solid waste, hazardous and non-hazardous waste, and agricultural and animal waste. With Brunei Darussalam's limited land capacity and an addition to the landfills receiving waste daily, it has been estimated the landfill is to be at its full capacity by 2030 (*No Time to Waste*, 2021). Nonetheless, poultry litter consists of valuable nutrients and can be transformed into organic soil amendment through composting, co-composting, and pyrolysis. Several studies have provided results in improving the soil's chemical, physical and biological properties, at the same time increasing the yield of crops with soil organic amendment produced from poultry litter, moreover, organic-mineral fertilizer derived from poultry

waste proved to be as effective as costly commercial mineral fertilizer (Gržinić et al., 2023; Mironiuk et al., 2023). This promotes organic farming practices and at the same time reduces dependency on synthetic fertilizer and mitigating their environmental impacts. Therefore, this paper aims to explore approached that improve soil fertility while supporting long-term agriculture sustainability, with a focus on sustainable soil management and strengthening food security in Brunei.

Methodology

To evaluate the current status of utilization of poultry manure for sustainable soil management, this review study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), which provides guidelines in selecting, identifying, and synthesizing studies (Page et al., 2021). This study utilized three databases: Scopus, EBSCOHost, and Google Scholar (non-Scopus database). The databases encompassed a broad selection of peer-reviewed academic journal articles, providing comprehensive coverage for literature data. The search study employed a combination of keywords and Boolean operators to ensure inclusion of all relevant studies. The keywords included, but were not limited to, acid soil, tropical soil, sustainable soil management, poultry manure, organic amendment, and Southeast Asia Agriculture.

To prevent the generalization of this literature study, a list of criteria was designed to ensure that the retrieved documents fell within the search scope and relevance of this study (Figure 1). The inclusion and exclusion criteria were as follows:

- i. Papers from 2015 to 2025,
- ii. English medium and English translated documents,
- iii. Documents are limited to countries of Southeast Asia,
- iv. Studies conducted use organic amendment (compost and biochar) from poultry manure with and/or without adding other sources,
- v. Studies conducted on acid soil conditions,
- vi. Outcome on improvement in crop yield and soil chemical, biological, and physical properties,
- vii. Studies unrelated to the use of organic amendment, and acid soil,
- viii. Studies that only focus on plant growth and yield without linking results to soil improvements.

Following the retrieval of relevant literature, Mendeley software was used to manage the references and remove the duplicates. For each included study, the following information was extracted: title, author, year, abstract, keywords, and relevance to Brunei.

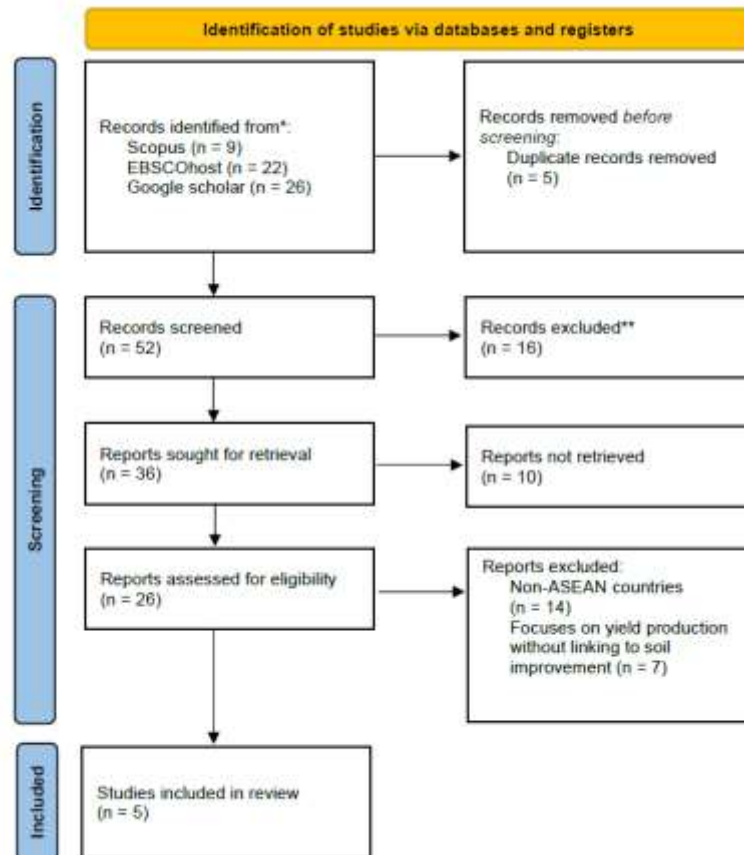


Figure 5. Literature search and documents analysis process.

Based on the search conducted, Figure 1 reveals that only 5 documents were included in the final review for this document analysis process. Of the three databases used and the records searched using the selected keywords, a total of 52 documents were identified after removing duplicate documents. During the screening process, only 26 documents were assessed for eligibility, as several documents were not retrieved and excluded because their titles, abstracts, and keywords were not relevant to the topic. The final screening process assessed the eligibility of the documents according to the inclusion and exclusion criteria stated above, and only five studies were included for review, as shown in Table 1.

Results and Discussion

Inadequate information on the production of organic amendment from poultry manure in Brunei Darussalam

A total of 5 documents were eligible and included in this study review. The documents were further assessed for their relevance to Brunei and environmental benefits, which align with the topic of this study. Although these studies were not conducted in Brunei, each study is highly relevant to Brunei's agricultural issues. The listed documents (Table 1) are highly relevant to Brunei's agricultural issues because each of the studies was

conducted in areas affected by acid soil (von Uexküll & Mutert, 1995). According to studies conducted, the use of poultry waste is crucial in improving soil health and enhancing nutrient availability for plants. This is because poultry waste has high nutrient content, rich in essential elements, and the potential to improve soil fertility, making it a widely used raw material to produce organic amendments (Alarefee et al., 2021).

Globally, poultry waste production has increased over the past few years due to the intensification of poultry farming, which plays a significant role in modern poultry farming, while also providing food and nutritional security for the growing world population. However, this has left an environmental footprint due to several factors, and one of them is inefficient manure and litter management and use (Gržinić et al., 2023). It is essential to mention that direct use of fresh poultry litter can lead to several environmental problems, including ammonia volatilization, soil acidification and crop damage, transfer of pathogens, and heavy metal contamination (Alarefee et al., 2021; Drózdź et al., 2020). Without proper awareness of these issues, it can lead to improper soil management, leading to reduced crop yield and quality, vulnerability to pests and diseases, and environmental issues like water pollution. As suggested by Ali et al. (2023) and Alarefee et al. (2021), transforming poultry waste into an organic amendment is a sustainable and cost-effective method, a solution for soil health restoration, and productive management for crop production. Integrating such practices into a structured waste management framework would not only support circular agriculture by closing nutrient loops but also contribute to sustainable soil management in Brunei, particularly in addressing the challenges posed by its acidic and nutrient-poor soil.

Food Systems, Consumption, and Nutrition

Table 1. List of documents included in literature studies relevant to Brunei

No.	Title	Publication year	Author(s)	Relevance to Brunei	Environmental benefits	Soil health effects	Type of document
1	Co-Composted Chicken Litter Biochar Increases Soil Nutrient Availability and Yield of <i>Oryza sativa</i> L.	2023	Ali et al.	Highly relevant	- Mitigate environmental pollution - Reduction in the use of inorganic fertilizer - Waste management	Improve nutrients availability soil and	Journal article
2	Efficiency of rice husk biochar with poultry litter co-composts in oxisols for improving soil physico-chemical properties and enhancing maize performance	2021	Alarefee et al.	Highly relevant	- Waste management - Reduce ammonia emissions - Reduction in the use of inorganic fertilizer - Reduce heavy metal uptake by the crop	Increased macronutrients Restoration and stabilization of soil organic carbon	Journal article
3	Utilization of urea and chicken litter biochar to improve rice production	2021	Maikol et al.	Highly relevant	Reduce the need for synthetic N	Improved nutrient retention soil	Journal article

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No.	Title	Publication year	Author(s)	Relevance to Brunei	Environmental benefits	Soil health effects	Type of document
					- Reduces toxicity in soil - Enhanced sequestration	AI C Improve biological properties Enhanced water infiltration	
4	Growth and yield response of peanut, (<i>Arachis hypogaea</i> L.) and soil characteristics with application of inorganic and organic fertilizer and dolomite addition	2019	Arangote et al.	Highly relevant	- Reduce soil N₂O emission - Enhance yield	crop Improve soil macro and micronutrients Improve soil texture and selected chemical properties	Journal article
5	Effects of biochar and chicken litter ash on selected soil chemical properties and nutrients uptake by <i>Oryza sativa</i> L. var. MR 219	2015	Yusof et al.	Highly relevant	Reducing reliance chemical fertilizer	on Improved soil structure, water tension, and overall soil fertility	Journal article

Potential of using poultry manure to improve soil productivity and crop production

Poultry litter is a waste product from poultry farms, primarily consisting of manure with a mixture of shed feathers, spilled feed, and bedding materials. It is a significant byproduct of broiler and layer operations, and a valuable resource due to its high nutrient content. A study conducted by Rogeri et al., (2016) determined the composition of poultry manure, and the chemical properties of poultry litter presented pH of the poultry manure was alkaline, and the concentrations of N, P₂O₅, and K₂O were lower than 5.0%. Nitrogen (N) in poultry litter was in an organic form; however, ammonium was at 9.6% of total N, and very low traces of nitrate were detected. And the average organic carbon (C) and C/N ratio was at 28.3% and 11.2%, respectively. However, variation in the composition of poultry litter may occur due to different management of feed ration, dietary supplement, and litter storage and handling, which include the amount of bedding used, litter removal frequency, and use of windows to treat litter (Ashworth et al., 2020; Bolan et al., 2010) (Table 2).

Table 1. Nutrient composition of manures and composts (g/kg dry weight basis)

Nutrients	Poultry manure compost		Pig manure	Mushroom	Biosolid
	Layer	Broiler	compost	compost	compost
Nitrogen	32.8	25.7	15.2	17.5	21.8
Phosphorus	10.8	6.7	6.5	7.5	10.1
Potassium	15.2	10.1	8.2	9.2	5.9
Calcium	18.5	16.2	4.2	21.5	19.7
Magnesium	6.2	3.5	3.7	5.2	4.2
Sulphur	8.5	5.2	3.4	3.5	7.0

Source: Ashworth et al., (2020)

It is essential to analyze the nutrient composition of poultry manure to ensure that its application aligns with the specific nutrient requirements of the target crop. Compared to other manure sources, poultry litter contains exceptionally high levels of total N and phosphorus (P); however, the disproportionate relationship between these nutrients and the actual crop requirements can lead to nutrient imbalances in agricultural fields (Muduli et al., 2019). Therefore, transforming poultry litter into stabilized organic amendment is a critical process for mitigating hazards associated with its direct application and conserving the nutrients.

Improper management of poultry litter may pose significant environmental and human health risks. Poultry litter contains valuable nutrients, making it useful for agriculture, but also includes pollutants like ammonia and other odour compounds, and these substances can contribute to water, air, and land pollution, and they may even be toxic to human health due to improper disposal (Singh et al., 2018). Poultry production also generates ethane, ammonia, and nitrous oxide, which are greenhouse gases emitted through waste and litter management, as well as the application of untreated poultry manure as an organic amendment (Zisis et al., 2023). Without effective management and proper treatment of the poultry manure, this can waste the manure's potential, leading to nutrient loss through evaporation, runoff, and leaching.

Effective manure management can reduce environmental and health impacts while aiming for profitability and preventing nutrient loss. Several methods are available for the management and disposal of poultry litter; however, this study specifically focuses on its utilization as a soil amendment through land application in agricultural systems. Composting is a cost-effective method that results in a more sustainable and stable product for application. This process kills pathogens and controls disease outbreaks, odour control, moisture management, and minimizes loss of important nutrients, such as nitrogen and phosphorus, from leaching and runoff, by adding additives like zeolite and biochar (Zisis et al., 2023; Drózdź et al., 2020; Singh et al., 2018). Similarly, pyrolysis involves the thermal decomposition of organic materials in the absence of oxygen, resulting in the production of biochar. This process transforms the poultry litter into a stable and carbon-rich solid, containing readily available phosphorus and potassium, and improves the physical properties of the organic amendment with high surface area and porosity, making it suitable for adsorption and filtration applications (Pandey et al., 2019; Yıldız et al., 2019). Biochar is also environmentally safe because of its ability to reduce emissions of ammonia and carbon dioxide (Drózdź et al., 2023; Simbolon et al., 2024). Given Brunei's emphasis on improving agricultural productivity and reducing reliance on imported inputs, these methods offer potential for enhancing soil fertility using locally available organic waste, while minimizing negative environmental and health impacts.

Implication of soil organic amendment in Brunei

The studies demonstrate the high relevance of poultry litter and co-application of compost and biochar for enhancing sustainable agriculture in Brunei (Table 1). Research by Alarefee et al., (2021), Ali et al., (2023), and Maikol et al. (2021) underscores the environmental benefits of these practices, including the reduction in the use of synthetic fertilizer, mitigation of ammonia and greenhouse gas emissions, improved waste management, and enhanced carbon sequestration. Utilizing and transforming poultry litter into a stable product for land application in agricultural systems has presented its benefits, particularly in addressing nutrient loss and pollution concerns. These practices align closely with the principles of circular agriculture, where agricultural waste is recycled back into the system to improve soil fertility, reduce external inputs, and close nutrient loops. Additionally, studies by Arangote et al. (2019) and Yusof et al. (2015) show significant improvements in soil health, including increased availability of macro- and micronutrients, stabilization of organic carbon, better water infiltration, and improved soil structure and fertility. The use of co-composted poultry litter and biochar also helps reduce heavy metal uptake in crops and alleviates soil toxicity, especially in acid-probe soils, which are prevalent in Brunei. Collectively, these findings highlight the potential of biochar and poultry litter amendments to improve crop yield, promote soil sustainability, support circular agriculture, and reduce environmental impact in Brunei's agriculture sector.

Conclusion

The review highlights the potential of utilizing poultry manure as a sustainable organic amendment to address the challenges posed by acid soil in Brunei. The findings demonstrate that poultry litter, when appropriately processed through composting or pyrolysis, significantly improves soil chemical, physical, and biological properties. These enhancements lead to increased crop productivity, reduced dependency on synthetic fertilizers, and minimized environmental pollution. Although the reviewed studies were conducted in other Southeast Asia countries, their relevance to Brunei is evident due to similar soil conditions and agricultural challenges. The transformation of poultry waste into stable soil amendment not only supports sustainable agriculture but also aligns with Brunei's food security and waste management goals, thereby promoting circular agriculture practices.

However, it is important to note that most of the reviewed studies were conducted under controlled or small-scale conditions and may not fully capture the complexities of large-scale application in Brunei's agroecological context. Despite these limitations, it is recommended that Brunei adopt an integrated waste management system that facilitates the classification, collection, and processing of poultry manure to aid its conversion into compost and biochar. It is also important to initiate localized pilot project to test poultry litter amendments on Brunei's soil to validate and adapt findings from regional studies to the national context.

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References

- Alarefee, H., Ishak, C. F., Karam, D. S., & Othman, R. (2021). Efficiency of Rice Husk Biochar with Poultry Litter Co-Composts in Oxisols for Improving Soil Physico-Chemical Properties and Enhancing Maize Performance. *Agronomy*, 11(12), 2409. <https://doi.org/10.3390/agronomy11122409>
- Ali, M., Ahmed, O. H., Jalloh, M. B., Primus, W. C., Musah, A. A., & Ng, J. F. (2023). Co-Composted Chicken Litter Biochar Increases Soil Nutrient Availability and Yield of *Oryza sativa* L. *Land*, 12(1), 233. <https://doi.org/10.3390/land12010233>
- Arangote, V. R., De, R. B., Saura, L., James, R., & Rollon, C. (2019). Growth and yield response of peanut, (*Arachis hypogaea* L.) and soil characteristics with application of inorganic and organic fertilizer and dolomite addition International Journal of Biosciences | IJB |. *Int. J. Biosci*, 15(6), 164–173. <https://doi.org/10.12692/ijb/15.6.164-173>
- Ashworth, A. J. J., Chastain, J. P. P., & Moore, P. A. A. (2020). Nutrient Characteristics of Poultry Manure and Litter. *Animal Manure: Production, Characteristics,*

- Environmental Concerns, and Management*, April, 63–87. <https://doi.org/10.2134/asaspecpub67.c5>
- Bolan, N. S., Szogi, A. A., Chuasavathi, T., Seshadri, B., Rothrock, M. J., & Panneerselvam, P. (2010). Uses and management of poultry litter. *World's Poultry Science Journal*, 66(4), 673–698. <https://doi.org/10.1017/S0043933910000656>
- Department of Agriculture and Agri-food. (2022). *Agriculture & Agrifood Statistics in Brief 2021*. <http://www.agriculture.gov.bn/SiteCollectionDocuments/Statistik/Brunei Darussalam Agriculture Statistics in Brief 2021.pdf>
- Department of Agriculture and Agri-food. (2023). *Agriculture & Agrifood Statistics in Brief 2023*.
- Department of Environment Parks and Recreation. (n.d.). *Status Of Hazardous Waste Management In Brunei Darussalam*. <http://www.env.gov.bn/SitePages/Status Of Hazardous Waste Management In Brunei Darussalam.aspx>
- Drózdź, D., Malińska, K., Wystalska, K., Meers, E., & Robles-Aguilar, A. (2023). The Influence of Poultry Manure-Derived Biochar and Compost on Soil Properties and Plant Biomass Growth. *Materials*, 16(18), 6314. <https://doi.org/10.3390/ma16186314>
- Drózdź, D., Wystalska, K., Malińska, K., Grosser, A., Grobelak, A., & Kacprzak, M. (2020). Management of poultry manure in Poland – Current state and future perspectives. *Journal of Environmental Management*, 264. <https://doi.org/10.1016/j.jenvman.2020.110327>
- Grealish, G. J., & Fitzpatrick, R. W. (2013). Acid sulphate soil characterization in Negara Brunei Darussalam: a case study to inform management decisions. *Soil Use and Management*, 29(3), 432–444. <https://doi.org/10.1111/sum.12051>
- Gržinić, G., Piotrowicz-Cieślak, A., Klimkowicz-Pawlas, A., Górny, R. L., Ławniczek-Wałczyk, A., Piechowicz, L., Olkowska, E., Potrykus, M., Tankiewicz, M., Krupka, M., Siebielec, G., & Wolska, L. (2023). Intensive poultry farming: A review of the impact on the environment and human health. *Science of The Total Environment*, 858, 160014. <https://doi.org/10.1016/j.scitotenv.2022.160014>
- Maikol, N., Haruna, A. O., Maru, A., Asap, A., & Medin, S. (2021). Utilization of urea and chicken litter biochar to improve rice production. *Scientific Reports*, 11(1), 9955. <https://doi.org/10.1038/s41598-021-89332-y>
- Mironiuk, M., Samoraj, M., Witek-Krowiak, A., Górecki, H., Moustakas, K., & Chojnacka, K. (2023). Processing of nuisance animal waste into agricultural products. *Environmental Pollution*, 319(July 2022). <https://doi.org/10.1016/j.envpol.2022.120924>
- Muduli, S., Champati, A., Popalghat, H. K., Patel, P., & Sneha, K. (2019). Poultry waste management: An approach for sustainable development. *International Journal of Advanced Scientific Research*, 4(January), 8–14. www.allscientificjournal.com
- No Time to Waste. (2021, February 8). *Borneo Bulletin*. <https://borneobulletin.com.bn/no-time-to-waste/>

- Osman, K. T. (2018). Acid Soils and Acid Sulfate Soils. In *Management of Soil Problems* (pp. 299–332). Springer, Cham. <https://doi.org/10.1007/978-3-319-75527-4>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Pandey, D. S., Katsaros, G., Lindfors, C., Leahy, J. J., & Tassou, S. A. (2019). Fast Pyrolysis of Poultry Litter in a Bubbling Fluidised Bed Reactor: Energy and Nutrient Recovery. *Sustainability*, 11(9), 2533. <https://doi.org/10.3390/su11092533>
- Ringrose-Voasde, A., Wong, M., Winston, E., Fitzpatrick, R., Grealish, G., & Hicks, W. (2008). *Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Volume 2 – Soil Management in the Agricultural Development Areas*.
- Rogeri, D. A., Ernani, P. R., Mantovani, A., & Lourenço, K. S. (2016). Composition of Poultry Litter in Southern Brazil. *Revista Brasileira de Ciência Do Solo*, 40, 1–7. <https://doi.org/10.1590/18069657rbcs20140697>
- Sade, H., Meriga, B., Surapu, V., Gadi, J., Sunita, M. S. L., Suravajhala, P., & Kavi Kishor, P. B. (2016). Toxicity and tolerance of aluminum in plants: Tailoring plants to suit to acid soils. *BioMetals*, 29(2), 187–210. <https://doi.org/10.1007/s10534-016-9910-z>
- Simbolon, L. M., Pandey, D. S., Horvat, A., Leahy, J. J., Tassou, S. A., & Kwapinska, M. (2024). Influence of the pyrolysis temperature on fresh and pelletised chicken litter with focus on sustainable production and utilisation of biochar. *Biomass Conversion and Biorefinery*, 14(20), 26443–26457. <https://doi.org/10.1007/s13399-023-04787-5>
- Singh, P., Mondal, T., Sharma, R., Mahalakshmi, N., & Gupta, M. (2018). Poultry Waste Management. *International Journal of Current Microbiology and Applied Sciences*, 7(08), 701–712. <https://doi.org/10.20546/ijcmas.2018.708.077>
- von Uexküll, H. R., & Mutert, E. (1995). Global extent, development and economic impact of acid soils. *Plant and Soil*, 171(1), 1–15. <https://doi.org/10.1007/BF00009558>
- Wong, A. (2020, December 29). *Increased production costs raise price of poultry in Brunei*. BizBrunei. <https://www.bizbrunei.com/2020/12/increased-production-costs-raise-price-of-poultry-chicken-brunei/>
- Yıldız, Z., Kaya, N., Topcu, Y., & Uzun, H. (2019). Pyrolysis and optimization of chicken manure wastes in fluidized bed reactor: CO₂ capture in activated bio-chars. *Process Safety and Environmental Protection*, 130, 297–305. <https://doi.org/10.1016/j.psep.2019.08.011>
- Yusof, M. R. M., Ahmed, O. H., King, W. S., & Zakry, F. A. A. (2015). Effects of biochar and chicken litter ash on selected soil chemical properties and nutrients uptake by *Oryza sativa* L. var. MR 219. *International Journal of Biosciences (IJB)*, February 2015, 360–369. <https://doi.org/10.12692/ijb/6.3.360-369>

Zisis, F., Giamouri, E., Mitsiopoulou, C., Christodoulou, C., Kamilaris, C., Mavrommatis, A., Pappas, A. C., & Tsiplakou, E. (2023). An Overview of Poultry Greenhouse Gas Emissions in the Mediterranean Area. *Sustainability*, 15(3), 1941. <https://doi.org/10.3390/su15031941>

Women Entrepreneurs and the Sustainability of the “Kopi Hitam” Agroindustry: Optimizing Social Capital and Entrepreneurship Orientation

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Abstract

Women entrepreneurs have an important role as a driving force for economic development and social progress in rural areas. Agroindustry at the MSMEs scale is the most sub-sector of women entrepreneurs. Kopi hitam agroindustry of women entrepreneurs has existed since 1958 in the center of coffee villages in West Sumatra Province, Indonesia and has survived to this day. The objectives of this study are: 1) Analyzing the influence of social capital on the sustainability of agroindustry through entrepreneurship orientation 2) Analyzing the influence of social capital on the sustainability of agroindustry directly. This research was conducted in a coffee village, West Sumatra using a census method using a questionnaire. Data were analyzed by qualitative and quantitative descriptive methods using SmartPLS-4 software. Results The social capital research significantly increased entrepreneurial orientation which was reflected through the level of trust built in women entrepreneurs with their agro-industry partners, but entrepreneurial orientation significantly reduced the sustainability of agroindustry through competitive aggressiveness in maintaining the quality of authentic kopi hitam flavor hereditary and directly Social capital does not significantly increase the sustainability of agro-industry if there are no entrepreneurial actions. The negative influence of entrepreneurial orientation is due to the unconfirmed level of innovation supporting the sustainability of agroindustry. Therefore, innovation an important role in supporting the sustainability of the agroindustry in the face of increasingly competitive business competition. The managerial recommendation for the sustainability of the kopi hitam agroindustry for women entrepreneurs is to improve the quality of social capital and business scale.

Keywords: agroindustry, social capital, sustainability

JEL code: L26, Q12, Q13, O13, Z13

SDG classification: SDG 5, SDG 8, SDG 9, SDG 12

Introduction

Entrepreneurship has an important role in encouraging economic growth and sustainable development of a nation. In Indonesia, the entrepreneurship ratio is currently at 3.47 percent, still below the ideal standard of 4 percent (Masduki, 2023). However, dominated by Micro, Small, and Medium Enterprises (MSMEs) in the agro-industrial sector which absorb 97 percent of the workforce and contribute 60.5 percent to the national GDP, there is great potential to increase entrepreneurship in this country. Women are playing an increasingly important role in the agro-industrial sector, with a significant increase in agroindustry ownership. Data shows that women make up a large percentage of micro and small businesses, making their empowerment a focus in the Sustainable Development Goals (SDGs), which target gender equality. Therefore, improving policies that support women entrepreneurs is urgently needed to maximize their contribution to the economy (Spence et al. 2011).

The matrilineal culture in Minangkabau gives women a strong position in the management of the family economy, with *bundo kanduang* as the leader who manages assets and property in the customs. The kopi hitam business in West Sumatra, which has successfully adapted to the "*coffeeshop*" business model, is a real example of how women's entrepreneurship can innovate to remain competitive. Overall, women's empowerment in entrepreneurship is very important to improve welfare and support Indonesia's economic growth towards a more inclusive and sustainable direction (Anggadwita and Dhewanto 2015).

Agroindustry in West Sumatra, which are the backbone of the regional economy, are mostly (63%) managed by women (Wahyudi I, 2022). This research focuses on female agroindustry in kopi hitam processing that are able to survive in a competitive market despite having limited resources and technology. The sustainability of kopi hitam agroindustry refutes Schumpeter and Marshall's theory of market competition. The coffee agroindustry center in West Sumatra, which is managed by women, has existed since 1958 in Tanah Datar Regency. This study discusses the sustainability of kopi hitam agroindustry run by women, focusing on the influence of social capital and entrepreneurial orientation. Since 2014, women-managed kopi hitam agroindustry have grown and survived, although some have stagnated. The sustainability of this business is influenced by an "entrepreneurial orientation," which includes innovative, proactive abilities, courage to take risks, autonomy, and aggressiveness in competing. This research also highlights the role of social capital in shaping self-values and habits, which has an impact on entrepreneurial orientation (Layoo and Rahman 2019).

This study aims to find out how the social capital dimension and entrepreneurial orientation affect the sustainability of female kopi hitam agroindustry, which are in a dynamic business environment. This study will test whether all dimensions of social capital have a positive effect on the sustainability of agroindustry, in contrast to previous research that did not find a significant positive impact. There are two objectives of this research including: 1) The influence of social capital on the sustainability of female kopi hitam agroindustry through entrepreneurship orientation. 2) The influence of social capital on the sustainability of women's kopi hitam agroindustry directly.

Methodology

Research location and time

The selection of this location was carried out by a deliberate method (*stratified purposive sampling*) starting from the selection of West Sumatra Province, Tanah Datar Regency and Nagari Koto Tuo. This research was conducted in Nagari Koto Tuo with the highest number of women kopi hitam entrepreneurs in West Sumatra, so it is dubbed as the center of coffee villages. The activities of this research consist of field activities as a form of research observation and data collection activities to be used in processing data. Research activities start from writing proposals until they are completed in November 2024.

Data types and sources

The type of data used in this study consists of primary and secondary data. Primary data was obtained by conducting observations and interviews with respondents through questionnaire instruments. Secondary data is obtained from literature studies through books, government institutions, and other literature that can be used as a reference in supporting primary data. The primary data are presented in Table 1 below.

Table 1. Data types and sources

Data Types	Data components	Sources
Primer	Respondent biodata Overview of the business Characteristics of social capital Characteristics of entrepreneurial orientation Business Sustainability	Kopi hitam agroindustry Entrepreneur
Sekunder	Contribution of agroindustry in Indonesia Number of Kopi hitam agroindustry Nagari Koto Tuo	BPS, Ministry of Cooperatives Nagari Koto Tuo Office Previous research

Materials, tools and observations

The method used for primary data collection with a systematic procedure through a structured interview technique guided through a physical *questionnaire (offline)*. Primary data consisted of respondent biodata, characteristics of kopi hitam agroindustry, dimensions of social capital, and dimensions of entrepreneurial orientation in women entrepreneurs. The data obtained from the questionnaire are also research variables. The average time for each respondent's interview was 25-40 minutes. This research was assisted by 7 enumerators spread across each jorong nagari. Questionnaire with closed-ended questions using Likert scale measurements. For this study, a 7-point likert scale will be used because it can minimize measurement errors and make the data more precise (Munshi 2014).

The sample was determined using a census method used to obtain primary data with a complete enumeration process of everyone from the population as a respondent. The population used in this study is female entrepreneurs in Kopi hitam agroindustry engaged in kopi hitam processing in the coffee village center of Tanah Datar Regency. Based on data from the village office in West Sumatra, which is commonly called Wali Nagari Koto Tuo, it was found that the number of women kopi hitam entrepreneurs is 172 that carry out processing processes ranging from *roasting – grinding – packing – marketing*, but after going down to the agroindustry field that are still operating is 160 agroindustry. This number is in one village, so it is called a coffee village center. Therefore, Nagari Koto Tuo was chosen *purposively* because this region has the largest population of entrepreneurial women in Tanah Datar Regency and can represent West Sumatra.

Method of analysis

The PLS analysis was carried out with the help of the SmartPLS program. With the method of collecting data through a census carried out on all kopi hitam business actors in Nagari Koto Tuo totaling 160 Agroindustry. It can be said that it meets the sample measurement criteria in PLS-SEM.

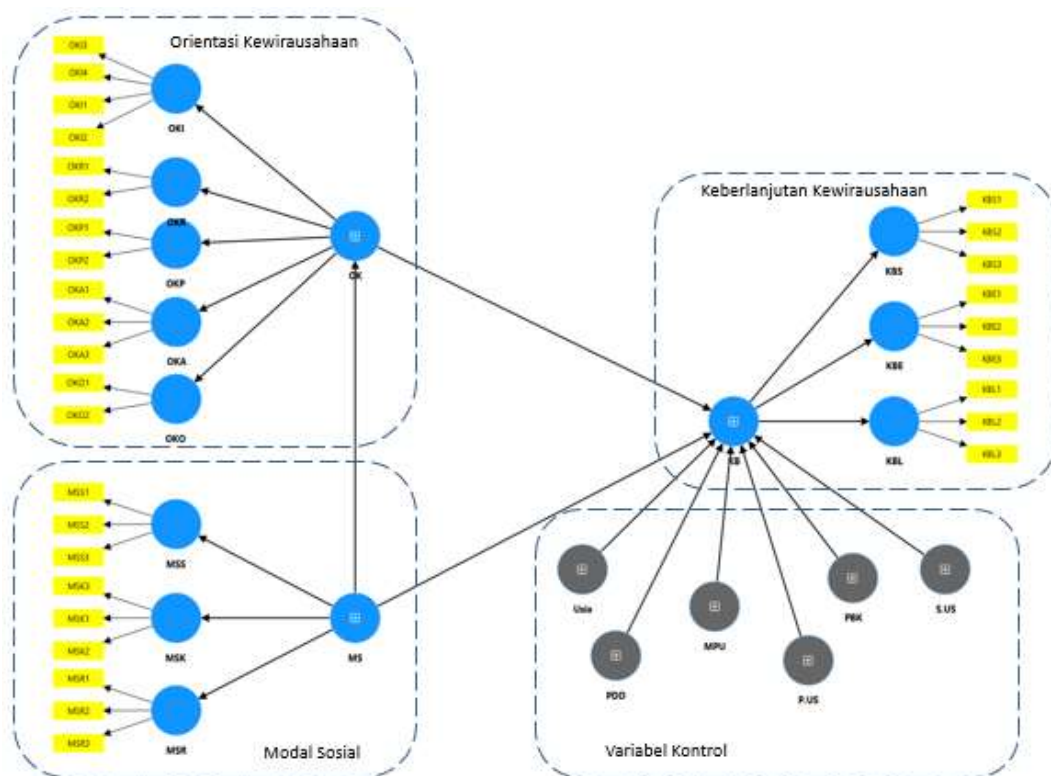


Figure 1. Initial model before estimation

In Figure 1, the initial model before the above estimate is explained by the yellow smart-PLS instrument with a total of 31 indicators, the *first-order latent variables* are explained by the light blue Smart-PLS instrument with a total of 11 latent, and the *second-order latent variables* are explained by 3 dark blue Smart-PLS instruments, namely social

capital, entrepreneurial orientation, and sustainable entrepreneurship. For reflective models, two measurements were made of the outer model and inner model as follows:

1. Measurement model (*outer model*)

The model is considered valid if the loading factor (LF) value is ≥ 0.7 . Meanwhile, the Average Variance Extracted (AVE) should be greater than 0.5, as recommended by Hair et al. (2022). The discriminant validity assessment based on the Fornell-Larcker criterion requires that the correlation between each indicator and its latent construct be higher than its correlation with other latent constructs. In other words, the square root of the AVE value should exceed the correlation values among the latent variables (Hendra, 2020). Reliability testing is conducted by examining the value of composite reliability (CR), where a construct is deemed reliable if $CR > 0.7$. A higher CR value indicates greater reliability (Hair et al., 2022).

2. Structural model (*inner model*)

The first step in this fit test process aims to evaluate the overall degree of goodness of fit (GOF) between the data and the model. To know the model, one of them can be seen through the *Predictive relevance* (Q-Square) value, which is a test conducted to show how well the observation value is produced using the blindfolding procedure in the structural model. The Q-Square value has a range of $0 < Q^2 < 1$, the closer to 1 the better the better.

Empirical model

With limited coffee bean resources in the central area of coffee villages, according to Spence *et al.* (2011), is one of the factors that drives sustainable entrepreneurial transformation. Through the social capital dimension and the entrepreneurial orientation dimension, women entrepreneurs find information disclosure and opportunities to be able to have sustainable agroindustry to face competitive business competition (Figure 2) below.

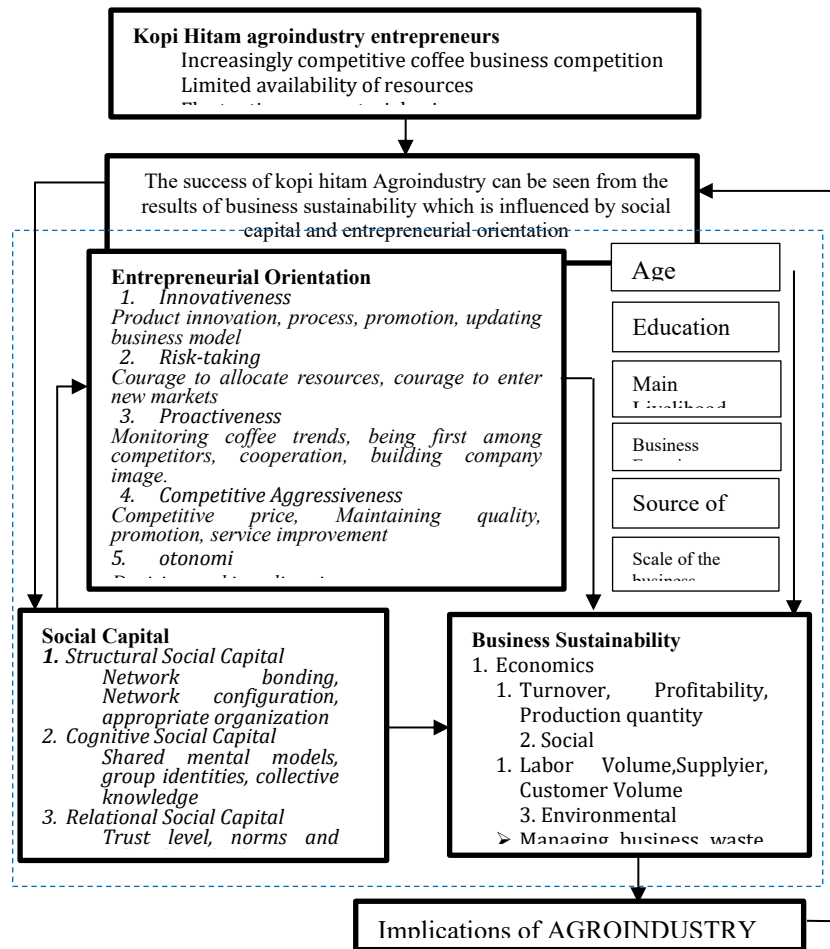


Figure 2. Empirical model

Hipotesis penelitian

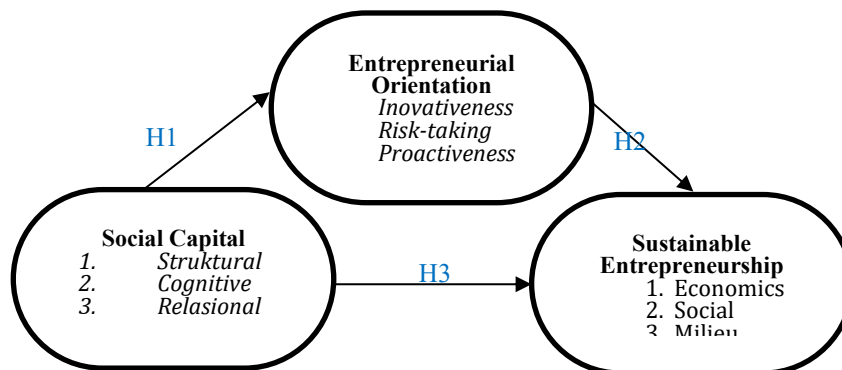


Figure 3. Research hypothesis

H1: Social capital increases entrepreneurial orientation

H2: Entrepreneurship orientation promotes sustainable entrepreneurship

H3: Social capital boosts sustainable entrepreneurship

Results and Discussion

Respondent characteristics

Distribution by age

The results of the study describe the largest percentage of productive age at 91 percent with a total of 145 people with an age range of 25-64 years and the rest of 9 percent or 15 people of non-productive age. This can be illustrated by the young generations, many who continue the business management relay and one of the businesses that has been found to be sustainable is the kopi hitam brand "ASMA" which was first started in 1958 by Asma's mother until now continued by her descendants who are still productive and several other agroindustry.

Table 2. Distribution by age

Age	Sum	Percentage
Productive life	145	91%
Non-productive	15	9%

Distribution based on education level

The characteristics of women entrepreneurs who manage kopi hitam agroindustry have the highest percentage at the high school/vocational/MAN education level, which is 57 percent or as many as 92 people. Entrepreneurial women who study at university from diploma to bachelor level only have a percentage of 5 percent or as many as 8 people. This means that the perception of the coffee village center community towards education is quite important in supporting business continuity, because the higher education will affect decision-making patterns, openness of access to information and relationships that support business sustainability

Table 3. Distribution based on education level

Education level	Sum	Percentage
No school	1	1%
Elementary School	14	9%
Junior High School	45	28%
High School/Vocational School	92	57%
Bachelor Degree	8	5%

Distribution by main livelihood

Businesses that are used as the main source of income will produce maximum performance. The majority of the data on the distribution of the main livelihood has the highest percentage, namely 84 percent with a total of 135 women entrepreneurs choosing kopi hitam agroindustry as the main source of income for generations. The remaining 16 percent or as many as 25 entrepreneurial women have other jobs besides managing the kopi hitam business.

Table 4. Distribution by main livelihood

Main Livelihoods	Sum	Percentage
Main	135	84%
Non-Primary	25	16%

Business experience

The business experience that has the highest percentage is in the < 10-year span, which is 27 percent or as many as 44 people. This is because, first, there has been a hereditary regeneration of kopi hitam business management in the last 10 years. Second, there is a new kopi hitam business that began to be established in the last 10 years. Based on the results of the analysis, business experience has a significant effect on business sustainability. The results of this study are not in line with Rumangkit et al. (2024) that the length of business experience is not directly proportional to sustainability. The smallest percentage is in entrepreneurial women who are no longer productive with a range of 61-70 years of entrepreneurial experience.

Table 5. Distribution of business experience

Business experience	Sum	Percentage
<10 years	44	27%
11-20 years	29	18%
21-30 years	35	22%
31-40 years	27	17%
41-50 years	16	10%
51-60 years	6	4%
61-70 years	3	2%

Scale of business

The scale of kopi hitam agroindustry businesses managed by women entrepreneurs based on primary data has the highest percentage on a small scale, namely 56 percent or as many as 90 agroindustry, and on a micro scale with a percentage of 44 percent or as many as 70 agroindustry. This means that as many as 90 agroindustry have annual sales above 300 million to 2.5 billion with a workforce of 5-19 people. Continued in the SEM-PLS analysis, the small business scale has a higher (stronger) influence on

entrepreneurship sustainability than the micro scale. A total of 70 agroindustry have annual sales below 300 million with a workforce of 1-4 people. The following is an overview of the percentage of the scale of kopi hitam agroindustry for women entrepreneurs in the kopi hitam village center.

Table 6. Business-scale distribution

Scale of Efforts	Sum	Percentage
Micro	70	44%
Small	90	56%

Initial model fit test (goodness of fit)

The first step in this fit test process aims to evaluate the overall degree of *goodness of fit* (GOF) between the data and the model. To know the model as a whole, one of them can be seen through *the predictive relevance* (Q-square) value, which is a test conducted to show how well the observation value is produced using *the blindfolding procedure* in the structural model. The Q-square value has a range of $0 < Q^2 < 1$, the closer to 1 value the better. The following is the calculation of GOF on the model.

$$\begin{aligned}
 Q^2 &= 1 - (1-R^2_{OK})(1-R^2_{KB})(1-R^2_{KBE})(1-R^2_{KBL}) \\
 &= 1 - (1-0,210)(1-0,725)(1-0,919)(1-0,403) \\
 &= 1 - (0,79)(0,813)(0,275)(0,081)(0,597) \\
 &= 1 - 0,009 \\
 &= 0,99
 \end{aligned}$$

The results of *the Q-square* calculation show that the estimated value of the research model is 0.99 or 99 percent, thus it can be concluded that the model in this study has a relevant predictive value, where the model used can explain the information in the research data by 99 percent. Then the *path coefficient* is obtained through *the bootstrapping procedure*. *The path coefficient* provides the test results of the hypothesis that has been formulated. In *the path coefficient* consists of:

Table 7. Hypothesis testing

	Original sample	T-Count	P values	f-square	R-square	Hipotesis	Decision
MS -> OK	0,458	5,617	0,000**	0,264	0,210	Subtract Ho	Improve, significantly
MS -> KB	0,131	1,537	0,124	0,120		Accept Ho	Enhance, insignificant
OK -> KB	-0,075	1,652	0,099*	0,010		Accept Ho	Decrease, significant
Age -> KB	-0,049	1,097	0,273	0,007		Accept Ho	Degrading, insignificant

Food Systems, Consumption, and Nutrition

PDD -> KB	0,043	0,941	0,347	0,007	Accept Ho	Degrading, insignificant
P,US -> KB	0,092	1,888	0,059*	0,021	Subtract Ho	Improve, significantly
S,US -> KB	0,825	31,003	0,000*	2,163	0,725	Subtract Ho Improve, significantly

Remarks: **significant at p-value 1%, * significant at p-value 10%

The influence of social capital on entrepreneurial orientation

This study found that social capital has a significant effect on the entrepreneurial orientation of women kopi hitam entrepreneurs, with an increase in social capital of 1% increasing entrepreneurial orientation by 45.8%. The dimension of relational social capital, such as trust, cooperation with business partners, and compliance with common rules, strongly supports business sustainability. In addition, the relationship between women business actors also creates a supportive environment, where criticism and input are given for the improvement of the kopi hitam business.

H1: Social capital significantly increases entrepreneurial orientation

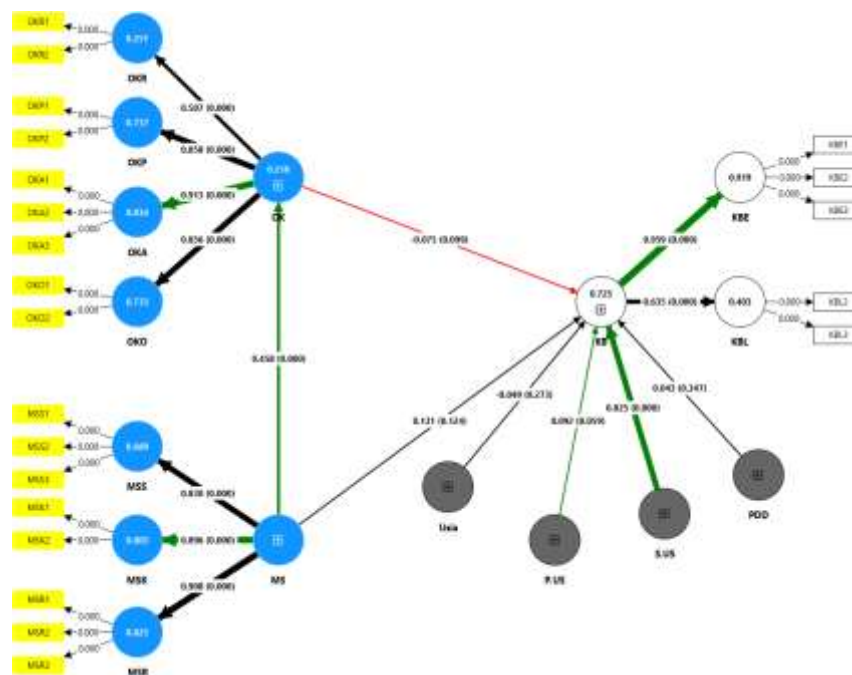


Figure 4. The model of the relationship between social capital and entrepreneurial orientation

Cognitive social capital, which includes mutual understanding and common views, plays a big role in increasing competitive aggressiveness and maintaining the quality of kopi hitam products that are already known to customers. A well-built social network helps strengthen motivation to develop a business and maintain consumer loyalty. Nonetheless,

the innovation and risk-taking dimensions remain low, with only a few female entrepreneurs daring to take big risks in the venture.

The structural social capital dimension also has an effect, where strong network ties and configurations of social networks help to expand access to capital and increase interaction between business actors, governments, and consumers. Nonetheless, the study also notes that information overload can negatively impact innovation. Overall, social capital improves women's entrepreneurial orientation, especially in terms of competitive and proactive aggressiveness, but its impact on innovation and risk-taking is still limited.

The influence of entrepreneurial orientation on entrepreneurial sustainability

This study shows that entrepreneurial orientation has a significant effect on business sustainability, with dimensions such as competitive aggressiveness, proactiveness, autonomy, and risk taking having a positive impact on entrepreneurial sustainability. Competitive aggressiveness has the highest influence, related to the economic performance of the business through competitive prices, maintaining quality, and improving coffee product services. Meanwhile, the proactive dimension shows that monitoring market trends and managing raw material stocks is key to business sustainability.

The innovation dimension in entrepreneurship orientation shows a very low and insignificant influence on business sustainability. This is due to women entrepreneurs preferring to focus on the quality of traditional kopi hitam products and maintaining the authentic taste that loyal customers have become known for. The brewing process using firewood from cinnamon is a factor that distinguishes traditional kopi hitam, which makes consumers loyal to the product. This indicates that innovations related to changes in raw materials or production methods are not prioritized.

Overall, while dimensions such as risk-taking, proactiveness, and competitive aggressiveness have a positive impact on business sustainability, low innovation is a holding factor. This causes the overall entrepreneurial orientation to have a negative influence on business sustainability, due to the lack of innovation needed to face increasingly competitive market competition. Therefore, despite a strong entrepreneurial orientation, the low level of innovation limits the long-term sustainability potential of the business.

H2: Entrepreneurship orientation significantly reduces the sustainability of entrepreneurship

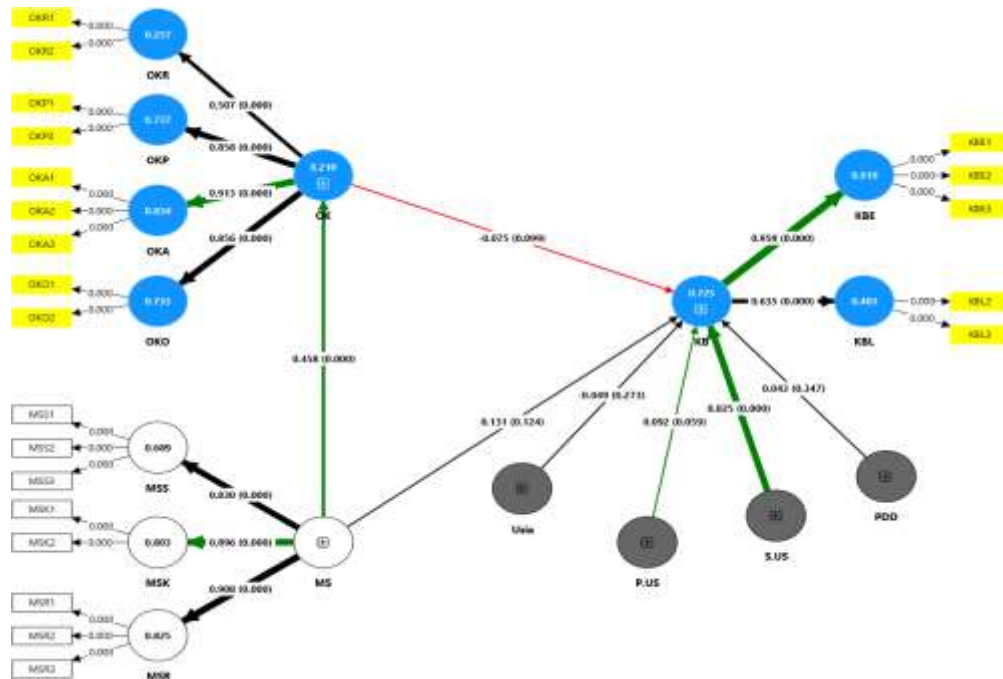


Figure 5. A model of the relationship between entrepreneurial orientation and entrepreneurial sustainability

The influence of social capital on entrepreneurial sustainability

Social capital consists of structural, cognitive, and relational dimensions that play a role in supporting entrepreneurial sustainability, but in this study, it is not confirmed to have a direct effect on entrepreneurial sustainability. Although social capital has a positive effect on entrepreneurial sustainability, the results of the hypothesis test show that the effect is not significant ($\beta = 0.131$, $p\text{-value} = 0.124$). This shows that although social capital can build strong relationships between business actors, families, partners, and customers, its influence on economic performance and business production is not large enough without involving entrepreneurial orientation.

Structural social capital, such as network ties in the family and business partnerships, open access to information and capital that supports business operations. Long-standing agreements and cooperation between business actors and raw material middlemen play an important role in maintaining smooth coffee production. In addition, the configuration of an intensive network between women entrepreneurs can encourage the evaluation of business problems and build a sales increase strategy. Relational social capital, with a high level of trust between partners and families, creates a sense of togetherness and security that supports the achievement of economic goals.

Although social capital has an important role in supporting entrepreneurial sustainability, its influence on overall business sustainability is insignificant. Increasing social capital needs to be supported by the dimensions of entrepreneurial orientation, such as innovation, risk-taking, proactiveness, competitive aggressiveness, and autonomy.

Without these elements, the social capital formed among entrepreneurial women is not enough to significantly increase business sustainability.

H3: social capital does not significantly increase entrepreneurial sustainability

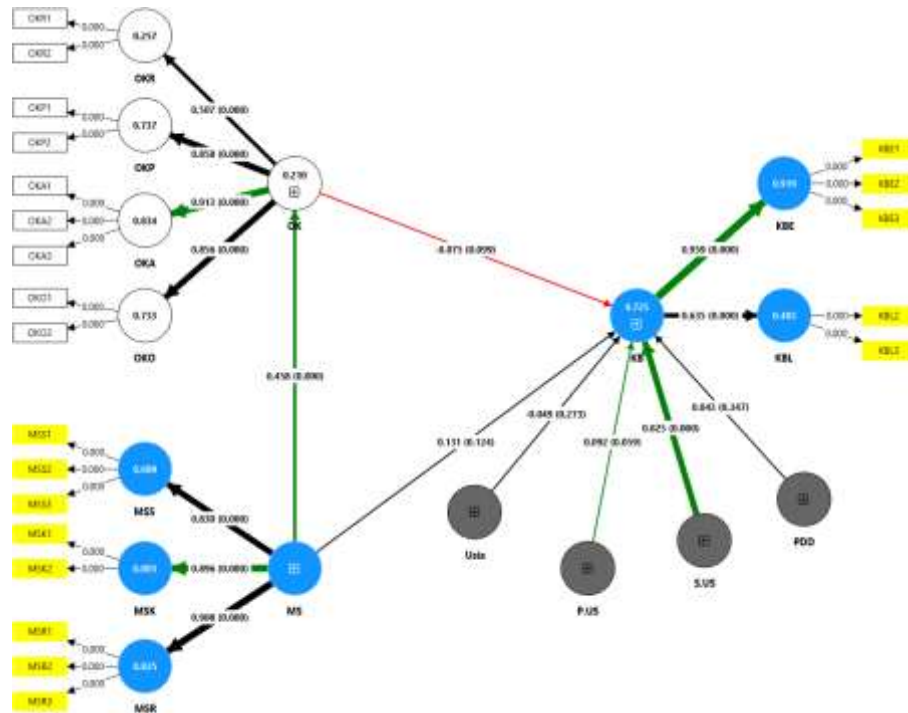


Figure 6. A model of the relationship between social capital and sustainability

The implications for the sustainability of women's entrepreneurship can be explained in two main points. First, social capital plays a significant role in the sustainability of women's businesses, because it builds strong relationships and mutual trust between business actors. This social capital opens access to capital, market opportunities, and increased business capacity. The quality of relationships in social networks is more important than quantity, as extensive relationships can provide new knowledge that supports women's entrepreneurial abilities. Cooperation between business partners, raw material suppliers, and customers can increase production, sales, and profitability of the business, ultimately supporting entrepreneurial sustainability. Policies that support women's business communities can strengthen these networks, facilitating meetings between entrepreneurs, mentors, and investors.

Second, increasing the scale of business has a significant effect on entrepreneurial sustainability. Larger business scale drives increased sales, which has an impact on the additional needs of labor, customers, and business legality. It contributes to economic, social, and environmental sustainability, and supports economic development and social progress in rural areas. Increasing the scale of businesses in women-dominated agroindustry can accelerate the achievement of the national entrepreneurship target, which is 4%, which indicates the status of a developed country. Therefore, the

development of the scale of entrepreneurial women businesses is very important in achieving long-term development goals.

Conclusion

Social capital significantly increases entrepreneurial orientation which is reflected most highly through the relational dimension to the competitive aggressiveness dimension of kopi hitam. Entrepreneurial orientation has a significant effect on reducing entrepreneurial sustainability. This means that the dimensions of competitive aggressiveness, proactiveness, and autonomy that represent the highest entrepreneurial orientation have no effect on increasing entrepreneurial sustainability. This is closely related to innovations that have low value in women entrepreneurs in running businesses, so that the weak ability to innovate has an impact on the vulnerability of businesses to face competitive competition to be sustainable. Social capital does not have a significant effect on increasing entrepreneurial sustainability. This means that increasing social capital does not have a real effect on entrepreneurship sustainability directly, there needs to be a mediation variable to see the influence of social capital on entrepreneurship sustainability.

Advice for women entrepreneurs to expand social networks by actively participating in entrepreneurship training, exhibitions and bazaars from the Dispora and Discoperindag for agroindustry in West Sumatra, then participating in business matching to expand market opportunities and cooperation. This network expansion can open wider information that supports the creation of innovations in the kopi hitam agroindustry business model in the future and can face increasingly competitive coffee business competition. In addition, broader information can be used as data to act proactively and risk-taking to support entrepreneurial sustainability. For further research development, it can be expanded by directly looking at the influence between the dimensions of latent variables on entrepreneurship sustainability. So that the discussion will be more complex and can provide other strategies for the implications of women's entrepreneurship sustainability.

References

- Aljarodi A, Thatchenkery T, Urbano D. 2022. Female Entrepreneurial Activity and Institutions: Empirical Evidence from Saudi Arabia. *Research in Globalization*. 5(October):100102.doi:10.1016/j.resglo.2022.100102.
- Anggadwita G, Dhewanto W. 2015. Women's Entrepreneurial intentions in micro and small enterprises (MSEs) in Indonesia: The influence of environmental factors on perceived behavioral control. *Journal of Administrative and Business Studies*. 1(1):1–7.doi:10.20474/jabs-1.1.1.
- Babajide AA, Obembe D, Solomon H, Woldesenbet K. 2022. Microfinance and Entrepreneurship: The Enabling Role of Social Capital Among Female Entrepreneurs. *Int J Soc Econ*.doi:10.1108/IJSE-11-2020-074.

- Bardasi, E., S. Sabarwal, and K. Terrell. 2011. "How do Female Entrepreneurs Perform? Evidence from Three Developing Regions." *Small Business Economics* 37(4): 417-441
- Bastaman A, Juffiasari R. 2015. Faktor-Faktor Yang Mempengaruhi Pengambilan. *Prosiding Seminar Nasional*. 9(2013):265–277.
- Berii D. 2019. THE FACTORS AFFECTING WOMEN'S ECONOMIC EMPOWERMENT IN MICRO AND SMALL SCALE ENTERPRISE IN THE CASE OF YEKA SUB CITY CENTER FOR REGIONAL AND LOCAL DEVELOPMENT ADDIS ABABA, ETHIOPIA.
- Botha M. 2020. Prior Entrepreneurial Exposure and Action of Women Entrepreneurs: Exploring the Moderation Effects of Entrepreneurial Competencies in a Developing Country Context. *Front Psychol*. 11(May).doi:10.3389/fpsyg.2020.00922.
- [BPS] Badan Pusat Statistik Kabupaten Tanah Datar. 2022. Jumlah Penduduk Kecamatan Sungai Tarab Menurut Nagari dan Jenis Kelamin 2022. BPS Kabupaten Tanah Datar
- Cao Q, Simsek Z, Jansen JJP. 2015. CEO Social Capital and Entrepreneurial Orientation of the Firm: Bonding and Bridging Effects. *J Manage*. 41(7):1957–1981.doi:10.1177/0149206312469666.
- Cardella G.M., Hernández-Sánchez BR, Sánchez-García JC. 2020. Women Entrepreneurship: A Systematic Review to Outline the Boundaries of Scientific Literature. *Front Psychol*. 11.doi:10.3389/fpsyg.2020.01557.
- Carland, J.W. & Hoy, F. & Boulton, W.R. & Carland, J.A., 1984, Differentiating Entrepreneurs from Small Business Owners: A Conceptualization, *Academy of Management Review*, 2, 79-93.
- Daradkeh M, Mansoor W. 2023. The impact of network orientation and entrepreneurial orientation on startup innovation and performance in emerging economies: The moderating role of strategic flexibility. *Journal of Open Innovation: Technology, Market, and Complexity*. 9(1):100004.doi:10.1016/j.joitmc.2023.02.001.
- DiVito L, Bohnsack R. 2017. Entrepreneurial orientation and its effect on sustainability decision tradeoffs: The case of sustainable fashion firms. *J Bus Ventur*. 32(5):569–587.doi:10.1016/j.jbusvent.2017.05.002.
- Etriya E, Scholten VE, Wubben EFM, Kemp RGM, (Onno)Omta SWF. 2018. The importance of innovation adoption and generation in linking entrepreneurial orientation with product innovation and farm revenues: The case of vegetable farmers in West Java, Indonesia. *International Food and Agribusiness Management Review*. 21(7):969–988.doi:10.22434/IFAMR2017.0038.
- Fuentes-Fuentes M del M, Bojica AM, Ruiz-Arroyo M. 2015. Entrepreneurial orientation and knowledge acquisition: effects on performance in the specific context of women-owned firms. *International Entrepreneurship and Management Journal*. 11(3):695–717.doi:10.1007/s11365-014-0336-1.
- Grande J, Madsen EL, Borch OJ. 2011. The relationship between resources, entrepreneurial orientation and performance in farm-based ventures. *Entrepreneurship and Regional Development*. 23(3–4):89–111.doi:10.1080/08985620903183710.

- Hair J, Hult T, Ringle C, Sarstedt M. 2022. *A PRIMER ON PARTIAL LEAST SQUARES STRUCTURAL EQUATION MODELING (PLS-SEM) Third Edition*.
- Hammad R, El Naggar R. 2023. The Role of Digital Platforms in Women's Entrepreneurial Opportunity Process: Does Online Social Capital Matter? *Hum Behav Emerg Technol*. 2023.doi:10.1155/2023/5357335.
- Hmedan AE. 2023. The Impact of Cognitive Social Capital on Entrepreneurial Orientation. *International Journal of Engineering, Business and Management*.(2).doi:10.22161/ijebm.7.2.
- Hogg, M., Abrams, D., Otten, S., & Hinkle, S., 2004. The Social Identity Perspective. *Small Group Research*, 35, pp. 246 - 276. <https://doi.org/10.1177/1046496404263424>.
- Iglesias-Sánchez PP, Fayolle A, Jambrino-Maldonado C, de las Heras-Pedrosa C. 2022b. Open innovation for entrepreneurial opportunities: how can stakeholder involvement foster new products in science and technology-based start-ups? *Heliyon*. 8(12).doi:10.1016/j.heliyon.2022.e11897.
- Jiménez-Zarco AI, Clemente-Almendros JA, González-González I, Aracil-Jordà J. 2021. Female Micro-Entrepreneurs and Social Networks: Diagnostic Analysis of the Influence of Social-Media Marketing Strategies on Brand Financial Performance. *Front Psychol*. 12(April).doi:10.3389/fpsyg.2021.630058.
- Kariv D. 2008. The Relationship between Stress and Business Performance among Men and Women Entrepreneurs. *Journal of Small Business and Entrepreneurship*. 21(4):449–476.doi:10.1080/08276331.2008.10593435.
- Kollmann T, Stöckmann C, Niemand T, Hensellek S, de Cruppe K. 2021a. A configurational approach to entrepreneurial orientation and cooperation explaining product/service innovation in digital vs. non-digital startups. *J Bus Res*. 125(November 2018):508–519.doi:10.1016/j.jbusres.2019.09.041.
- Kollmann T, Stöckmann C, Niemand T, Hensellek S, de Cruppe K. 2021b. A configurational approach to entrepreneurial orientation and cooperation explaining product/service innovation in digital vs. non-digital startups. *J Bus Res*. 125:508–519.doi:10.1016/j.jbusres.2019.09.041.
- Liñán F, Jaén I, Martín D. 2022. Does entrepreneurship fit her? Women entrepreneurs, gender-role orientation, and entrepreneurial culture. *Small Business Economics*. 58(2):1051–1071.doi:10.1007/s11187-020-00433-w.
- Masduki, T. 2023 Mar 10. Indonesia Mau Jadi Negara Maju, Kejar Dulu Jumlah Pengusaha 4 Persen Total Penduduk. *Liputan 6*. Diunduh 2024 Jun 3. <https://www.liputan6.com/bisnis/read/5229915/indonesia-maju>
- Miftakhuljanah O, Priatna WB, Suharno S. 2016. Karakter Wanita Wirausaha Pada Industri Kecil Kerupuk Kemplang Di Kabupaten Ogan Ilir. *Jurnal Agribisnis Indonesia*. 4(2):123.doi:10.29244/jai.2016.4.2.123-136.
- MIWE. 2022. The Mastercard Index of Women Entrepreneurs Contents 2022 Report. Mastercard Index of Women Entrepreneurs

- Mozumdar L, Materia VC, Hagelaar G, Islam MA, Velde G van der, Omta SWF. 2022a. Contextuality of Entrepreneurial Orientation and Business Performance: The Case of Women Entrepreneurs in Bangladesh. *Journal of Entrepreneurship and Innovation in Emerging Economies*. 8(1):94–120.doi:10.1177/23939575211062433.
- Mozumdar L, Materia VC, Hagelaar G, Islam MA, Velde G van der, Omta SWF. 2022b. Contextuality of Entrepreneurial Orientation and Business Performance: The Case of Women Entrepreneurs in Bangladesh. *Journal of Entrepreneurship and Innovation in Emerging Economies*. 8(1):94–120.doi:10.1177/23939575211062433.
- Muskibah M, Hidayah LN. 2020. Penerapan Prinsip Kebebasan Berkontrak dalam Kontrak Standar Pengadaan Barang dan Jasa Pemerintah di Indonesia. *Refleksi Hukum: Jurnal Ilmu Hukum*. 4(2):175–194.doi:10.24246/jrh.2020.v4.i2.p175-194.
- Nakku VB, Agbola FW, Miles MP, Mahmood A. 2020. The interrelationship between SME government support programs, entrepreneurial orientation, and performance: A developing economy perspective. *Journal of Small Business Management*. 58(1):2–31.doi:10.1080/00472778.2019.1659671.
- Pambudy R. 2022 Jul 14. Kewirausahaan Menjadi Kunci Indonesia Keluar dari Middle Income Trap. Orasi Ilmiah. PPID. Diunduh 2024 Agu 1. <https://ppid.ipb.ac.id/prof-rachmat-pambudy-tegaskan-kewirausahaan-menjadi-kunci-indonesia-keluar-dari-middle-income-trap/>
- Prakasa Y. 2018. EXPLORING THE IMPACT OF SOCIAL CAPITAL ON ENTREPRENEURIAL ORIENTATION AND BUSINESS PERFORMANCE (Study on Members of Agroindustry Communities in Malang). *Profit*. 12(1):20–31.doi:10.21776/ub.profit.2018.012.01.3.
- Rezaee, Z, Brigitte W., Lambert, K, Ramamoorti S. 2024. The Sustainable Business Blueprint: Planning, Performance, Risk, Reporting, and Assurance. London. Routledge
- Ringle, C. M., Wende, S., and Becker, J.-M. 2015. "SmartPLS 3." Boenningstedt: SmartPLS GmbH, <http://www.smartpls.com>.
- Rodrigo-Alarcón J, García-Villaverde PM, Ruiz-Ortega MJ, Parra-Requena G. 2018c. From social capital to entrepreneurial orientation: The mediating role of dynamic capabilities. *European Management Journal*. 36(2):195–209.doi:10.1016/j.emj.2017.02.006.
- Rosário AT, Raimundo RJ, Cruz SP. 2022. Sustainable Entrepreneurship: A Literature Review. *Sustainability (Switzerland)*. 14(9).doi:10.3390/su14095556.
- Rumangkit S, Arief M, Alamsjah F, Elidjen. 2024 Jun 19. Profiling dan pemetaan riset innovation ambidexterity melalui pendekatan bibliometrik. *Entrepreneurship Bisnis Manajemen Akuntansi (E-BISMA)*.:145–160.doi:10.37631/ebisma.v5i1.1415.
- Saadi H, Yaghoubi-Farani A, Jalilian S, Movahedi R. 2016. The effect of social capital on rural women's entrepreneurial orientation. *International Journal of Entrepreneurship and Small Business*. 27(2–3):289–307.doi:10.1504/IJESB.2016.073989.

- Salassa DI, Mohammad Baga L, Etriya E. 2023. Hubungan Budaya Bugis Terhadap Akses Finansial dan Pelatihan Pada Perempuan Wirausaha di Sulawesi Selatan. *Jurnal Agribisnis Indonesia*. 11(1):48–63.doi:10.29244/jai.2023.11.1.48-63.
- Schaltegger S, Wagner M. 2011. Sustainable entrepreneurship and sustainability innovation: Categories and interactions. *Bus Strategy Environ*. 20(4):222–237.doi:10.1002/bse.682.
- Schumpeter, JA, 1934, Teori Pembangunan Ekonomi, Cambridge, MA: Harvard University Press.
- Setini M, Yasa NNK, Supartha IWG, Giantari IGAK, Rajiani I. 2020. The passway of women entrepreneurship: Starting from social capital with open innovation, through to knowledge sharing and innovative performance. *Journal of Open Innovation: Technology, Market, and Complexity*. 6(2).doi:10.3390/joitmc6020025.
- Spence M, Ben Boubaker Gherib J, Biwolé VO. 2011. Sustainable Entrepreneurship: Is Entrepreneurial will Enough? A North-South Comparison. *Journal of Business Ethics*. 99(3):335–367.doi:10.1007/s10551-010-0656-1.
- Storey, D., and F. Greene. 2010. *Small Business and Entrepreneurship*. London, U.K.: Pearson. The Sustainable Business Blueprint.
- Vadnjal M, Vadnjal J, Vadnjal B. 2023. Social capital and woman entrepreneurs: the characteristics of social capital among woman entrepreneurs across different life stages. *Zbornik radova Ekonomskog fakulteta u Rijeci / Proceedings of Rijeka Faculty of Economics*. 41(2):477–498.doi:10.18045/zbefri.2023.2.477.

Digital Readiness of Vegetable Farmers and Community Development in Selected Areas in The City of Calamba, Laguna, Philippines: Exploring the Nexus

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Abstract

Digital readiness plays a crucial role in enhancing the productivity and competitiveness of farmers, which on a wider scale can propel community development (CD). The study determined the relationship between digital readiness and the economic, social, and cultural dimensions of CD through an interview of 102 farmers in the vegetable farming communities in selected barangays in Calamba City, Laguna, Philippines. The methodologies used by Horrigan (2016) and Roberts and Hernandez (2019) were adapted to determine the level of digital readiness of the farmer-respondents, and classified them to: Unprepared, Traditional, Reluctant, Cautious Clicker, and Digitally Ready. Descriptive analysis was performed along with Pearson's product moment correlation analysis to evaluate the existence of relationship between digital readiness and the dimensions of CD. Fisher's Exact Probability test was done to determine the relationship between digital readiness and CD. Results revealed that the farmer-respondents are on the average 58 years old, dominated by women (58%), had average household size of 5, and average area cultivated of less than a hectare. Cautious Clickers are 73.53% while those Digitally Ready account for 10.78%, and none of them are Unprepared. Among the six elements of digital readiness, own ability was rated the lowest by the farmer-respondents. The self-rating on CD revealed an average of 3.77 (out of 5.0) with "crisis response" (3.94) as highest and "voicing own opinion" as lowest. Low correlation was noted between digital readiness and the dimensions of CD but Fisher's Exact probability proved the highly significant relationship between digital readiness and community development.

Keywords: digital readiness, community development, nudging

JEL code: O33

SDG classification: SDG 9

Introduction

Community development is both a process and an outcome for a society composed of people who are able to work together for their common good that radiates into a progressive environment of camaraderie and collectiveness, safety and forward looking. Disaggregating the two terms, community is referred to as people who live in the same location, share common interests and culture and usually common characteristics as well, and have mutual relations. Development on the other hand, is being able to realize the potential for growth that improves the effectivity of group effort to achieve the common goal of the community (Louisiana Community Network, n.d.). In order for individuals to transcend to the pursuit of common goals for the community, they must first be able to attend to the basic needs and amenities of their families. However, without enough resources such requisites might not be achievable at all. This might be true among the communities of vegetable growers in selected areas in the City of Calamba, Laguna.

Although the City of Calamba, Laguna is considered as having a highly developed mixed economy owing to it being the house of many industrial parks and hubs, the area is still a food hub that supplies vegetables and other agricultural crops to its neighboring towns and to some extent to the National Capital Region as well. Within the city, several barangays continue to grow vegetables and other crops. Exploratory studies revealed that vegetable farmers continue to be challenged by the problem of marketing their produce due mainly to lack of access to market information and lack of ready markets (Hassan et al., 2021).

Marketing systems must be competitive, dynamic, and include ongoing change and advancement. Digital strategy is becoming increasingly crucial. Marketing arrangements can be strengthened by digital marketing in an effort to address travel/face-to-face limits, low consumption, post-harvest losses, and information asymmetry. In order to create, communicate, and provide value to consumers and other stakeholders, digital marketing can be encouraged by actions, institutions, and processes that are made possible by digital technology (Kannan and Li, 2017). Products may be promoted through one or more electronic media channels with the proper use of information and communication technology (ICT), and the open interchange of information through data analytics and management can reduce information asymmetry.

The traditional system of marketing, particularly for agricultural goods, raises the risk of information asymmetry, in which one side of the transaction knows more about the market than the other party. The one with the information advantage usually has the upper hand when it comes to negotiations about prices and buying and selling terms. Unfortunately, farmers are the ones who usually lack access to market data, and as a result, transactions are biased in favor of those with whom they are connected. Due to the asymmetries in pertinent market information, such as product specifications, costs, and quality, upstream players have a difficult time negotiating favorable terms and face significant transaction costs (Aquino et al., 2015).

Digital readiness is seen a crucial factor in enhancing the productivity and competitiveness of farmers, especially in the age of digital transformation. Recognizing the digital divide as a critical issue in the agricultural sector in the Philippines, ascertaining the level of digital readiness of vegetable farmers is seen as crucial especially since they can also be a vehicle for enhanced community development.

The general objective of the study was to assess how digital readiness among vegetable farmers contributes to community development in selected areas in the City of Calamba, Laguna, Philippines. Specifically, it characterized the vegetable farmers in the selected areas; determined the vegetable farmers' level of digital readiness; assessed the level of community development in the study areas in terms of social, economic, and cultural dimensions; and determined the relationship between digital readiness and these dimensions in the vegetable farming communities; and proposed courses of actions for enhancing community development in the selected areas.

The significance of the study lies in the following areas: a) addressing the growing importance of digital technology in the agricultural sector in a developing country like the Philippines, and how it can help enhance market information and marketing practices; 2) contributing to the ongoing discourse on community development and the role of technology in promoting sustainable and inclusive development; and 3) identifying how digital readiness can help farmers increase their income and improve their overall living conditions. The study can also serve as a basis for policymakers and development practitioners in designing programs and policies that can support the digital transformation of agriculture in the Philippines for enhanced community development.

Methodology

The explanatory design of research was utilized in this study. Primary data were collected through personal interviews of randomly selected 102 vegetable farmers in the major vegetable growing areas in the city, namely: Bunggo, Hornalan, Kay-Anlog, and Looc. The first three are upland communities while Looc is an urban area situated alongside the Laguna Lake. Prior to administering the questionnaire, the researcher obtained permission from the City Agriculture officers of Calamba City and the chairs of the respective barangays. During the actual individual survey using a structured questionnaire, the research objectives were thoroughly discussed with the respondents using the Informed Consent Form (ICF), stressing that the proceedings and results of the study will be used for research purposes only and that whatever data collected from them will be treated with utmost confidentiality and kept for a maximum of two years after the approval of the manuscript, after which filled-up questionnaires will be shredded. The ICF was signed by the respondents before the data collection itself. Since the instrument used in the interviews included scaled measurements, Cronbach's alpha was computed to examine the reliability and internal consistency of multi-item scales (DeVellis, 2005). This was applied to the indicator statements used per sub-element in community development dimensions.

Descriptive analysis was used in the characterization of the farmer-respondents and their economic, social and cultural activities. Frequencies, percentages, means, and modes were utilized. Tables and charts were used whenever appropriate to facilitate better understanding. Level of digital readiness was determined by adapting the methodology of Horrigan (2016) and Roberts and Hernandez (2019) enabling the classification of the farmer-respondents into: unprepared, traditional, reluctant, cautious clicker, and digitally ready. Community development scoring was performed by computing the corresponding points to the indicator statements for the social and cultural dimensions and taking the mean ratings. Also, correlation analysis between level of digital readiness and the

indicators of community development was performed. In addition, Fisher's Exact Probability test was conducted to determine the relationship between the farmer-respondents' digital readiness and community development.

Results and Discussion

Socio-economic and farm profile of the farmer-respondents

The average age of the farmer-respondents was 58 years, well within the average of Filipino farmers reported at the 19th Congress of the Senate of the Philippines (2024). The youngest was 32 years old while the oldest was 82 years but most of them (31% were found in the age bracket 53-62 years. By barangay, the oldest was 62 years on the average, in Hornalan while the youngest was in Looc at 52 years. Aside from being quite old, in general, the farmer-respondents were dominated by females who were found to be 58 percent on the average. They were found to be highest in Hornalan at 78 percent. However, in Kay-Anlog, the males were the dominant, accounting for 58 percent. In vegetable farming, women are often engaged in planting, weeding, harvesting, post-harvest tasks such as threshing, processing and marketing. Men are engaged more in land preparation and other tasks that require more muscle work (FAO, n.d.). In terms of civil status, 95 percent of the farmer-respondents were married while the remaining 5 percent were single or became single again either by being widowed or separated. This implies that frequently, vegetable farming is a shared activity between husband and wife in the family.

Household income was PhP20,800 per month on the average, with the highest at PhP25,952 in Bunggo and the lowest in Looc at PhP16,222 per month. The lowest income range was at PhP2,000 – 14,250 as reported by 41 percent of all the respondents. Overall, there were two respondents who had a monthly income of higher than PhP61,250 (Table 1).

Table 1. Socio-economic profile, 102 vegetable and fruit growers in selected barangays in Calamba City, Laguna, 2025

Profile	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=120)	
	No	%	No	%	No	%	No	%	No.	%
Age										
32-42	3	14	1	4	3	8	3	17	10	10
43-52	6	29	5	22	3	8	6	33	20	20
53-62	5	24	9	39	13	32	5	28	32	31
63-72	5	24	6	26	17	42	2	11	30	29
73-82	2	10	2	9	4	10	2	11	10	10
Average (Years)	55		58		62		52		58	
Sex										
Male	7	33	5	22	23	58	8	44	43	42

Food Systems, Consumption, and Nutrition

Female	14	67	18	78	17	42	10	56	59	58
Civil Status										
Single ^a	0	0	0	0	2	5	3	17	5	5
Married	21	100	23	100	38	95	15	83	97	95
Income (PhP/Month)										
2,000-14,250	7	33	15	65	11	28	9	50	42	41
14,251-24,500	8	38	2	9	12	30	6	33	28	27
24,501-36,750	1	5	4	17	12	30	3	107	20	20
36,751-49,000	1	5	0	0	3	8	0	0	4	4
49,001-61,250	3	14	1	4	2	5	0	0	6	6
≥ 61,251	1	5	1	4	0	0	0	0	2	2
Average (PhP)	25,952	17,426		22,095		16,222		20,800		

^aIncludes those who were separated/widowed

The farm profile of the respondents is shown in Table 2. They are composed of pure vegetable growers (85%) and those who plant both fruits and vegetables (15%). They cultivate an average of 9,524 square meters (sqm) for vegetables but the highest proportion of them had 1,000-5,000 sqm. Bunggo had the largest area planted to vegetables while Kay-Anlog had the smallest at an average of 8,085 sqm. For fruits, the average area planted was 4,687 and the largest was for Kay-Anlog at 4,893 and smallest was in Bunggo at 2,000 sqm. Looc had no reported area for fruits.

Among the vegetable farmer-respondents, 48 percent were landowners, but 35 percent were tenants and the rest (17%) are renters only. Similarly, for fruits, the landowners dominated (60%) while tenants accounted for 27 percent and the renters 13 percent (Table 2).

Table 2. Farm profile, 102 vegetable and fruit growers in selected barangays in Calamba City, Laguna, 2025

FARM CHARACTERISTICS	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=102)	
	No.	%	No.	%	No.	%	No.	%	No.	%
<i>Type of Grower</i>										
Vegetable	20	95	22	96	27	68	18	100	87	85
Fruit & Vegetables	1	5	1	4	13	32	0	0	15	15

Food Systems, Consumption, and Nutrition

FARM CHARACTERISTICS	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=102)	
	No.	%	No.	%	No.	%	No.	%	No.	%
<i>Farm Size (sqm)</i>										
Vegetables										
>1,000	0	0	0	0	2	5	1	6	3	3
1,000 - 5,000	2	10	14	61	22	55	4	22	42	41
5,001 - 10,000	15	71	5	22	6	15	7	39	33	32
10,001 - 15,000	2	10	2	9	5	12.5	2	11	11	11
<15,000	2	10	2	9	5	12.5	4	22	13	13
Total	21	100	23	100	40	100	18	100	102	100
Average	11,300		9,438		8,085		10,757		9,524	
Fruits										
>1,000	-	-	-	-	1	8	0	0	1	1
1,000 - 5,000	1	20	1	25	8	62	0	0	10	10
5,001 - 10,000	-	-	-	-	3	23	0	0	3	3
10,001 - 15,000	-	-	-	-	1	8	0	0	1	
Total	1	20	1	25	13	100	0	0	15	15
Average	2,000		4,692		4,893		0		4,687	
<i>Land Ownership</i>										
Vegetables										
Owner	13	62	13	57	19	48	4	22	49	48
Tenant	5	24	8	35	17	43	6	33	36	35
Renter	3	14	2	9	4	10	8	44	17	17
Fruits										
Owner	1	5	1	4	7	54	0	0	9	60
Tenant	0	0	0	0	4	31	0	0	4	27
Renter	0	0	0	0	2	15	0	0	2	13

Media practice and internet connectivity

All the farmer-respondents used only cellphones when it comes to transacting with their input suppliers, buyers, and logistic providers (Table 3). These devices are the most accessible and affordable to them and easiest to use. According to them, if they have a buyer and they are unable to provide such requirement, they can easily text or call their co-farmers for additional supplies. This promotes camaraderie and cohesiveness and increases their income earning capacity and also of their fellow farmer. They said that

their marketing network is getting bigger. These in a way further enhances community development through the social and economic components. This is in line with the findings of Xie et al. (2021) in China that smallholder farmers are increasingly embracing digital agricultural technology, and the government is mostly responsible for encouraging this trend. Numerous farmers use smartphone applications to receive data on crop pricing, weather forecasts, and pest management, among other things.

Table 3. Distribution of gadget used by 102 vegetable and fruit growers for communication in selected barangays in Calamba City, Laguna, 2025

Gadget Use	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=102)	
	No.	%	No.	%	No.	%	No.	%	No.	%
Type of Gadgets Used										
<i>Supplier</i>										
Cellphone	21	100	23	100	39	97.5	18	100	101	99
<i>Buyer</i>										
Cellphone	19	90	23	100	37	93	18	100	97	95
<i>Logistics Provider</i>										
Cellphone	14	67	22	96	27	68	18	100	85	83

In terms of internet connectivity and usage, 91 percent of the farmer-respondents claimed to have internet access at home although there were those who still have none (9%). They are others who have more than two internet service providers in their area (97%) although the status of their internet access varied per barangay. While 50 percent of them reported that their internet connection is stable, only 30 percent of those in Hornalan and 78 percent of those in Looc claimed the same level of stability. About 23 and 21 percent stated that they had fair and unstable internet connectivity, respectively (Table 4).

Table 4. Internet provision for 102 vegetable and fruit growers in selected barangays in Calamba City, Laguna, 2025

Internet Provision/Status	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=102)	
	No.	%	No.	%	No.	%	No.	%	No.	%
Internet access at home										
Yes	19	90	19	83	37	93	18	100	93	91
No	2	10	4	17	3	8	0	0	9	9
Internet service providers in the area										
One	1	5	0	0	1	3	0	0	2	2
Two	0	0	0	0	1	3	0	0	1	1

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More than two	20	95	23	100	38	95	18	100	99	97
Status of internet access										
Very stable	0	0	0	0	0	0	0	0	0	0
Stable	11	52	14	61	12	30	14	78	51	50
Fair	5	24	5	22	9	23	4	22	23	23
Unstable	4	19	1	4	16	40	0	0	21	21
Very unstable	0	0	0	0	0	0	0	0	0	0
No internet	1	5	3	13	3	8	0	0	7	7

Three internet sources were noted in the barangays covered by the study: home wifi, broadband/pocket wifi, and cellular data. Of these three, cellular data is being used by majority (56%) while the least was broadband (6%) which actually is only one in Bunggo. Home wifi usage was at 36%. Only Facebook as a social media platform is being used although they are transacting in three online selling platforms including Shopee (64%), Lazada (63%), and Tiktok (1%) (Table 5).

Table 5. Media used by 102 vegetable and fruit growers in selected barangays in Calamba City, Laguna, 2025

Media Use	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=102)	
	No.	%	No.	%	No.	%	No.	%	No.	%
Internet Sources/Connections										
Home Wi-fi	18	86	17	74	32	80	7	39	74	73
Broadband/Pocket Wi-fi	1	5	0	0	0	0	1	6	2	2
Cellular Data	2	10	5	22	6	15	10	56	23	23
Social media platforms used										
Facebook	21	100	22	96	38	95	17	94	99	97
Online selling platforms accessed										
Shopee	9	43	16	70	26	65	14	78	65	64
Lazada	12	57	16	70	22	55	14	78	64	63
Tiktok	1	5	0	0	0	0	0	0	1	1

Digital readiness

Figure 1 showcases the distribution of the farmer-respondents to different levels of digital readiness per barangay. It is obvious that in all the barangays, cautious clickers dominated with shares ranging from a low of 56.52 percent for those in Bunggo to as high as 88.89 percent in Looc. Barangay Kay-Anlog had the second highest percentage of cautious clickers at 82.50 percent. Similarly, Hornalan was also dominated by cautious

clickers with 61.9 percent share. Cautious clickers are characterized by being mindful of potential risks such as online scams, phishing attempts, or malware and takes steps to ensure their digital security. This could involve being careful about the links they click, verifying the authenticity of websites, and being generally cautious about online interactions. This corresponds to a computed score of 91 to 120 points.

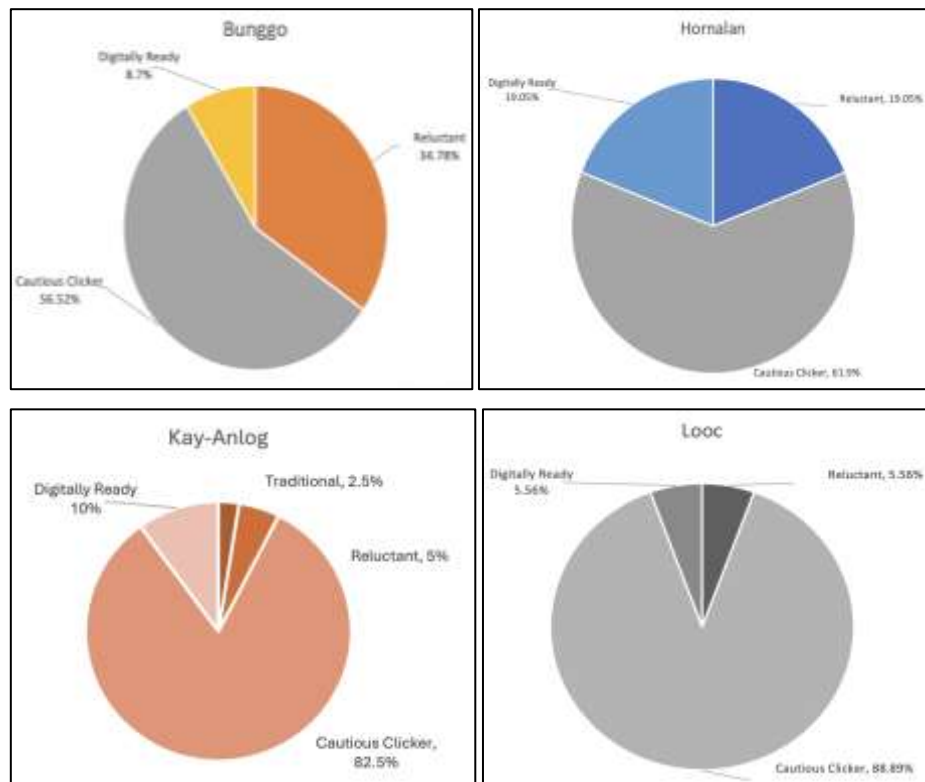


Figure 1. Distribution by level of digital readiness, selected barangays, Calamba City, Laguna

Those digitally ready had shares of 5.56 (Looc) to 19.05 percent (Hornalan). Having a higher percentage share of digitally ready farmer-respondents is the reason why it had the lowest share of cautious clickers. The respondents were classified as digitally ready if they are prepared and equipped to leverage digital technologies for various aspects of farming operations. Digital readiness in agriculture involves the adoption and effective use of digital tools, technologies, and data-driven approaches to enhance productivity, efficiency, and overall farm management. They have a computed score of 121 to 150 points.

The reluctant ones are those who exhibit hesitation, resistance, or unwillingness to embrace or engage with digital technologies. Digital readiness encompasses the ability and willingness to effectively use and adapt to digital tools, platforms, and processes. When someone is described as "reluctant" in this context, it implies a certain degree of apprehension or aversion towards incorporating digital elements into vegetable farming and marketing of produce. The computed score for reluctant is 61 to 90 points. The reluctant ones are highest in Bunggo at 34.78 percent but lowest in Kay-Anlog (5%). In

Hornalan and Looc, the Reluctants were 19.05 and 5.56 percent, respectively. There were noted to be traditional farmers accounting for 2.5 percent in Kay-Anlog. The traditional prefers in-person instruction and face-to-face interactions with people or peers and may be less accustomed to or comfortable with using digital tools, online platforms, and electronic resources for their learning needs.

It can be seen in Figure 2 that the barrier to digital readiness among the farmer-respondents in all the selected barangays was ability. As operationally defined, ability refers to the skills and competencies of the vegetable farmer to effectively use and leverage digital technologies. In the context of digital readiness, farmers need to have the appropriate abilities and proficiency to navigate, adapt to, and utilize digital tools and platforms for acquiring the necessary inputs and support for production and also for marketing their produce. In addition, while the farmers are moving towards greater efficiency, being members of a community, they also facilitate its development as the whole is as good as its part. In the end, digital readiness and community development are mutually reinforcing.

Among the barangays, the lowest rating for ability was at 2.4 in Hornalan while the highest was in Looc (3.2). Looc could have enjoyed the advantage of being an urban area in the heart of the city where facilities and opportunities to get information from are more plentiful. Overall, ability had a mean rating of only 2.8.

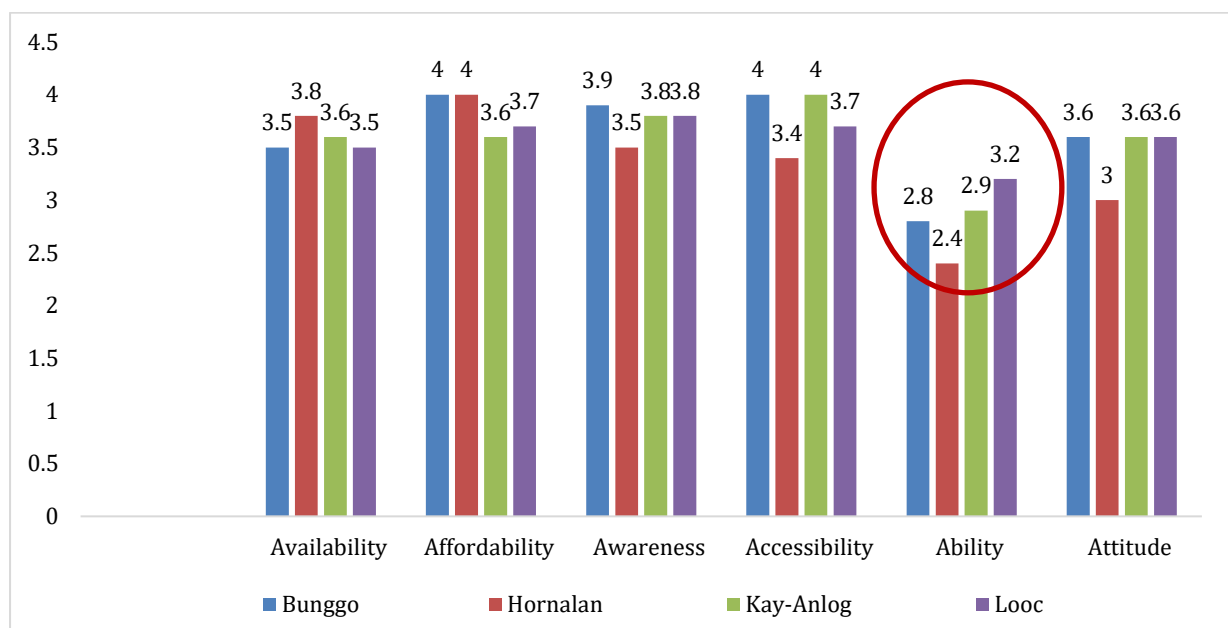


Figure 2. Elements of digital readiness, selected barangays, Calamba City, Laguna, 2025

Affordability was rated the same (4.0) in Bunggo and Hornalan. Also, a 4.0 rating was given to accessibility in Bunggo and Kay-Anlog. Along with awareness, these were the highest rated digital readiness elements with overall rating 3.8 each. Meanwhile, the second lowest was attitude with an average rating of 3.4 - ranging from 3.0 in Hornalan to 3.6 in the rest of the barangays. By definition, affordability refers to the extent to which the vegetable farmer can reasonably bear the costs associated with acquiring and

utilizing digital technologies. It is a crucial element because it directly influences the accessibility and adoption of digital tools and services. Accessibility refers to the extent to which digital technologies are designed and implemented in a way that makes them easily accessible and usable by a broad range of users. This element emphasizes the importance of creating digital tools and platforms that are user-friendly, inclusive, and considerate of diverse needs and abilities. Awareness on the other hand, measures the level of understanding and familiarity that the vegetable farmer has regarding digital technologies. It involves having the necessary knowledge and awareness to effectively and confidently engage with digital tools and services. This aspect is crucial because it lays the foundation for individuals to make informed decisions, navigate digital platforms, and leverage technology for various purposes.

Meanwhile, attitude had also been rated lower with 3.4 for all the farmer-respondents but even lower at 3.0 for those in Hornalan. Attitude refers to the psychological and emotional disposition farmers and organizations have toward adopting and utilizing digital technologies. It encompasses the mindset, openness, and emotional readiness to embrace digital tools and navigate the challenges associated with technological advancements. The FGDs revealed the adamance of the participants to adopt digital platforms and other tools for fear of them being unable to cope. They are also wary of the online scams and some false information because they do not know how to distinguish fake news from authentic information. Many of them also claimed that they are too old for new technologies. This is supported by the fact that the average age in the study areas was 58 years.

Benefits of the Community from Using Digital Devices

Social benefits

After computing for Cronbach's Alpha for reliability of scaled indicators, eight indicator statements related to benefits from using digital devices were retained, in which the respondents had to indicate their level of agreement/disagreement (1=strongly disagree to 5=strongly agree). Overall, the farmer-respondents gave these eight statements an average rating of 3.8 but the highest rating was 4.0 for the statements "Digital devices improve the crisis response in our community" and "Digital devices help me decrease feeling of hopelessness when faced with problems" (Table 6).

Per barangay, highest rating of 4.2 was noted in Hornalan for "Digital devices allow our community to set our common goals." In this barangay, the farmer-leader's house, which is strategically located, serves as the meeting place at the same venue for bringing the farmer-members freshly harvested produce for pick-up by the buyers. The second highest rate benefit with average rating of 4.1 was given to the "Digital devices help me decrease feeling of hopelessness when faced with problems." In Looc, the benefit statement "The digital devices improve the crisis response in our community" had the highest mean rating of 4.1 but the lowest was for "The digital devices facilitate the healing of community members who had misunderstanding" at 3.6. In Bunggo and in Kay-Anlog, this indicator statement had also the lowest mean rating of 3.1, and 3.6, respectively, in fact, it was the lowest among all the indicators in all the barangays covered (Table 8). During the FGDs it was specifically discussed that due to the habit of people of posting everything on Facebook, oftentimes, simple misunderstandings are being escalated in

the social media. This according to them is the downside of social media but in terms of crisis response, digital devices particularly the use of cellphones are most helpful especially in the uplands where physical mobility is still a nagging problem particularly among those who do not have their own vehicle. With each barangay having its own ambulance and disaster response team, seeking assistance has become faster among community members.

Among all the benefits rated, it is notable that “Digital devices allow me to voice my own opinion on the concerns of the community” was given the lowest mean rating except in Looc (Table 6). This goes to show that in terms of community development process, these barangays are still lacking of more participative community engagement and democratic process of planning for collective community concerns.

Economic benefits

In terms of economic benefits, it appears that currently, the economic benefits for digital devices are still not substantial as the reported net benefit per farmer-respondent per month was only PHP355.25. This is in the form of savings from transportation cost net of their expenses on internet subscription or data cost for those who do not have post-paid contracts with internet providers. Kay-Anlog had the highest reported savings of PHP686 per month since they are able to sell online using their own Facebook selling site (Table 7). More commonly, the farmers' children are doing this for them.

Table 6. Social benefits from using digital devices, 102 vegetable and fruit growers, selected barangays, Calamba City, Laguna, 2025

Benefits (Digital devices...)	Mean Rating				
	Bunggo (n=21)	Hornalan (n=23)	Kay- Anlog (n=40)	Looc (n=18)	All (n=102)
1. Allow me to participate in community activities	3.8	3.9	3.8	4.0	3.9
2. Allow me to voice my own opinion on the concerns of the community	3.2	3.4	3.6	3.8	3.5
3. Allow our community to set our common goals	3.1	4.2	3.7	3.8	3.7
4. Improve the crisis response in our community	3.9	3.9	3.9	4.1	4.0
5. Enable our community to be successful despite some problems	3.3	4.0	3.8	3.7	3.7
6. Facilitate the healing of community members who had misunderstanding	3.1	3.8	3.6	3.6	3.5
7. Help address critical needs in our community such as safety and order	3.6	4.0	3.9	4.0	3.9
8. Help me decrease feeling of hopelessness when faced with problems	3.9	4.1	3.9	3.9	4.0

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Table 7. Savings generated in using digital device by 102 vegetable and fruit growers, selected barangays, Calamba City, Laguna, 2025

Item	Bunggo (n=21)	Hornalan (n=23)	Kay-Anlog (n=40)	Looc (n=18)	All (n=102)
Costs/Expenses (Daily)					
Internet Subscription/Data Cost	42	47	40	27	40.70
Mobile Depreciation	5	6	7	7	6.36
Sub-total	47	53	47	34	47.06
Savings					
Saved Cost from using digital devices					
Transportation Cost	200	200	733	162	402.31
Sub-total	200	200	733	162	402.31
Net Savings (PhP/month)	153	147	686	128	355.25

Community Development

Social development score

Looking from the lens of the farmer-respondents, it can be seen in Table 10 that the majority (79%) of them regard their barangay as having high level of community development. Additionally, there were 14 percent who rated their community as within very high development level. In Kay-Anlog, 90 percent regarded their community as highly developed while 83 percent of those in Looc held the same opinion. Bunggo had the lowest proportion (62%) who claimed their community as highly developed but 19 percent of them considered their barangay as very highly developed (Table 8).

Table 8. Social development score, 102 vegetable and fruit growers, selected barangays, Calamba City, Laguna, 2025

Level of Social Development	Bunggo (n=21)		Hornalan (n=23)		Kay-Anlog (n=40)		Looc (n=18)		All (n=102)	
	No.	%	No.	%	No.	%	No.	%	No.	%
Very Low	0	0	0	0	0	0	0	0	0	0
Low	3	14	0	0	0	0	0	0	3	3
Moderate	1	5	1	4	2	5	0	0	4	4
High	13	62	17	74	36	90	15	83	81	79
Very High	4	19	5	22	2	5	3	17	14	14
Total	21	100	23	100	40	100	18	100	102	100

Cultural development score

For cultural development, eight indicators were used, all of which are related to how each of the barangays promote people interaction and preserve their traditional celebrations supposed to be for community unity and cohesion. A score of one is assigned if the given cultural development indicator is present in the barangay and the total score corresponds to the total number of indicators practiced/present in the area.

Table 9 shows that all the four barangays had a score of three each, but Looc had a unique way of preserving culture and promoting mutual support. It is implementing community wastes management games and its people are actively participating in the annual "Sayaw, Indak Street Dance Competition in the city. In Bunggo, a unique feature is the holding of annual summer sports league and the presence of private resorts and events venues which can be rented for special occasions and gatherings.

Table 9. Social development score, 102 vegetable and fruit growers, selected barangays, Calamba City, Laguna, 2025

Cultural Development Indicator	Bunggo (n=21)	Hornalan (n=23)	Kay-Anlog (n=23)	Looc (n=18)
1. Fiesta	√	√	√	√
2. Community outreach programs		√	√	
3. Religious gatherings espousing cohesion and social responsibility			√	
4. Cultural celebrations		√		√
5. Annual summer sports league	√			
6. Local resorts/events venues	√			
7. Community wastes management games				√
Score	3	3	3	3

Correlation Between Digital Readiness and Community Development Indicators

Correlation analysis between digital readiness and community development indicators revealed weak relationships as evidenced by low correlation coefficients ranging from 0.07 to 0.29. The lowest was for "Participation in community activities" and "Facilitating settlement of misunderstanding among community members." The highest although still quite low was for "Enabling community to be successful despite some problems" (Table 10). These low coefficients could have been due to relatively small size of 102 and the high concentration of the farmer-respondents to the readiness level cautious clicker.

Table 10. Correlation between digital readiness and community development elements, 102 vegetable and fruit growers, selected barangays, Calamba City, Laguna, 2025

Community Development Elements	Correlation Coefficient
1. Participation in community activities	0.07
2. Voicing my own opinion on the concerns of the community	0.16
3. Setting of common goals	0.15
4. Improving the crisis response in our community	0.20
5. Enabling community to be successful despite some problems	0.29
6. Facilitating settlement of misunderstanding among community members	0.07
7. Addressing critical needs in our community such as safety and order	0.22
8. Decreases feeling of hopelessness when faced with problems	0.14

Table 11. Results of Fisher's exact probability test between digital readiness and community development, 102 vegetable and fruit growers, selected barangays, Calamba City, Laguna, 2025

Digital Readiness	Community Development			
	Very Low	Low	Moderate	High
Traditional	0	0	1	0
Reluctant	1	14	0	0
Cautious Clicker	0	69	4	2
Digitally Ready	2	5	4	0
Total	3	88	9	2
Fisher's Exact	0.000***			

While weak correlation between digital readiness and the elements of community development were found when individual correlation analyses were performed, the results of the Fisher's Exact Probability Test revealed a highly significant relationship between the two as evidenced by the Fisher's Exact value of 0.000 implying significance at one percent level of probability (Table 11). These results proved the positive relationship between digital readiness and community development.

Conclusions and Recommendations

The results of the study point to the following conclusions: the average age of the farmer-respondents was 58 years, they were dominated by females, majority were land-owners with an average area planted of more than 9,000 square meters. Their household income was PhP20,800 per month. Cellphones were the only digital devices that they use but a small proportion of them are able to sell on Facebook and maintain online selling site. It

can also be concluded that ability is the main barrier to digital readiness; the farmer-respondents are cautious clickers; generally the study areas have high level of community development but setting of common goals and voicing own opinions continue to be efforts to be pursued; and that digital readiness and community development are highly related. The

This study recommends the following courses of action that could first and foremost facilitate the digital readiness and hence community development in the study areas:

Implementation of Training Programs appropriate to the varying levels of digital readiness of the farmers and other community members. It was concluded that ability is the main barrier among the farmer-respondents towards getting digitally ready. The study also proved that community development is significantly and highly associated with the digital readiness of the farmer-respondents who themselves are active community stakeholders. It is therefore recommended that training programs be fitted to the existing level of digital readiness of the would-be participants. For operationalization, target participants' existing level of digital readiness should be determined first for appropriate grouping by readiness level.

Integration of values formation and social responsibility in all training modules. Respondents claimed that in terms of healing or resolution of issues within the community, the use of social media has the tendency to be aggravating rather than resolving disputes and amending relationships. On the other hand, in terms of crisis response and safety and order, digital access and use are much appreciated. These two are very important concerns in the pursuit of community development. Prosperous communities are cohesive and collaborative, but these traits are founded on trusts and mutual respects, thus warranting the inclusion of these in the digital readiness training modules. The Data Privacy Law and Cyber Law including their attendant provisions should also be carefully explained to encourage non-breach among community members.

Provision of relevant digital infrastructure to enhance connectivity. To support the use of digital devices and platforms stable internet connectivity is a must. In the study areas, only 50 percent reported having stable internet connectivity and 23 percent had fair. It was also shown that the social component of community development is largely benefitted by the use of digital devices. This implies that more stable internet connectivity can improve digital transaction among the community members and therefore the chance of enhancing community development is higher. The government should therefore prioritize highly productive agricultural areas for the development of information and communication technology infrastructure.

Promote succession farming. The study found that the average of the farmer-respondents is 58 years implying the need for younger members of the community to assume some responsibilities in the farm for eventual succession in the future. The younger generation is more attuned to the use of digital devices and digital platforms. In the long-term, ensuring adequate internet infrastructure can help keep them in farming-related activities.

Establishment of more common areas for more relaxed social interactions. Common areas can have the dual purpose of being meeting or relaxation areas, depending on the amenities present. Then can also function as seasonal holding areas or showrooms for fresh harvests, facilitating marketing.

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References

- Hassan, S. Z., Jajja, M. S. S., Asif, M., & Foster, G. (2021). Bringing more value to small farmers: a study of potato farmers in Pakistan. *Management Decision*, 59(4), 829-857.
- Horrigan, J.B. (2016). Digital Readiness Gaps. Pew Research Center. Available at: <http://www.pewinternet.org/2016/09/20/2016/Digital-Readiness-Gaps. pp. 11-13>
- Horrigan, J. (2016). *Senior Communications Manager* 202. 419, 4372. https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2016/09/PI_2016.09.20_Digital-Readiness-Gaps_FINAL.pdf
- Kannan, P.K. & Li, A. (2017). Digital Marketing: A Framework, Review and Research Agenda. *International Journal of Research in Marketing*, 34(1)22-45; DOI: 10.1016/j.ijresmar.2026.11.006
- Louisiana Community Network (undated). Introduction to Community Development. Retrieved from https://www.opportunitylouisiana.gov/docs/default-source/community-development-toolkit/lcn_module_1_overview.pdf?sfvrsn=d1b4d405_2 on 12 May 2023.
- Roberts, T. & Hernandez, K. (2019). Digital Access is not Binary: The 5A's of Technology Access in the Philippines. *E J InfoSys Dev Countries*, 2019.
- Xie, L., Luo, B. & Zhong, W. (2021). How Are Smallholder Farmers Involved in Digital Agriculture in Developing Countries: A Case Study from China. *Land*, 10(3), 245; <https://doi.org/10.3390/land10030245>

Risks Faced by Coffee Supply Chain Stakeholders Due to Climate Change: A SCOR Framework-Based Literature Review

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Abstract

Coffee is one of the most important agricultural commodities globally, yet it faces significant threats from climate change, impacting productivity, quality, and supply chain stability. This study aims to review existing literature on the risks encountered by stakeholders in the coffee supply chain due to climate change. A systematic literature review (SLR) approach was employed, using the SCOR (Supply Chain Operations Reference) framework to categorize and analyze risks across supply chain processes—Plan, Source, Transform, Fulfill, and Return. The literature was sourced from Semantic Scholar, with 500 relevant papers identified, and 27 studies meeting the inclusion criteria were analyzed to identify recurring risk patterns and mitigation strategies. Results indicate that 85% of the studies focused on production-related risks, highlighting issues like yield reduction and quality degradation, while only 15% addressed risks across the entire supply chain. Geographically, Ethiopia was the most studied region (5 studies), followed by Nicaragua (4 studies) and Indonesia (3 studies), reflecting regional vulnerabilities. Methodologically, 48% of the studies employed quantitative approaches, 26% used mixed methods, and 19% were qualitative. Key risks include unpredictable weather patterns, shifts in cultivation zones, and logistical disruptions, particularly affecting smallholder farmers, processors, and distributors. The study emphasizes the limited application of SCOR-based risk management models and highlights the need for integrated strategies to enhance supply chain resilience. This research offers practical insights for policymakers, industry stakeholders, and farming communities in developing effective climate adaptation strategies.

Keywords: climate change, coffee supply chain, SCOR framework

JEL code: Q13

SDG classification: SDG 12, SDG13

Introduction

Coffee is one of the most important agricultural commodities in the world, providing livelihoods for over 25 million farmers across more than 60 tropical countries (Laderach et al., 2017). This commodity serves as a source of income for smallholder farmers and forms the backbone of national economies in many developing countries. In Latin America, Africa, and Asia, coffee plays a vital role in agricultural exports and local economic stability (Morales et al., 2022). The global coffee industry is now facing significant challenges due to the intensifying effects of climate change. The impacts of climate change not only threaten coffee crop productivity but also affect the quality of coffee beans, the geographical distribution of cultivation areas, and price stability in global markets (Laderach et al., 2011).

Climate change has led to extreme temperature fluctuations, altered rainfall patterns, and increased frequency of extreme weather events such as droughts and floods. These conditions directly impact the growth and yield of coffee crops. For instance, in Nicaragua, Laderach et al. (2017) found that climatic suitability for coffee production had significantly declined, resulting in reduced quality and yield of coffee harvests. In Brazil, rising maximum temperatures and water stress are projected to render Arabica coffee cultivation economically unviable in 35% to 75% of the studied areas throughout the 21st century (Dias et al., 2024). Similarly, in Ethiopia, climate change is projected to reduce land suitability for specialty coffee production by up to 30% (Chemura et al., 2021).

The impact of climate change on the coffee industry is not limited to productivity declines. The climate crisis also exacerbates inequalities in the global coffee supply chain, particularly for smallholder farmers with limited adaptive capacity. Smallholder farmers, who produce more than 60% of the world's coffee, often face barriers in accessing adaptive technologies, financial resources, and information needed to cope with climate challenges (Siles et al., 2022). Morales et al. (2022) emphasized that the adaptive capacity of farmers in Peru is heavily influenced by support from actors within the coffee value chain, including private companies, farmer cooperatives, and local governments.

Climate change also increases risks related to water quality and availability for irrigation. Humphries et al. (2024) demonstrated that in Thailand, changes in rainfall patterns and increased potential evapotranspiration necessitate improved water management strategies to sustain coffee productivity. Additionally, coffee quality is affected by changing environmental factors. Adane & Bewket (2021) found that high-quality coffee production in Yirgacheffe, Ethiopia, positively influences smallholder farmers' ability to adapt to climate change by increasing income and diversifying economic resources.

While many studies have explored the impacts of climate change on coffee production, there remains a knowledge gap in understanding how these risks affect the entire coffee supply chain, from farmers to end consumers. Research by Baihaqi et al. (2022) in Central Aceh, Indonesia, identified price, quality, production, and labor risks as the primary challenges in the Arabica coffee supply chain in the region. Meanwhile, Bunn et al. (n.d.) modeled the impacts of climate change on global coffee production, revealing that yield declines and price increases could reduce the coffee market volume by over 5 million tons per year, with production shifting to higher elevations.

To address these challenges, a systematic approach is needed to analyze the risks emerging at all stages of the coffee supply chain. One of the frameworks that can be utilized is the *Supply Chain Operations Reference* (SCOR) model (The Association for Supply Chain Management (ASCM), 2022). This framework provides a structured methodology for evaluating supply chain performance, identifying critical points vulnerable to climate disruptions, and designing effective mitigation strategies (Zhou, 2020). The application of SCOR in the context of climate change within the coffee supply chain remains very limited. This research aims to fill that gap by offering a more comprehensive understanding of how climate change affects the entire coffee supply chain ecosystem (Ríos et al., 2019).

This study aims to review existing literature on the risks stakeholders face in the coffee supply chain due to climate change. This research focuses on identifying the most vulnerable areas within the coffee supply chain and exploring mitigation strategies that have been implemented in various geographical contexts. The outcomes of this study are expected to contribute significantly to enhancing the resilience of the coffee supply chain against climate change. Additionally, this research seeks to provide practical insights for policymakers, coffee industry players, and farming communities in designing more effective interventions to address future climate change challenges.

Methodology

This study employs a *systematic literature review* (SLR) approach to identify and analyze the risks faced by coffee supply chain actors due to climate change, categorized based on processes within the SCOR framework (*Plan, Order, Source, Transform, Fulfillment, Return*). The SLR approach is chosen because it provides a comprehensive, transparent, and structured review of relevant literature, minimizing bias and ensuring replicable results.

Search

The literature search process is the initial stage in SLR, aiming to identify all studies relevant to the research topic. The search was conducted using the Semantic Scholar corpus, which includes over 126 million academic papers. The research question guiding the search was: "*What are the risks faced by coffee supply chain actors or stakeholders due to climate change if categorized based on the supply chain process within the SCOR framework (Plan, Order, Source, Transform, Fulfillment, Return)?*" Based on this question, 500 of the most relevant papers were retrieved. This stage ensures that all relevant literature, whether supporting or contradicting the research hypothesis, is identified. Without a systematic search, research risks selection bias, where only studies supporting certain views are considered, thereby reducing the validity of the results.

Screening

After collecting the literature, a screening process was conducted to ensure that only studies meeting the inclusion criteria were analyzed further. The screening process was

carried out transparently and in multiple stages to enhance the validity of the results. The screening criteria include:

Table 1. Screening criteria

Screening Criteria	Description	Research Question
Supply Chain Actors	Studies must focus on one or more coffee supply chain actors such as farmers, processors, traders, roasters, or retailers.	<i>Does the study focus on one or more coffee supply chain stakeholders (farmers, processors, traders, roasters, or retailers)?</i>
Climate Change Impact	Research must discuss the impacts of climate change on coffee production and/or supply chain processes.	<i>Does the research examine climate change impacts on coffee production and/or supply chain processes?</i>
Risk Analysis	Studies must include risk analysis, vulnerabilities, or challenges related to climate change.	<i>Does the study analyze risks, vulnerabilities, or challenges related to climate change?</i>
SCOR Framework	Research must be mappable to at least one SCOR process.	<i>Can the research be mapped to at least one SCOR framework process?</i>
Type of Study	Accepted studies include primary research, systematic reviews, or meta-analyses.	<i>Is the study a primary research study, systematic review, or meta-analysis?</i>
Geographic Relevance	Research must be conducted in coffee-producing or trading regions.	<i>Was the research conducted in coffee-producing or coffee-trading regions?</i>
Empirical Evidence	Studies must present empirical evidence, not just opinions or commentary.	<i>Does the study present empirical evidence rather than just opinion or commentary?</i>
Climate Change Focus	Research must consider climate change factors alongside economic analysis if applicable.	<i>Does the study consider climate change factors alongside any economic analysis?</i>

The purpose of literature screening is to exclude studies that are irrelevant or fail to meet certain methodological standards. This is crucial to avoid information bias and ensure the analysis is based on valid and reliable data. If this stage is neglected, research outcomes may be influenced by low-quality or irrelevant studies, compromising the credibility of the findings.

Extraction

Data extraction is a systematic process of gathering relevant information from the selected studies. This process follows strict extraction guidelines to ensure consistency and accuracy of the collected data. The data categories extracted are organized in the Table 2 below.

Table 2. Extraction category

Category	Scope	Example Extraction
Study Design	Identifies the type of research design (qualitative, quantitative, case study, mixed methods).	Descriptive qualitative case study, Quantitative cross-sectional study, Mixed methods research
Setting and Geographic Scope	Determines the specific research location (country, region, district) and scale of analysis (farmer-level, district, regional).	Nicaragua, Chikmagalur and Coorg districts, farm-level analysis
Climate Risk Identification Methods	Outlines methods used to assess climate risks (Fishbone Diagram, FMEA, Maxent model), climate scenarios, key climate variables (temperature, rainfall).	Analytical Method: Fishbone Diagram, Climate Variables: Temperature, Rainfall, Primary Risks: Pest outbreaks, Yield reduction
Supply Chain Process Focus	Maps findings into SCOR processes (Plan, Order, Source, Transform, Fulfillment, Return) and identifies specific risks or adaptations.	Primary SCOR Process: Source, Specific Risks: Delays in procurement, Increased sourcing costs
Quantification of Climate Change Impact	Captures quantitative assessments of climate change impacts (yield changes, climate projections, spatial variation of impacts).	Yield Change: -15%, Climate Scenario: RCP 8.5, Spatial Variation: Higher losses in low-altitude areas
Adaptation Strategies	Identifies proposed or implemented adaptation strategies, categorized by type (technological, managerial, policy) and implementation scale (farmer-level, regional).	Current Strategies: Diversified cropping (Technological, Farm-level), Proposed Strategies: Improved irrigation systems (Technological, Regional)
Supply Chain Risks Based on SCOR	Identifies risks according to SCOR Digital Standard processes.	Plan: Unpredictable demand, Order: Fluctuations in order volumes, Source: Supply shortages, Transform: Quality inconsistencies, Fulfillment: Distribution delays, Return: Increased product returns due to spoilage
Research Methods	Outlines the research methods used in the studies.	Survey, Interviews, Case study
Research Objectives	Determines the objectives of each article.	To assess climate-related supply chain risks
Conclusions	Summarizes research findings and their relation to risks.	Climate variability significantly impacts sourcing reliability
Impact on Supply Chain Performance	Assesses whether articles discuss the impact of risks on supply chain performance using the SCOR framework (reliability,	Reliability: Reduced, Agility: Increased adaptation time, Environmental: Not mentioned

Category	Scope	Example Extraction
	responsiveness, agility, cost, profit, assets, environment, social).	
Mitigation Strategies	Assesses whether articles discuss mitigation strategies for the risks faced.	Use of drought-resistant coffee varieties, Policy incentives for sustainable farming

This structured data extraction is essential to ensure that the collected information is consistent and can be systematically compared across studies. Without a strict extraction approach, the risk of missing critical data increases, which could hinder the quality of analysis and conclusions.

Risk Analysis Based on SCOR Framework

Once the data is extracted, an analysis using the SCOR framework is conducted to identify risks at each stage of the coffee supply chain. SCOR provides a structure that allows for systematic risk mapping from planning to returns.

Table 3. SCOR framework

SCOR Process	Risk Description
Plan	Risks related to supply chain planning, such as weather uncertainty and changes in cultivation areas.
Order	Risks associated with fluctuations in order volumes and customer demand uncertainty.
Source	Risks in sourcing raw materials, such as water scarcity and increased pest prevalence.
Transform	Risks in production, such as variations in coffee quality and increased production costs.
Fulfillment	Risks in fulfilling customer orders, such as distribution disruptions and shipping delays.
Return	Risks in managing product returns due to changes in product quality.

SCOR-based analysis allows the identification of critical points in the coffee supply chain that are vulnerable to climate change. Without this approach, risks may be identified partially, reducing the effectiveness of the mitigation strategies developed.

Data analysis and interpretation

The data analysis in this literature review aims to identify patterns and trends from various studies related to climate change risks in the coffee supply chain. Data interpretation follows proper literature review principles, involving the synthesis of findings across studies, evaluation of methodological consistency, and identification of research gaps. This process includes categorizing data into key emerging themes, comparing study

results to identify consistencies or discrepancies, and assessing the strengths and limitations of each study. Climate risks are identified at every stage of the supply chain based on the SCOR framework, including planning, sourcing, production, transformation, and distribution, with significant impacts on smallholder farmers, processors, and distributors. Thematic analysis highlights geographic vulnerability patterns, stakeholder-specific impacts, and adaptation strategies such as agroforestry, water management, and the development of climate-resilient coffee varieties. This interpretation connects empirical findings with practical implications, offering insights for mitigation and enhancing the resilience of the coffee supply chain to climate change while guiding future research to address existing gaps.

Results and Discussion

Characteristics of included studies

The 27 studies included in this review exhibit variations in research focus, geographical scope, and methodological approaches. Analyzing these characteristics is crucial to understanding how climate change risks in the coffee supply chain have been explored from different perspectives. The majority of the studies emphasize the impact of climate change on coffee production. Ten studies specifically explore how climate change affects coffee yields, highlighting production as the most vulnerable stage in the supply chain (da Silva et al., 2020; Moat et al., 2017; Bunn, 2015; Clay & Bro, 2010; Chemura et al., 2021; Läderach et al., 2017; Phong et al., 2021; Murthy et al., 2022; Nasution et al., 2020; Harvey et al., 2014). Additionally, three studies focus on climate risk analysis, reflecting efforts to understand broader vulnerabilities within the supply chain (Nguyen et al., 2015; Baihaqi et al., 2021; Ramos et al., 2019). Two other studies examine adaptation strategies implemented by coffee industry stakeholders to cope with climate change (Bravo et al., 2019; Musau et al., 2015). Meanwhile, topics such as coffee quality, the role of stakeholders in the supply chain, farmers' preferences, and supply chain planning are each highlighted in only one study (Getachew et al., 2021; Melesse & Tarekegn, 2020; Zamora et al., 2019; Hernandez et al., 2014). This pattern suggests that while production remains the primary focus, there is a growing awareness of the need to expand research into other aspects of the supply chain.

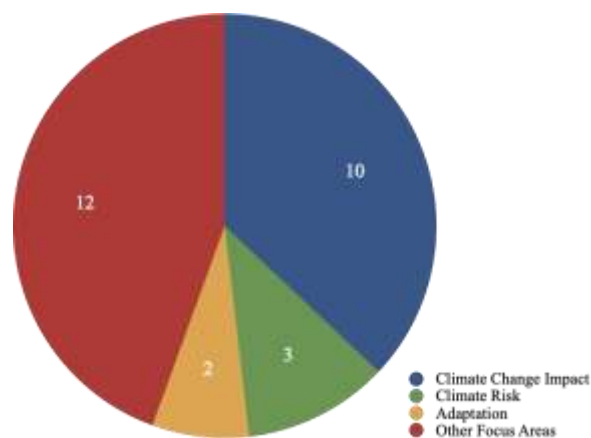


Figure 1. Literature grouping by topic

The analyzed studies cover various coffee-producing regions worldwide, with Ethiopia being the most frequently studied country (five studies). This reflects Ethiopia's significant role as one of the largest coffee producers globally (Moat et al., 2017; Melesse & Tarekegn, 2020; Getachew et al., 2021; Chemura et al., 2021; Läderach et al., 2017). Nicaragua follows with four studies, highlighting attention on the Central American region, which is particularly vulnerable to climate change (Bravo et al., 2019; Harvey et al., 2014; Phong et al., 2021; Zamora et al., 2019). Additionally, four studies have a global scope, indicating efforts to generalize findings across different geographical contexts (Bunn, 2015; da Silva et al., 2020; Ramos et al., 2019; Läderach et al., 2010). Indonesia is the focus of three studies (Baihaqi et al., 2021; Nasution et al., 2020; Musau et al., 2015), while India, Brazil, and Costa Rica are each analyzed in two studies (Murthy et al., 2022; Clay & Bro, 2010; Harvey et al., 2014; da Silva et al., 2020; Läderach et al., 2017). Countries such as Guatemala, Uganda, and Kenya appear in only one study each (Hernandez et al., 2014; Musau et al., 2015; Zamora et al., 2019). This geographical diversity highlights the importance of local context in assessing the impact of climate change on the coffee supply chain while also indicating that some coffee-producing regions remain underrepresented in the literature.

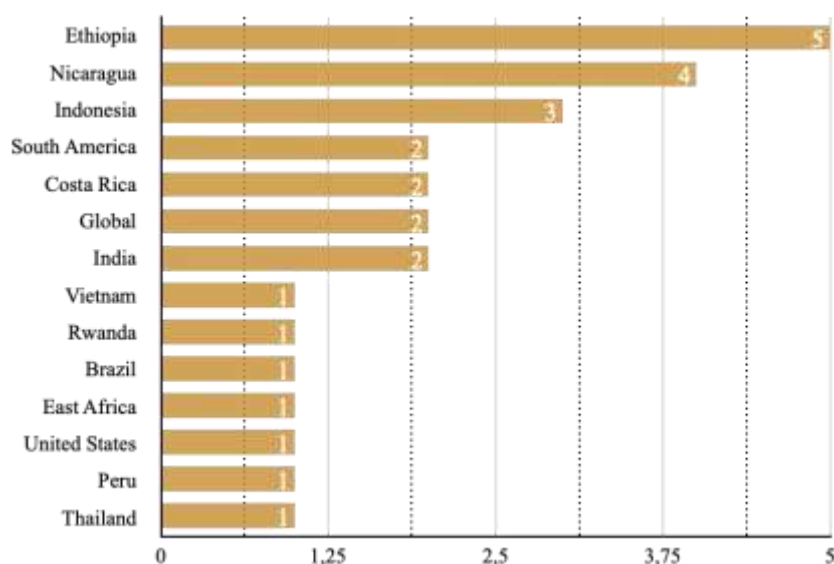


Figure 2. Literature grouping based on country of research location

In terms of supply chain scope, the majority of studies (23 out of 27) focus on the production stage. This dominance indicates that climate change risks at the production level are considered the most critical by researchers (Moat et al., 2017; Melesse & Tarekegn, 2020; Getachew et al., 2021; Chemura et al., 2021; Läderach et al., 2017; Bravo et al., 2019; Harvey et al., 2014; Phong et al., 2021; Zamora et al., 2019; Baihaqi et al., 2021; Nasution et al., 2020; Musau et al., 2015; Murthy et al., 2022; Clay & Bro, 2010; da Silva et al., 2020; Nguyen et al., 2015; Bunn, 2015; Ramos et al., 2019; Läderach et al., 2010; Hernandez et al., 2014; Musau et al., 2015; Zamora et al., 2019; Harvey et al., 2014). However, only four studies examine the supply chain as a whole, indicating that research addressing the interconnections between upstream and downstream processes remains limited (Ramos et al., 2019; Baihaqi et al., 2021; da Silva

et al., 2020; Hernandez et al., 2014). Coffee processing and distribution are each the focus of two studies (Nguyen et al., 2015; Nasution et al., 2020), while aspects such as export, value chains, and communities are mentioned in only one study each (Bravo et al., 2019; Musau et al., 2015; Zamora et al., 2019). This pattern reveals a research gap in exploring other stages of the supply chain beyond production, which is essential for understanding the holistic impact of climate change.

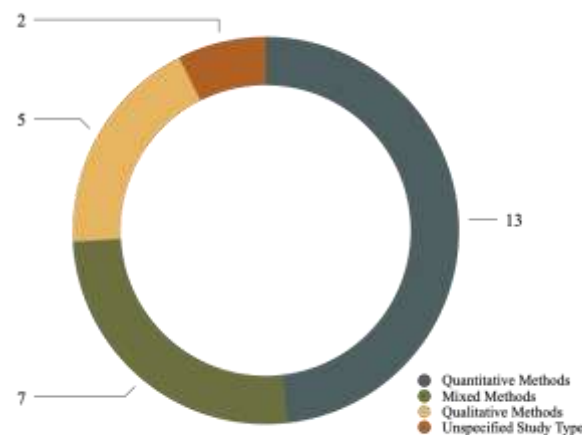


Figure 3. Literature grouping based on research method

From a methodological perspective, quantitative approaches are the most commonly used, found in 13 studies. This approach enables robust data-driven analyses to statistically measure the impact of climate change (Moat et al., 2017; Chemura et al., 2021; Bunn, 2015; Baihaqi et al., 2021; Ramos et al., 2019; da Silva et al., 2020; Phong et al., 2021; Murthy et al., 2022; Läderach et al., 2017; Getachew et al., 2021; Nguyen et al., 2015; Nasution et al., 2020; Harvey et al., 2014). Seven studies employ mixed methods, combining quantitative and qualitative analyses to gain a deeper understanding of risks (Melesse & Tarekegn, 2020; Bravo et al., 2019; Musau et al., 2015; Hernandez et al., 2014; Zamora et al., 2019; Läderach et al., 2010; Clay & Bro, 2010).

Five other studies use qualitative approaches, focusing on in-depth interviews or case studies to explore the subjective experiences of supply chain actors (Musau et al., 2015; Nasution et al., 2020; Phong et al., 2021; Harvey et al., 2014; Bravo et al., 2019). Two studies do not explicitly mention the methods used, indicating a lack of methodological transparency in a small portion of the research (Nguyen et al., 2015; Hernandez et al., 2014). The dominance of quantitative approaches reflects a tendency to produce measurable data; however, the presence of qualitative and mixed-method studies highlights the importance of contextual and narrative understanding in assessing risks.

Table 4. Summary of study characteristics

Study Focus	Geographic Region	Supply Chain Scope	Study Type
Climate change impact on coffee production	Ethiopia	Production	Quantitative
Quality coffee production and climate adaptation	Ethiopia (Yirgacheffe)	Production, Processing	Mixed methods
Stakeholder roles in quality coffee production	Ethiopia (Yirgacheffe)	Production, Processing	Mixed methods
Farmers' preferences for coffee production strategies	Nicaragua	Production	Quantitative
Global coffee production under climate change	Global	Production, Distribution	Quantitative
Climate risk impacts on robusta coffee	India	Production	Quantitative
Scale-dependent climate risks in coffee agroforestry	India	Production	Quantitative
Climate change impact on specialty coffees	Ethiopia	Production	Quantitative
Climate risks for Arabica coffee	Brazil	Production	Quantitative
Transboundary climate risk governance	Brazil-Germany	Entire supply chain	Qualitative
Agroforestry system resilience	Costa Rica	Production	Qualitative
Climate change and Rwandan coffee sector	Rwanda	Production, Export	Not specified
Climate change impact on coffee water requirements	Thailand	Production	Quantitative
Climate change impact on coffee supply chains	Nicaragua, Mexico	Production, Supply chain	Quantitative
Coffee production adaptation to climate change	Nicaragua	Production	Mixed methods
Climate change impact on wild and cultivated coffee	Ethiopia	Production	Quantitative
Smallholder coffee farmers' vulnerability	Peru	Production, Value chain	Mixed methods
Climate change impacts and certification programs	Global (focus on Central/South America)	Entire supply chain	Qualitative
Risk mitigation in Arabica coffee farming	Indonesia	Production	Qualitative
Climate change impact on global coffee sector	Global	Production, Distribution	Quantitative

Study Focus	Geographic Region	Supply Chain Scope	Study Type
Climate change impacts on tea and coffee farming	East Africa	Production	Not specified
Risk analysis for coffee growers	Vietnam	Production	Mixed methods
Transformation of coffee agroforestry systems	Nicaragua	Production	Mixed methods
Supply chain risk analysis for Arabica coffee	Indonesia	Entire supply chain	Mixed methods
Climate change adaptation for Arabica coffee farmers	Indonesia	Production	Quantitative
Climate resilience in coffee farming communities	Costa Rica	Production, Community	Qualitative
Coffee supply chain planning under climate change	Global (U.S. market focus)	Entire supply chain	Quantitative

With this structure, the relationships between research focus, geographical regions, supply chain scope, and methodologies appear more integrated, providing a comprehensive overview of how these studies contribute to understanding climate change risks in the coffee supply chain. The majority of studies emphasize the impact of climate change on production in regions such as Ethiopia, Nicaragua, Indonesia, and Brazil (Moat et al., 2017; Bravo et al., 2019; Baihaqi et al., 2021; da Silva et al., 2020). While most research focuses on production, some studies have begun to explore the entire supply chain, including processing and distribution (Bunn, 2015; Ramos et al., 2019; Nguyen et al., 2015). Methodologically, quantitative approaches dominate; however, mixed-method and qualitative studies provide essential contextual insights (da Silva et al., 2020; Bravo et al., 2019; Musau et al., 2015). This highlights the need for a more holistic approach to understanding climate change risks across all stages of the coffee supply chain.

Climate-Related Risks Across Supply Chain Processes

Planning risks

Climate change has become a significant challenge in managing the coffee supply chain, particularly in the planning stage. Based on the analysis of 27 studies, nine types of risks were identified that affect the planning process within the SCOR (Supply Chain Operations Reference) framework. These risks encompass various aspects, ranging from weather uncertainties to the need for new planning strategies, with impact levels varying from moderate to high (Bunn, 2015; Baihaqi et al., 2021; Ramos et al., 2019; da Silva et al., 2020; Moat et al., 2017; Chemura et al., 2021; Phong et al., 2021; Läderach et al., 2017; Musau et al., 2015). No risks with low impact were identified, underscoring that climate change poses serious consequences for the sustainability of the coffee industry.

Table 5. Planning risks

SCOR Process	Climate Risk Type	Impact Level	Affected Stakeholders
Plan	Increased uncertainty in weather patterns	High	Farmers, Processors, Distributors
	Reduced suitable areas for coffee cultivation	High	Farmers, Land Managers
	Variability in coffee quality and quantity	Medium	Processors, Roasters
	Unpredictable yield forecasts	High	Farmers, Traders
	Shifts in optimal growing regions	Medium	Farmers, Regional Planners
	Mismatched resource availability and demand	High	Entire Supply Chain
	Financial constraints due to market fluctuations	Medium	Farmers, Traders
	Need for new planning strategies	Medium	Farmers, Policymakers
	Uncertainty in cultivation and resource allocation	High	Farmers, Suppliers

The majority of the identified risks have a high impact on the stability of the supply chain. Five out of the nine risks are categorized as high-impact, while the remaining four are considered moderate (Bunn, 2015; da Silva et al., 2020; Baihaqi et al., 2021; Moat et al., 2017; Chemura et al., 2021; Phong et al., 2021; Ramos et al., 2019; Läderach et al., 2017; Musau et al., 2015). These risks directly affect various stakeholders within the coffee supply chain, with farmers being the most vulnerable group. Seven of the nine identified risks have a direct impact on farmers, highlighting their critical position in facing the challenges posed by climate change (Bravo et al., 2019; Getachew et al., 2021; Nasution et al., 2020; Harvey et al., 2014; Melesse & Tarekegn, 2020; Läderach et al., 2010; Musau et al., 2015). In addition to farmers, processors and traders are each affected by two of these risks, indicating that the impact of climate change extends beyond the production stage to include coffee processing and trading (Nguyen et al., 2015; Phong et al., 2021; Ramos et al., 2019; Hernandez et al., 2014).

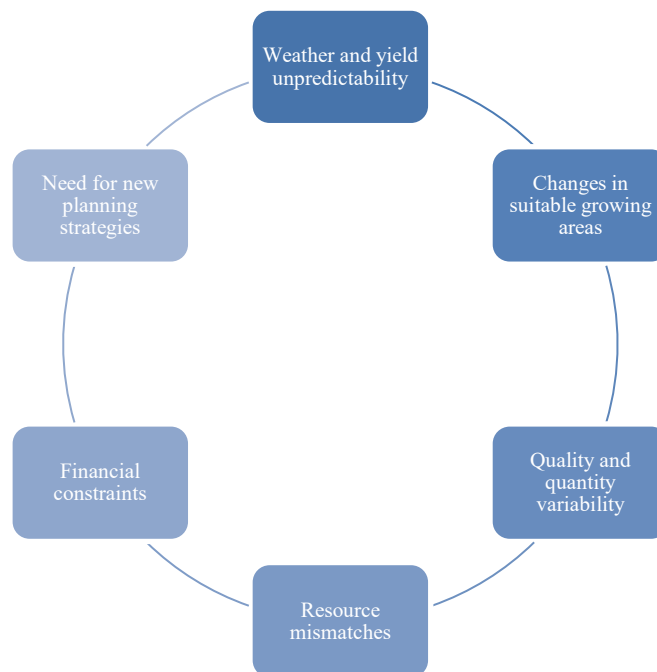


Figure 4. Planning risks type

The identified planning risks encompass a range of issues, including weather and yield uncertainties, shifts in optimal cultivation areas, variability in coffee quality and quantity, and mismatches between resources and market demand (Bunn, 2015; da Silva et al., 2020; Baihaqi et al., 2021; Moat et al., 2017; Chemura et al., 2021). Weather uncertainty, as one of the high-impact risks, hinders the ability of farmers and other supply chain actors to make effective long-term plans (Läderach et al., 2017; Phong et al., 2021; Ramos et al., 2019). Unpredictable fluctuations in temperature and rainfall complicate the prediction of planting, harvesting, and distribution schedules, ultimately increasing the risk of production and logistical failures (Nasution et al., 2020; Harvey et al., 2014; Musau et al., 2015).

The shift in optimal cultivation areas due to rising global temperatures also presents a major challenge. Coffee plants, which are sensitive to temperature changes, now require cultivation at higher altitudes to achieve suitable climate conditions (Bunn, 2015; Moat et al., 2017; Chemura et al., 2021). This shift not only increases production and logistical costs but also triggers potential land-use conflicts with other commodities (Läderach et al., 2017; da Silva et al., 2020; Harvey et al., 2014). In this context, land managers and regional planners face the need to adjust land-use policies to be more adaptive to climate change (Phong et al., 2021; Ramos et al., 2019; Nasution et al., 2020).

Additionally, variability in coffee yield quality and quantity due to climate change impacts processing efficiency and trade stability (da Silva et al., 2020; Chemura et al., 2021; Baihaqi et al., 2021). Processors and roasters face difficulties maintaining product quality standards because of changes in coffee bean characteristics, such as size, flavor, and chemical composition (Moat et al., 2017; Getachew et al., 2021; Phong et al., 2021). This not only affects competitiveness in the global market but also adds challenges in fulfilling

contracts with international buyers (Nguyen et al., 2015; Ramos et al., 2019; Musau et al., 2015).

The mismatch between resource availability and market demand also poses a significant risk. Climate change can lead to shortages of essential resources like water and labor even when coffee demand remains high or increases (da Silva et al., 2020; Phong et al., 2021; Ramos et al., 2019). This situation creates additional pressure on the entire supply chain, from farmers to distributors, and may lead to increased overall production costs (Baihaqi et al., 2021; Harvey et al., 2014; Musau et al., 2015).

Financial risks also emerge as an indirect consequence of climate change. Fluctuations in global coffee prices, triggered by uncertainties in yield and product quality, create financial challenges for farmers and traders (da Silva et al., 2020; Baihaqi et al., 2021; Ramos et al., 2019). Rising production costs, combined with unstable selling prices, exacerbate economic risks, especially for smallholder farmers with limited access to financing and insurance (Harvey et al., 2014; Nasution et al., 2020; Bravo et al., 2019). This situation narrows the space for innovation and adaptation, thereby increasing vulnerability to climate change (Moat et al., 2017; Musau et al., 2015; Phong et al., 2021).

Alongside these challenges, climate change also demands the development of more responsive planning strategies. Farmers and policymakers must adopt more adaptive approaches, including the implementation of new technologies, crop diversification, and the development of policies that support climate resilience (Harvey et al., 2014; Bravo et al., 2019; Musau et al., 2015). Without innovative planning strategies, the risks faced by the coffee supply chain will continue to escalate, threatening the long-term sustainability of the industry (Bunn, 2015; Baihaqi et al., 2021; Ramos et al., 2019; Phong et al., 2021).

Overall, this analysis confirms that climate change has broad and complex impacts on planning within the coffee supply chain. Farmers remain the most affected group, but the impacts are also felt by processors, traders, distributors, and other stakeholders (Baihaqi et al., 2021; Harvey et al., 2014; Musau et al., 2015; Ramos et al., 2019). Therefore, an integrated and collaborative approach involving all stakeholders is essential for developing effective adaptation strategies (Bravo et al., 2019; Nguyen et al., 2015; Phong et al., 2021). Further research is also needed to understand the dynamics of interactions among these risks and how mitigation strategies can be optimally applied across different geographical and social contexts (Bunn, 2015; da Silva et al., 2020; Moat et al., 2017; Chemura et al., 2021).

Sourcing and production risks

Climate change has become a significant determinant in altering the dynamics of the coffee supply chain, particularly in the sourcing and production (transform) stages. These processes are crucial for ensuring the availability of high-quality raw materials and the efficiency of coffee production. Based on the analysis of 27 studies, ten types of risks were identified that affect both of these processes (Bunn, 2015; da Silva et al., 2020; Baihaqi et al., 2021; Moat et al., 2017; Chemura et al., 2021; Ramos et al., 2019; Phong et al., 2021; Läderach et al., 2017; Musau et al., 2015; Harvey et al., 2014). These risks

vary in their level of impact, ranging from moderate to high, with serious consequences for various stakeholders within the supply chain.

Table 6. Sourcing and production risks

SCOR Process	Climate Risk Type	Impact Level	Affected Stakeholders
Source	Changes in land suitability	High	Farmers, Suppliers
	Water scarcity	High	Farmers, Local communities
	Increased pest and disease pressure	Medium	Farmers, Agronomists
	Variability in input quality	Medium	Processors, Roasters
	Competition for suitable land	High	Farmers, Land managers
	Disruptions in seed and input supply	Medium	Farmers, Input suppliers
Transform	Changes in coffee bean characteristics	Medium	Processors, Roasters
	Reduced yields and quality	High	Farmers, Processors
	Increased production costs	Medium	Farmers, Processors
	Need for new processing techniques	Medium	Processors

According to the ten identified risks, four are categorized as having a high impact, while the remaining six have a moderate impact. No risks are classified as low-impact, underscoring that climate change exerts significant pressure on the stability of coffee sourcing and production (Bunn, 2015; Baihaqi et al., 2021; Ramos et al., 2019; da Silva et al., 2020; Moat et al., 2017; Chemura et al., 2021). The high-impact risks include changes in land suitability, water scarcity, increased pest and disease pressures, and declines in coffee yield and quality (Läderach et al., 2017; Phong et al., 2021; Musau et al., 2015; Harvey et al., 2014). These risks have the potential to disrupt production continuity and cause instability within the global supply chain.

Farmers are the most vulnerable group to these risks, with seven out of ten risks directly affecting them. Changes in land suitability due to rising global temperatures force farmers to seek new land at higher altitudes, where climate conditions are more favorable for coffee cultivation (Bunn, 2015; Moat et al., 2017; Chemura et al., 2021). However, this shift not only increases production costs but also complicates access to suitable land, often triggering land-use conflicts with other commodities (Läderach et al., 2017; da Silva et al., 2020; Harvey et al., 2014). Water scarcity, resulting from altered rainfall patterns and extreme temperatures, further exacerbates the situation, threatening both the productivity and livelihoods of farmers (Phong et al., 2021; Ramos et al., 2019; Nasution et al., 2020).

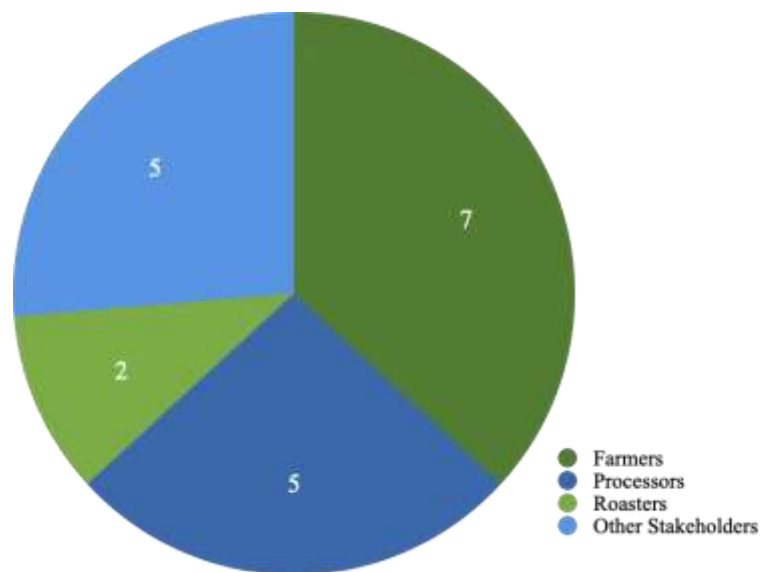


Figure 5. Affected stakeholders in sourcing and production risks

In addition to farmers, processors also face significant challenges due to climate change. Five of the ten identified risks directly impact processors, particularly in maintaining product quality and consistency (Nguyen et al., 2015; Baihaqi et al., 2021; Musau et al., 2015). Variability in the quality of inputs, such as coffee beans affected by climate fluctuations, complicates processing and meeting the quality standards expected by the global market (Getachew et al., 2021; Chemura et al., 2021; Harvey et al., 2014). Processors must also adapt to rising production costs and the need to develop new processing techniques to address changes in coffee bean characteristics (Ramos et al., 2019; Musau et al., 2015).

Coffee roasters are also affected, albeit to a lesser extent compared to farmers and processors. Changes in the physical and chemical characteristics of coffee beans, such as size, flavor, and chemical composition, influence the quality of the final product (da Silva et al., 2020; Moat et al., 2017; Phong et al., 2021). This adds challenges in maintaining the flavor consistency that consumers expect, which is a key factor in product competitiveness in the market (Nguyen et al., 2015; Harvey et al., 2014).

Another significant risk includes the increased pressure from pests and diseases, creating more favorable conditions for the proliferation of crop-damaging organisms. Higher temperatures and unstable humidity accelerate pest life cycles and expand their geographical range (Läderach et al., 2017; Chemura et al., 2021; Nasution et al., 2020). Farmers and agronomists must intensify pest control efforts, which not only adds to production costs but also has the potential to exacerbate environmental impacts if not managed properly (Musau et al., 2015; Ramos et al., 2019).

Disruptions in the supply of seeds and agricultural inputs also pose significant challenges in the sourcing process. Climate change can cause instability in the input supply chain, hindering farmers' ability to initiate or sustain their production (Baihaqi et al., 2021; Nasution et al., 2020; Phong et al., 2021). This creates uncertainty in the availability of raw materials, impacting the entire supply chain from farmers to coffee roasters (Ramos

et al., 2019; Musau et al., 2015; Nguyen et al., 2015). Competition for land suitable for coffee cultivation is also intensifying as climate change reduces the areas with favorable conditions. This pressure affects not only farmers but also land managers, who must adjust land-use policies to accommodate shifting needs (Moat et al., 2017; Läderach et al., 2017; da Silva et al., 2020). Land-use conflicts can exacerbate social and economic instability in coffee-producing communities (Harvey et al., 2014; Bravo et al., 2019; Musau et al., 2015).

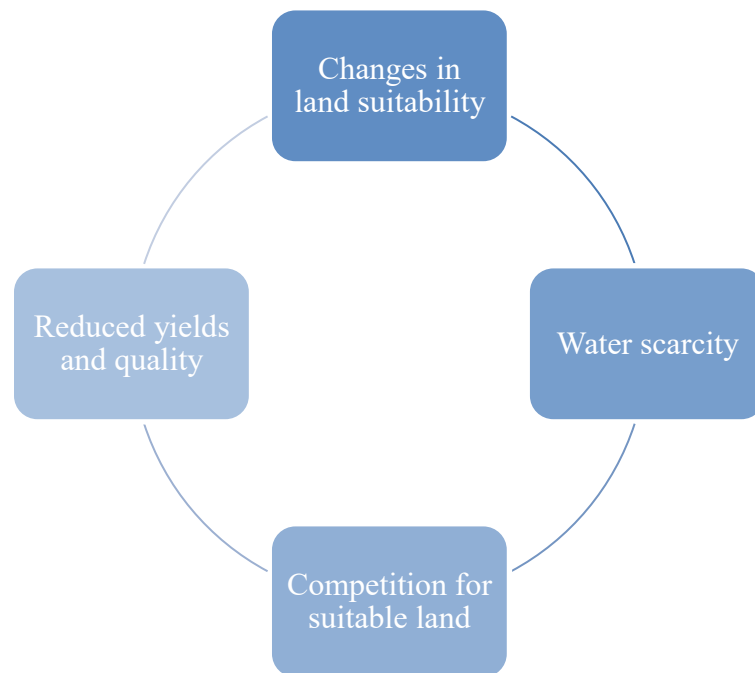


Figure 6. Sourcing and production risks type

In addition to these challenges, rising production costs have become an unavoidable issue. Adapting to climate change—such as adopting new technologies, implementing more intensive pest management, or diversifying crops—requires additional investments (Chemura et al., 2021; Ramos et al., 2019; Phong et al., 2021). This creates further financial strain for farmers and processors, especially those with limited access to financing (Harvey et al., 2014; Nasution et al., 2020; Bravo et al., 2019). The need for new processing techniques is also critical to maintaining product quality amid changing coffee bean characteristics. Processors must innovate in their processing methods to address variability in raw material quality, often necessitating additional training and investments in new technologies (Nguyen et al., 2015; Getachew et al., 2021; Musau et al., 2015).

Overall, the risks associated with sourcing and production processes in the coffee supply chain demonstrate that climate change presents complex and far-reaching challenges to the sustainability of this industry. While farmers remain the most affected, processors, coffee roasters, and other stakeholders within the supply chain also experience significant impacts (Bunn, 2015; Baihaqi et al., 2021; Ramos et al., 2019). Therefore, a collaborative approach involving all stakeholders is essential for developing effective adaptation strategies (Bravo et al., 2019; Nguyen et al., 2015; Phong et al., 2021). Further research

is also needed to explore solutions that can be applied across various geographical and social contexts to enhance the resilience of the coffee supply chain against climate change (Moat et al., 2017; Chemura et al., 2021; da Silva et al., 2020).

Transform and fulfillment risks

Climate change has a significant impact not only on the upstream stages of the coffee supply chain, such as planning and sourcing, but also on the downstream stages, namely transformation and fulfillment. The transformation process involves converting raw coffee beans into finished products, while fulfillment encompasses the distribution and delivery of products to end consumers. Both processes heavily rely on input stability, operational efficiency, and the reliability of distribution systems, all of which are increasingly vulnerable to climate fluctuations (Nguyen et al., 2015; Baihaqi et al., 2021; Ramos et al., 2019). Based on the analysis of 27 reviewed studies, nine types of climate change-related risks were identified that affect the transformation and fulfillment processes of coffee (da Silva et al., 2020; Chemura et al., 2021; Moat et al., 2017; Getachew et al., 2021; Musau et al., 2015). These risks vary in their impact, ranging from moderate to high, with significant implications for various stakeholders within the coffee supply chain (Phong et al., 2021; Läderach et al., 2017; Harvey et al., 2014).

Table 7. Sourcing and production risks

SCOR Process	Climate Risk Type	Impact Level	Affected Stakeholders
Transform	Variability in coffee quality	High	Processors, Roasters
	Need for adaptation in processing techniques	Medium	Processors
	Increased energy costs for processing	Medium	Processors
	Changes in flavor profiles	Medium	Roasters, Consumers
	Supply shortages	High	Distributors, Retailers
Fulfill	Delays in delivery schedules	Medium	Distributors, Retailers
	Challenges in meeting product specifications	High	Processors, Roasters
	Disruptions in transportation	Medium	Distributors
	Increased storage and handling costs	Medium	Distributors, Retailers

According to the nine identified risks, three are categorized as high-impact, while the remaining six have moderate impacts. No risks were classified as low-impact, indicating that climate change presents serious challenges in maintaining product quality, production efficiency, and smooth distribution (da Silva et al., 2020; Chemura et al.,

2021; Ramos et al., 2019). The high-impact risks primarily relate to variability in coffee quality, supply shortages, and difficulties in meeting product specifications (Moat et al., 2017; Baihaqi et al., 2021; Phong et al., 2021). Meanwhile, moderate-impact risks involve the need to adapt processing techniques, rising energy costs, changes in flavor profiles, delivery delays, transportation disruptions, and increased storage and handling costs (Nguyen et al., 2015; Getachew et al., 2021; Musau et al., 2015).

Processors and distributors are the stakeholders most affected by these risks. Processors face significant challenges in maintaining coffee bean quality amidst climate fluctuations that affect the size, flavor, and chemical composition of coffee beans (Harvey et al., 2014; Läderach et al., 2017; Musau et al., 2015). This variability complicates their efforts to maintain the product quality standards expected by the global market (Chemura et al., 2021; Baihaqi et al., 2021). Additionally, changes in coffee bean characteristics require processors to adopt new processing techniques, necessitating investments in technology and workforce training (Nguyen et al., 2015; Ramos et al., 2019). Rising energy costs due to higher ambient temperatures also add to operational expenses, which can ultimately affect the product's selling price (da Silva et al., 2020; Moat et al., 2017).

Distributors, on the other hand, face challenges in ensuring smooth logistics due to transportation disruptions and delivery delays caused by extreme weather (Phong et al., 2021; Musau et al., 2015). Transportation infrastructure vulnerable to natural disasters, such as floods and landslides, can hinder the distribution of coffee to markets, leading to delayed contract fulfillment and customer dissatisfaction (Harvey et al., 2014; Baihaqi et al., 2021). Additionally, unstable climate conditions increase the need for advanced storage facilities to maintain product quality during distribution (Ramos et al., 2019; Nguyen et al., 2015). This not only raises storage and handling costs but also affects the profit margins of distributors and retailers (Musau et al., 2015; da Silva et al., 2020).

Coffee roasters are not immune to the effects of climate change. Changes in coffee flavor profiles, resulting from variability in climate conditions during the coffee bean growth phase, affect the consistency of the final product (Getachew et al., 2021; Moat et al., 2017). Consumers, especially those sensitive to flavor quality, may switch to other brands if the coffee taste does not meet their expectations (Phong et al., 2021; Harvey et al., 2014). Furthermore, coffee roasters face difficulties in meeting product specifications required by the market, particularly in contracts with international buyers that impose strict quality standards (Musau et al., 2015; Baihaqi et al., 2021).

Supply shortages also represent a major challenge in the fulfillment process. Yield uncertainties due to climate change lead to fluctuations in the availability of coffee beans, impacting supply stability across the entire supply chain (da Silva et al., 2020; Chemura et al., 2021). These shortages not only affect distributors and retailers but can also cause significant price increases in the market, ultimately impacting consumers (Ramos et al., 2019; Nguyen et al., 2015). In some cases, supply shortages may result in contract breaches with large buyers, affecting company reputations and business sustainability (Musau et al., 2015; Harvey et al., 2014).

Beyond operational challenges, climate change also drives up production and distribution costs. Processors must invest in new technologies to adapt processing techniques, while distributors and retailers need to allocate additional budgets for more efficient storage and transportation (Nguyen et al., 2015; Ramos et al., 2019). If these increased costs are

not offset by improved productivity or higher selling prices, profit margins throughout the supply chain may shrink (da Silva et al., 2020; Baihaqi et al., 2021).

Overall, the risks associated with the transformation and fulfillment processes in the coffee supply chain demonstrate that climate change has complex and interconnected impacts. While processors and distributors are the most affected, coffee roasters, retailers, and consumers also experience significant consequences (Moat et al., 2017; Phong et al., 2021; Harvey et al., 2014). Therefore, a collaborative approach involving all stakeholders in the supply chain is essential for developing effective adaptation strategies (Bravo et al., 2019; Musau et al., 2015; Ramos et al., 2019). Technological innovation, improved operational efficiency, and strengthening distribution infrastructure are some of the steps that can be taken to mitigate the impacts of climate change (da Silva et al., 2020; Chemura et al., 2021). Furthermore, additional research is needed to explore solutions that can be applied across various geographical and social contexts to enhance the resilience of the coffee supply chain against climate change (Bunn, 2015; Baihaqi et al., 2021; Phong et al., 2021).

Thematic Analysis

Geographic vulnerability patterns

Climate change affects coffee production unevenly across different regions of the world, with impacts varying depending on the geographical and ecological characteristics of each area. Based on the analysis of 27 reviewed studies, four key themes emerge that illustrate geographic vulnerability patterns: altitude-dependent impacts, regional variability, differences in the effects on coffee varieties, and the identification of vulnerability hotspots (Bunn, 2015; Moat et al., 2017; Chemura et al., 2021; Läderach et al., 2017). Each of these themes has significant implications for the sustainability of coffee production and requires adaptation strategies tailored to local conditions (da Silva et al., 2020; Harvey et al., 2014; Phong et al., 2021; Ramos et al., 2019).

Table 8. Geographic vulnerability patterns

Theme	Key Findings	Supporting Evidence	Implementation Challenges
Altitude-dependent impacts	Coffee suitability shifting to higher elevations	Läderach et al. (2017) projects optimal growing elevation shifts from 800-1400 meters above sea level (masl) to 1200-1600 masl by 2050	Limited land availability at higher altitudes; socio-economic challenges of relocation
Regional variability in climate impacts	Different regions face varying levels of risk	Byrareddy et al. (2024) shows yield changes varying between +5% and -20% across different regions in India	Need for tailored adaptation strategies; potential for regional conflicts over resources
Differential impacts on coffee varieties	Arabica and Robusta	Chemura et al. (2021) indicates varying impacts on	Balancing variety selection with market demand; long-

Theme	Key Findings	Supporting Evidence	Implementation Challenges
Hotspots of vulnerability	affected differently	different specialty coffees in Ethiopia	term nature of coffee plant investments
	Certain areas identified as particularly at risk	Moat (2018) suggests up to 60% reduction in coffee-growing areas in Ethiopia without interventions	Prioritizing limited resources for adaptation; potential socio-economic disruptions in highly vulnerable areas

One of the key findings in the literature is the shift in land suitability for coffee cultivation to higher altitudes due to rising global temperatures. Läderach et al. (2017) project that by 2050, the optimal elevation for coffee cultivation will shift from 800-1400 meters above sea level (masl) to 1200-1600 masl. This shift is driven by increasing temperatures, making lower-altitude areas less suitable for coffee cultivation, particularly for the temperature-sensitive Arabica variety. However, relocating to higher altitudes presents new challenges, such as limited land availability at these elevations and socio-economic issues related to the relocation of farming communities (Moat et al., 2017; Phong et al., 2021). Moreover, high-altitude land is often already allocated for other purposes, such as protected forests or residential areas, potentially leading to land-use conflicts (Chemura et al., 2021; da Silva et al., 2020). Therefore, adaptation strategies must consider land constraints and the social impacts of relocating farmers to new areas (Harvey et al., 2014; Ramos et al., 2019).

Studies also show that the impact of climate change on coffee production varies significantly across regions. Byrareddy et al. (2024) demonstrate that changes in coffee yields in India range from a 5% increase to a 20% decrease, depending on geographical location. This variation is attributed to differences in microclimates, soil types, and local farming practices (Bunn, 2015; Läderach et al., 2017). Such variability highlights the importance of developing adaptation strategies tailored to the specific needs of each region (Nasution et al., 2020; Bravo et al., 2019). A uniform approach will be ineffective, as each area faces unique climate-related challenges (Nguyen et al., 2015; Musau et al., 2015). Additionally, regional variability can lead to potential resource conflicts, particularly in areas experiencing declining productivity, while others may maintain stable yields (Getachew et al., 2021; Ramos et al., 2019).

Climate change also affects different coffee varieties in distinct ways. Chemura et al. (2021) indicate that Arabica and Robusta varieties exhibit varying levels of vulnerability to climate change. Arabica, being more sensitive to temperature fluctuations and requiring cooler climates, is more adversely affected compared to Robusta, which is more tolerant of high temperatures and extreme environmental conditions (Moat et al., 2017; Phong et al., 2021). Beyond the differences between Arabica and Robusta, the study also highlights that specialty coffee in Ethiopia faces unique challenges due to climate change (Harvey et al., 2014; Musau et al., 2015). These differences create dilemmas for farmers and other stakeholders when selecting which coffee varieties to cultivate. On one hand, there is a need to maintain high-market-value varieties like Arabica, but on the other, there is pressure to shift to more climate-resilient varieties like Robusta (Nasution et al.,

2020; Bravo et al., 2019). Long-term investments in coffee crops further complicate these decisions, as changing varieties requires years before yielding results (Nguyen et al., 2015; Ramos et al., 2019).

Studies have also identified regions with very high levels of vulnerability to climate change. Moat (2018) estimates that without adaptation interventions, coffee-growing areas in Ethiopia could shrink by up to 60%. As one of the largest Arabica coffee producers globally, Ethiopia faces significant risks to its economic stability if adequate adaptation efforts are not implemented (Chemura et al., 2021; da Silva et al., 2020). High-vulnerability regions require prioritized resource allocation for adaptation (Harvey et al., 2014; Phong et al., 2021). The primary challenge lies in how to allocate limited resources to adaptation efforts in the areas most in need (Bunn, 2015; Läderach et al., 2017). Furthermore, significant changes in coffee production in these regions could trigger socio-economic disruptions, including forced migration, increased poverty, and economic instability in coffee-producing communities (Nasution et al., 2020; Bravo et al., 2019).

The geographic vulnerability patterns in coffee production due to climate change demonstrate that climate impacts are not uniform and depend on factors such as altitude, geographical location, coffee variety, and other local conditions (Ramos et al., 2019; Nguyen et al., 2015). The shift in land suitability to higher elevations, regional variability in yields, differences in the impact on coffee varieties, and the identification of high-vulnerability areas demand specific and localized adaptation approaches (Harvey et al., 2014; Musau et al., 2015). The studies reviewed, such as those by Läderach et al. (2017), Byraredy et al. (2024), Chemura et al. (2021), and Moat (2018), provide crucial insights into how climate change affects coffee production globally (Bunn, 2015; da Silva et al., 2020).

Effective adaptation strategies must account for these factors and involve all stakeholders in the coffee supply chain, from farmers to policymakers (Bravo et al., 2019; Nguyen et al., 2015). Cross-sector and cross-regional collaboration is essential to ensure that adaptation efforts are effectively implemented, particularly in regions most vulnerable to climate change (Musau et al., 2015; Phong et al., 2021). Furthermore, additional research is needed to explore solutions that can be applied across various geographical contexts to enhance the resilience of the global coffee supply chain against climate change (Ramos et al., 2019; Chemura et al., 2021).

Stakeholder-specific impacts

Climate change not only affects the physical processes within the coffee supply chain but also has a direct impact on the various stakeholders involved. Based on the analysis of 27 reviewed studies, it was found that the effects of climate change vary depending on the role and position of actors within the coffee supply chain. Five key themes related to specific impacts on stakeholders include the vulnerability of smallholder farmers, the need for adaptation among processors, logistical challenges faced by distributors, shifting consumer preferences, and the role of policymakers in risk management (Harvey et al., 2014; Baihaqi et al., 2021; Musau et al., 2015; Ramos et al., 2019; Bravo et al., 2019). Each of these themes highlights how different stakeholder groups encounter unique

challenges in responding to climate change (Nguyen et al., 2015; Chemura et al., 2021; Phong et al., 2021; Moat et al., 2017; da Silva et al., 2020).

Table 9. Stakeholder-specific impacts

Theme	Key Findings	Supporting Evidence	Implementation Challenges
Smallholder farmer vulnerability	Smallholders are most at risk due to limited resources	Morales et al. (2022) identifies smallholders as the most vulnerable actors in the coffee value chain	Limited access to finance and technology; need for targeted support programs
Processor adaptation needs	Processors face challenges in maintaining quality	Zhou et al. (2022) highlights variability in coffee quality affecting processors	Investment in new processing technologies; balancing cost and quality
Distributor logistics challenges	Climate change disrupts transportation and delivery	Tye and Grinspan (2020) note potential disruptions in supply chains	Need for more resilient logistics networks; increased costs
Consumer preference shifts	Changing coffee characteristics may affect demand	Läderach et al. (2011) suggest potential changes in coffee flavor profiles	Educating consumers; potential market volatility
Policymaker role in risk management	Need for supportive policies and regulations	Adane and Bewket (2022) emphasize the importance of empowering stakeholders in decision-making	Balancing different stakeholder interests; long-term policy planning

Smallholder farmers are the most vulnerable group to the impacts of climate change. Morales et al. (2022) identified that smallholder farmers often lack financial resources, technology, and access to adequate information to adapt their agricultural practices to climate change (Harvey et al., 2014; Nasution et al., 2020). Their reliance on traditional farming systems, which are susceptible to weather variability, exacerbates this situation. Additionally, limited access to financing and modern technologies constrains their ability to implement adaptation strategies such as crop diversification or the use of more climate-resilient coffee varieties (Bravo et al., 2019; Baihaqi et al., 2021). These limitations necessitate focused support programs to enhance smallholder farmers' adaptive capacity. Such programs could include training, access to climate-friendly technologies, and microfinance schemes that enable farmers to invest in sustainable farming practices (Getachew et al., 2021; Ramos et al., 2019). Without adequate interventions, smallholder farmers risk significant declines in productivity, threatening their economic sustainability and the stability of the global coffee supply (Nguyen et al., 2015; Musau et al., 2015).

Coffee processors face challenges in maintaining product quality amid climate variability that affects coffee bean quality. Zhou et al. (2022) highlighted that changes in coffee bean characteristics—such as size, moisture content, and chemical composition—complicate the standardization and processing of coffee (Chemura et al., 2021; Moat et al., 2017). This variability requires processors to invest in new processing technologies capable of accommodating fluctuations in raw material quality (da Silva et al., 2020; Ramos et al., 2019). However, such investments entail significant costs, and not all processors, particularly small to medium-sized enterprises, have the financial capacity to do so (Phong et al., 2021; Nguyen et al., 2015). Therefore, processors must find a balance between maintaining product quality and managing operational costs. Collaboration with technology providers and access to affordable financing can assist processors in implementing the necessary adaptive technologies (Baihaqi et al., 2021; Musau et al., 2015).

The distribution of coffee heavily relies on efficient logistics infrastructure, which is increasingly vulnerable to disruptions caused by climate change. Tye and Grinspan (2020) noted that climate change can disrupt the supply chain through delivery delays, damage to transportation infrastructure due to extreme weather, and rising logistics costs (Ramos et al., 2019; Nguyen et al., 2015). Distributors face challenges in ensuring smooth coffee deliveries from producers to consumers, especially under unpredictable weather conditions (Musau et al., 2015; Phong et al., 2021). To address these challenges, distributors need to strengthen their logistics networks by improving infrastructure resilience and adopting technologies that can predict and respond to climate risks more effectively (da Silva et al., 2020; Chemura et al., 2021). The increased logistics costs resulting from these adaptation efforts may affect the final coffee prices in the market, necessitating careful strategies to balance operational efficiency and price competitiveness (Moat et al., 2017; Baihaqi et al., 2021).

Climate change also impacts the flavor profile of coffee, which can influence consumer preferences. Läderach et al. (2011) suggested that changes in coffee flavor profiles, resulting from climatic variability during the coffee bean growth phase, may alter consumer perceptions of coffee quality (Harvey et al., 2014; Musau et al., 2015). Consumers accustomed to certain flavor profiles may feel dissatisfied if the taste of coffee changes, even if the physical quality of the product remains intact (Nguyen et al., 2015; Bravo et al., 2019). To address this challenge, producers and roasters need to educate consumers about the climate-related causes of changes in coffee flavor (Getachew et al., 2021; Ramos et al., 2019). This strategy not only helps maintain consumer loyalty but also fosters a broader understanding of the challenges faced by the coffee industry due to climate change (Chemura et al., 2021; Moat et al., 2017). Additionally, diversifying product offerings by introducing new coffee varieties aligned with market preferences can serve as a solution to accommodate these changes (da Silva et al., 2020; Baihaqi et al., 2021).

Climate change necessitates supportive policies for adaptation throughout the coffee supply chain. Adane and Bewket (2022) emphasized the importance of policymakers in empowering stakeholders through effective regulations and adaptation programs (Bravo et al., 2019; Nguyen et al., 2015). Supportive policies could include incentives for sustainable farming practices, the development of climate-resilient coffee varieties, and investments in logistics infrastructure resistant to extreme weather conditions (Harvey et

al., 2014; Musau et al., 2015). However, policymakers face challenges in balancing the interests of various stakeholders across the supply chain (Phong et al., 2021; Ramos et al., 2019). Furthermore, long-term policy planning is needed to ensure that implemented interventions can address the evolving challenges of climate change (da Silva et al., 2020; Chemura et al., 2021). Collaboration between governments, the private sector, and local communities is crucial in creating an environment conducive to effective adaptation (Moat et al., 2017; Baihaqi et al., 2021).

The impacts of climate change on the coffee supply chain affect not only production and distribution processes but also directly influence various stakeholders along the supply chain. Smallholder farmers, processors, distributors, consumers, and policymakers each face unique challenges that require tailored adaptation strategies (Harvey et al., 2014; Nasution et al., 2020; Bravo et al., 2019). The studies reviewed, such as those conducted by Morales et al. (2022), Zhou et al. (2022), Tye and Grinspan (2020), Läderach et al. (2011), and Adane and Bewket (2022), provide deep insights into how climate change affects each actor within the coffee supply chain (Bunn, 2015; Ramos et al., 2019; Nguyen et al., 2015). By understanding the specific impacts on stakeholders, more effective and sustainable adaptation solutions can be developed to address future climate change challenges (Moat et al., 2017; Chemura et al., 2021).

Adaptation and mitigation strategies

Climate change has posed various challenges in coffee production and distribution worldwide. To address these challenges, effective adaptation and mitigation strategies are required throughout the coffee supply chain. Based on the analysis of the adaptation and mitigation strategies table, six key themes have been identified for climate change adaptation in coffee production: agroforestry systems and shade management (Harvey et al., 2014), water management techniques (Byrareddy et al., 2024), development of climate-resilient coffee varieties (Chemura et al., 2021), diversification of income sources (Nasution et al., 2020), technology and data-driven approaches (Ramos et al., 2019), and policy and governance interventions (Adane and Bewket, 2022). Each theme is supported by a study that specifically addresses the respective approach, with several key findings consistently emerging across different research (Moat et al., 2017; Baihaqi et al., 2021; Phong et al., 2021).

Two studies highlight the importance of diversification, both in terms of crop diversification and income streams, as a key strategy to reduce risks associated with climate change (Nasution et al., 2020; Morales et al., 2022). Two other studies address water management issues, including the scarcity and variability of water resources (Byrareddy et al., 2024; Humphries et al., 2024). Additionally, two studies focus on risk management, particularly in terms of spreading risk through diversification or adaptive technologies (Bunn, 2015; Ramos et al., 2019). Other key findings, each mentioned in a single study, include microclimate regulation (Harvey et al., 2014), the development of climate-adapted coffee varieties (Chemura et al., 2021), enhanced data-driven decision-making (Phong et al., 2021), and creating an enabling environment for adaptation (Dzebo and Adams, 2023).

Table 10. Adaptation and mitigation strategies

Theme	Key Findings	Supporting Evidence	Implementation Challenges
Agroforestry and shade management	Effective for temperature regulation and diversification	Siles et al. (2022) propose active management of species for ecosystem benefits	Balancing shade levels with productivity; long-term investment required
Water management techniques	Critical for addressing water scarcity and variability	Humphries et al. (2024) emphasize farm-specific water management strategies	Infrastructure costs; competing water demands
Climate-resilient coffee varieties	Development and adoption of adapted cultivars	Negre (2023) suggests partnering with research providers for climate-resistant varieties	Long development time; ensuring farmer access to new varieties
Diversification of income sources	Reduces dependence on coffee and spreads risk	Morales et al. (2022) recommend crop and income diversification	Market access for alternative products; potential trade-offs with coffee production
Technology and data-driven approaches	Improve decision-making and risk management	Bunn (2015) uses machine learning for global coffee production modeling	Digital divide; data quality and accessibility issues
Policy and governance interventions	Create enabling environment for adaptation	Dzebo and Adams (2023) highlight need for improved global governance of adaptation	Coordinating across different governance levels; policy implementation challenges

However, the implementation of these strategies is not without challenges. Twelve distinct implementation challenges were identified, each reported in a separate study. These challenges include technical issues, such as balancing optimal shade levels in agroforestry systems (Siles et al., 2022), and the lengthy development time required for new coffee varieties (Negre, 2023). Economic challenges involve high infrastructure costs and limited market access for alternative products (Nguyen et al., 2015). On the social side, challenges include farmers' limited access to new varieties and the digital divide that hampers the adoption of new technologies in farming communities (Musau et al., 2015; Bravo et al., 2019). Furthermore, policy challenges include coordination across government levels and difficulties in implementing effective adaptation policies (Adane and Bewket, 2022; Moat et al., 2017).

Agroforestry and shade management are among the adaptation strategies that can mitigate the effects of extreme temperatures and enhance the diversification of agricultural ecosystems. Siles et al. (2022) demonstrated that active management of shade species can deliver significant ecosystem benefits, including improved soil fertility,

reduced erosion, and increased biodiversity (Harvey et al., 2014; Baihaqi et al., 2021). These systems also help regulate the microclimate around coffee plants, which is critical for reducing the stress caused by rising global temperatures (Ramos et al., 2019; Getachew et al., 2021). However, the implementation of agroforestry faces technical challenges in determining the optimal level of shade. Excessive shading can reduce yields, while insufficient shading fails to adequately protect plants from extreme temperatures (Nguyen et al., 2015; Chemura et al., 2021). Moreover, the long-term investment required to develop agroforestry systems can be a barrier for smallholder farmers with limited resources (Nasution et al., 2020; Bravo et al., 2019).

Effective water management has become increasingly crucial in addressing water scarcity and rainfall variability due to climate change. Humphries et al. (2024) emphasized the importance of water management strategies at the farm level, including drip irrigation systems, rainwater harvesting, and soil management to improve water retention (Byrareddy et al., 2024; Moat et al., 2017). These techniques help ensure an adequate water supply for coffee plants during dry seasons or periods of unpredictable rainfall (Phong et al., 2021; Ramos et al., 2019). However, the primary challenge in implementing water management techniques is the high cost of infrastructure, particularly for advanced irrigation systems (Nguyen et al., 2015; Baihaqi et al., 2021). Furthermore, competition for water resources in local communities can exacerbate conflicts over access to water, especially in regions facing chronic water shortages (Musau et al., 2015; Harvey et al., 2014).

The development and adoption of climate-resilient coffee varieties are vital adaptation strategies for maintaining coffee productivity and quality. Negre (2023) recommends partnerships with research institutions to develop coffee varieties that are more resistant to high temperatures, drought, and pest infestations (Chemura et al., 2021; Ramos et al., 2019). These varieties can help farmers reduce the risk of yield losses due to changing climatic conditions (Nguyen et al., 2015; Bravo et al., 2019). However, developing new coffee varieties takes time, and farmers often have limited access to these new options (Nasution et al., 2020; Moat et al., 2017). Additionally, adopting new varieties requires training and technical support for farmers, as well as adjustments to market preferences that may favor traditional coffee varieties (Musau et al., 2015; Getachew et al., 2021).

Diversifying income sources can help farmers reduce their dependence on coffee and spread the risks associated with fluctuating yields. Morales et al. (2022) recommend crop and income diversification as strategies to enhance farmers' resilience to climate change impacts (Nasution et al., 2020; Ramos et al., 2019). Diversification can also create new economic opportunities and improve the overall economic resilience of farming communities (Harvey et al., 2014; Nguyen et al., 2015). However, access to markets for alternative products is often limited, and diversification may require trade-offs with a focus on coffee production (Bravo et al., 2019; Baihaqi et al., 2021). Farmers may need additional support to develop value chains for alternative products and ensure that diversification genuinely increases their income (Musau et al., 2015; Getachew et al., 2021).

Technology and data-driven approaches can improve decision-making and risk management in coffee production. Bunn (2015) demonstrated how machine learning can be used to model global coffee production, helping predict climate risks and plan more effective adaptation strategies (Phong et al., 2021; Ramos et al., 2019). Technologies

such as climate sensors, land monitoring systems, and data-based applications can assist farmers in managing resources more efficiently (Nguyen et al., 2015; Baihaqi et al., 2021). However, the digital divide and data accessibility remain major barriers to implementing these technologies, particularly in rural areas (Moat et al., 2017; Chemura et al., 2021). Furthermore, inadequate data quality can reduce the effectiveness of technology-driven decision-making, requiring investments in data infrastructure and training for farmers (Musau et al., 2015; Harvey et al., 2014).

Adaptation and mitigation strategies for climate change in the coffee supply chain encompass a range of complementary approaches. The studies reviewed, such as those conducted by Siles et al. (2022), Humphries et al. (2024), Negre (2023), Morales et al. (2022), Bunn (2015), and Dzebo and Adams (2023), provide insights into how these various strategies can be implemented to enhance resilience to climate change (Ramos et al., 2019; Nguyen et al., 2015). While challenges in implementation remain, integrated and collaborative approaches can enhance the sustainability of the coffee industry in the future (Moat et al., 2017; Chemura et al., 2021).

Conclusion

This systematic review highlights that climate change significantly impacts the stability of the coffee supply chain, with most risks concentrated at the production stage, directly influencing crop yields and coffee quality. Using the Supply Chain Operations Reference (SCOR) framework, this study identifies various risks, including weather unpredictability, shifts in cultivation zones, logistical disruptions, and quality degradation, which severely affect smallholder farmers, processors, and distributors. The analysis further reveals a limited application of SCOR-based risk management models and emphasizes the necessity for integrated and collaborative strategies among stakeholders to enhance the resilience of the coffee supply chain against climate change challenges. These findings provide crucial insights for policymakers, industry stakeholders, and farming communities in developing effective and sustainable climate adaptation strategies.

References

- Abebe, G., Nasiro, K., & Mohammed Hawi. (2021). Climate Analogue Mapping for Coffee Production in Ethiopia. *International Journal of African and Asian Studies*, 74, 19–7. <https://doi.org/10.7176/JAAS/74-03>
- Achwan, S., Hamid, A. H., & Romano. (2019). The Impact of Climate Change and Adaptation Strategy of Arabica Coffee Farmers in Central Aceh Regency. *Russian Journal of Agricultural and Socio-Economic Sciences*, 85(1), 201–206. <https://doi.org/10.18551/rjoas.2019-01.24>
- Adane, A., & Bewket, W. (2021). Effects of quality coffee production on smallholders' adaptation to climate change in Yirgacheffe, Southern Ethiopia. *International Journal of Climate Change Strategies and Management*, 13(4/5), 511–528. <https://doi.org/10.1108/IJCCSM-01-2021-0002>

- Adane, A., & Bewket, W. (2022). Assessment of stakeholders' roles and linkages in quality coffee production in Yirgacheffe District, southern Ethiopia: Implications for local adaptation to climate change. *Norsk Geografisk Tidsskrift - Norwegian Journal of Geography*, 76(3), 164–176. <https://doi.org/10.1080/00291951.2022.2079559>
- Baihaqi, A., Sofiana, U., Usman, M., & Bagio, B. (2022). Risk analysis of arabica coffee supply chain in Aceh Tengah regency, Aceh Province, Indonesia. *Coffee Science*, 16. <https://doi.org/10.25186/v16i.1984>
- Bro, A. S., Ortega, D., & Clay, D. C. (2016). *Adaptive Capacity to Climate Change: Insights from Coffee Farmers in Nicaragua*. <https://ageconsearch.umn.edu/record/235729?v=pdf>
- Bunn, by, Hendrik Olbertz, J., Lucius Advisors, R., Dieter Kirschke, hc, Lotze-Campen, H., & Kappas, M. (n.d.). *Modeling the climate change impacts on global coffee production*.
- Byrareddy, V., Kath, J., Kouadio, L., M, S., & Vellingiri, G. (2023). Avoiding the Blind Spot: Climate Risks Vary Across Scales in Coffee-Based Agroforestry Systems. *SSRN Electronic Journal*, 1–1. <https://doi.org/10.2139/ssrn.4357158>
- Byrareddy, V. M., Kath, J., Kouadio, L., Mushtaq, S., & Geethalakshmi, V. (2024). Assessing scale-dependency of climate risks in coffee-based agroforestry systems. *Scientific Reports*, 14(1), 8028. <https://doi.org/10.1038/s41598-024-58790-5>
- Chemura, A., Mudereri, B. T., Yalew, A. W., & Gornott, C. (2021). Climate change and specialty coffee potential in Ethiopia. *Scientific Reports*, 11(1), 1. <https://doi.org/10.1038/s41598-021-87647-4>
- Dias, C. G., Martins, F. B., & Martins, M. A. (2024). Climate risks and vulnerabilities of the Arabica coffee in Brazil under current and future climates considering new CMIP6 models. *Science of The Total Environment*, 907, 167753. <https://doi.org/10.1016/j.scitotenv.2023.167753>
- Dzebo, A., & Adams, K. M. (2023). Contesting Legitimacy in Global Environmental Governance - an Exploration of Transboundary Climate Risk Management in the Brazilian-German Coffee Supply Chain. *SSRN Electronic Journal*, 15, 1–12. <https://doi.org/10.2139/ssrn.4060870>
- Eychène, C., Fallot, A., Nelson, M., Rapidel, B., Le Coq, J.-F., & Botta, A. (2020, December 15). Assessing the resilience of agroforestry systems in Central America: What do we learn about the transformability of coffee plantations? *3ème Congrès International Resilience, Resilience and Development: Mobilising for Transformation, Resilience Alliance*. <https://doi.org/https://hal.science/hal-03069465>
- Hakorimana, F., & Akçaöz, H. (2017). The Climate Change and Rwandan Coffee Sector. *Turkish Journal of Agriculture - Food Science and Technology*, 5(10), 1206–1215. <https://doi.org/10.24925/turjaf.v5i10.1206-1215.1376>
- Hoang Si, T., & Nguyen Thi, H. (2015). Risk Analysis: Case Study for Coffee Growers in The Central High Land Area (Tay Nguyen), Vietnam. *International Journal of Economics, Commerce & Management*, 3(8), 194–212. <https://ijecm.co.uk/wp-content/uploads/2015/08/3811.pdf>

- Humphries, U. W., Waqas, M., Hlaing, P. T., Wangwongchai, A., & Dechpichai, P. (2024). Determination of crop water requirements and potential evapotranspiration for sustainable coffee farming in response to future climate change scenarios. *Smart Agricultural Technology*, 8, 1. <https://doi.org/10.1016/j.atech.2024.100435>
- Laderach, P., Lundy, M., Jarvis, A., Ramirez, J., Portilla, E. P., Schepp, K., & Eitzinger, A. (2011). Predicted Impact of Climate Change on Coffee Supply Chains. In W. L. Filho (Ed.), *The Economic, Social and Political Elements of Climate Change, Climate Change Management*. (pp. 703–723). Springer. https://doi.org/10.1007/978-3-642-14776-0_42
- Laderach, P., Ramirez–Villegas, J., Navarro–Racines, C., Zelaya, C., Martinez–Valle, A., & Jarvis, A. (2017). Climate change adaptation of coffee production in space and time. *Climatic Change*, 141(1), 47–62. <https://doi.org/10.1007/s10584-016-1788-9>
- Moat, J. (2018). *Plant conservation in space, time and a changing world: forecasting the fate of Coffea arabica in Ethiopia* [The University of Nottingham]. <https://eprints.nottingham.ac.uk/id/eprint/52174>
- Morales, L. V., Robiglio, V., Baca, M., Bunn, C., & Reyes, M. (2022). Planning for Adaptation: A System Approach to Understand the Value Chain's Role in Supporting Smallholder Coffee Farmers' Adaptive Capacity in Peru. *Frontiers in Climate*, 4, 1–23. <https://doi.org/10.3389/fclim.2022.788369>
- Negre, L. (2023). The World of Coffee: 21st Century Solutions for A Commodity Facing Climate Change Risks. *Consilience*, 26, 1. <https://doi.org/10.52214/consilience.vi26.10936>
- Omar, N. M. W., Djuwendah, E., Trimo, L., & Mukti, G. W. (2024). Mitigasi Penyebab Risiko Usahatani Kopi Arabika (Studi Kasus pada Kelompok Tani Hutan Giri Senang, Kampung Legok Nyenang, Kecamatan Cilengkrang, Kabupaten Bandung). *Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis*, 10(2), 3037–3044. <https://doi.org/10.25157/ma.v10i2.14630>
- Panhuisen, S., & Pierrot, J. (2020). *Coffee Barometer 2020* (P. Kuipers & T. de Vries, Eds.). the Coffee Collective 2020. <https://ethosagriculture.com/wp-content/uploads/2022/02/Coffee-Barometer-2020-3.pdf>
- Ríos, J. R., Duque, D. F. M., & Gómez, J. C. O. (2019). Operational supply chain risk identification and prioritization using the SCOR model. *Ingeniería y Universidad: Engineering for Development*, 23(1), 1–20. <https://doi.org/10.11144/Javeriana.iyu23-1.oscr>
- Rwigema, C. P. (2021). Combating Climate Change Impacts in Tea and Coffee Farming in East Africa: Theoretical Perspective. *Strategic Journal of Business & Change Management*, 8(2), 521–553. <https://doi.org/http://dx.doi.org/10.61426/sjbcm.v8i2.2013>
- Siles, P., Cerdán, C. R., & Staver, C. (2022). Smallholder Coffee in the Global Economy—A Framework to Explore Transformation Alternatives of Traditional Agroforestry for Greater Economic, Ecological, and Livelihood Viability. *Frontiers in Sustainable Food Systems*, 6, 1–23. <https://doi.org/10.3389/fsufs.2022.808207>

- The Association for Supply Chain Management (ASCM). (2022). *SCOR Digital Standard*. ascm.org.
- Tye, S., & Grinspan, D. (2020). Building a Climate Resilient Future for Costa Rica's Coffee Farming Communities. *World Resources Institute*, 1–40. <https://doi.org/10.46830/wriprn.19.00103>
- Zhou, R. (2020). Coffee Supply Chain Planning under Climate Change [University of Tennessee]. In *Journal of Integrative Environmental Sciences* (Vol. 19, Issue 1). <https://doi.org/10.1080/1943815X.2022.2103570>

Geospatial Analysis of Rice Productivity and Technical Inefficiency Assessment of Irrigated Rice Farms in Cabusao, Camarines Sur Province, Philippines

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Abstract

This study examined the level of rice productivity and technical inefficiency among all the 114 farmer-beneficiaries of Camagong San Vicente Farmer Irrigators' Association (CSVFIA) in Cabusao, Camarines Sur. Employing Stochastic Frontier Analysis through the Cobb-Douglas production function, the research identified key determinants of productivity and technical inefficiency. Results revealed that farm inputs such as seeds, fertilizer, and fuel and machinery had positive and significant effects on productivity during the dry season. On the other hand, flooding, which was represented by a dummy variable, had a negative impact during the wet season. Quantum Geographic Information System (QGIS) mapping was employed to visually represent the spatial clustering of rice productivity and inefficiency levels across farmland locations. In addition, the K-Nearest Neighbor (KNN) was used to account for spatial interactions, allowing them to assess the influence of neighboring farms on individual productivity and inefficiency across cropping seasons. Mapping results showed substantial variability in productivity across farmland locations, with significant clustering influenced by irrigation canal networks and environmental constraints such as irrigation water inadequacy, soil salinity, and prolonged flooding which was further strengthened by their detrimental effects on technical inefficiency. The findings imply the need for targeted interventions, which include optimizing resource allocation, improving irrigation infrastructure to support efficient irrigation service and avoid salt intrusion, strengthening knowledge-sharing networks, and enhancing technical assistance support. By integrating geospatial analysis into productivity assessment, the study offers a relevant framework for addressing localized challenges and advancing rice self-sufficiency in the Philippines.

Keywords: rice productivity, technical inefficiency, stochastic frontier analysis, k-nearest neighbor, geospatial analysis

JEL code: D24, Q15, R39

SDG classification: SDG 1, SDG 2

Introduction

Rice production in the Philippines still plays an essential role in its economy and food supply which accounted for 21% of Gross Value Added in agricultural commodities (Inocencio and Inocencio, 2022) and employed around 2.4 million households in 2021 (PhilRice, 2022). The data from the 2018 National Food Consumption and Nutrition Report shows that rice largely contributed to the average Filipino's daily caloric intake with 1,156.59 grams in 2017. Despite the vital contribution of rice in the country, it is still the most imported agricultural commodity in 2021 with 2.975 million metric tons (MT) recorded import of the Philippines amounting to PhP56 billion. The government, thus, sees the need to attain rice self-sufficiency.

Among the policies aimed at attaining rice self-sufficiency is the Department of Agriculture's Masagana Rice Industry Development Program (MRIDP), which is a government initiative under President Ferdinand R. Marcos, Jr. The MRIDP aims to obtain 97.5% rice sufficiency in the country by 2028. According to German et al. (2022), one way to achieve rice sufficiency is through land expansion devoted to rice farming. With limited land, productivity is enhanced through intensive cultivation which in the case of rice is made possible by the presence of irrigation. Despite access to irrigation systems, variations in agricultural yields and resource maximization remain observed across farming communities in the Philippines (Pede et al., 2018). For productivity improvement, there is a need to determine the factors that affect rice production performance.

Additionally, the integration of spatial analysis into agricultural research through geospatial technologies provide new opportunities to understand location-specific factors influencing rice production. Many studies utilizing Geographic Information Systems (GIS) and remote sensing data have enabled more data-driven assessments of agricultural performance. For instance, Ozsahin et al. (2022) identified suitable lands for rice cultivation in the Edirne Plain, Turkey; Tobore et al. (2021) evaluated wetland soils for rice production using spatial techniques in West Africa; Bhatt et al. (2021) applied geospatial methods to assess water resource management in agricultural lands of Northern India; and Som-ard (2020) assessed rice security conditions in Sarakham province, Thailand using advanced geospatial techniques.

Although spatial methods have been widely utilized in agricultural research, there remains limited empirical work integrating these approaches with efficiency analysis—particularly in the context of irrigated rice farms in Camarines Sur. Mamiit et al. (2021) examined productivity hot spots and cold spots in Central Luzon, Philippines, emphasizing that rice production is inherently location-specific due to environmental factors including soil fertility and type, topography, and water availability. Their findings highlight the necessity of incorporating spatial mapping in the assessment of agricultural efficiency.

Hence, this study addresses this gap by conducting a geospatial analysis of rice productivity and assessing technical inefficiency among irrigated rice farms in the municipality of Cabusao, Camarines Sur. The specific objectives were: (1) to estimate the technical efficiency of rice farmers using stochastic frontier analysis (SFA); and (2) to identify and assess the key socio-economic, agronomic, and geospatial factors influencing technical inefficiency; and (3) to map and analyze spatial variations in rice productivity levels and inefficiencies. The research is crucial for the irrigation sector and local

government unit through increasing knowledge on policy strategies that can be implemented to improve the rice productivity in the area. The same knowledge can be of benefit to rice farmers by helping them improve their production system strategies. Also, given that only a limited number of studies have been conducted to examine the geospatial analysis of rice productivity in the the context of irrigated rice farms, this study can add to the limited literature that can be used by future researchers.

The rest of the paper is structured as follows: Section 1 presents the background of the study; Section 2 outlines the methodology, including the data collection, and analytical techniques; Section 3 discusses the results and their implications; and Section 4 concludes the paper with key findings and policy recommendations.

Methodology

Data collection

The study conducted a survey of all listed farmer-beneficiaries of Camagong San Vicente Farmer Irrigator's Association (CSVFIA) from July to August 2024, which is part of the Libmanan-Cabusao Pump Irrigation System (LCPIS) in the province of Camarines Sur. The province, occupying 123,700 hectares total irrigable area, ranked 6th as the country's top rice-producing province with 650,406 MT yield production in 2020. The association depends on the irrigation water from the Bicol River through a pump along a concrete lined canal irrigating a total of 120 hectares firmed-up service area. Complete enumeration was performed to better analyze the existence of agricultural efficiencies particularly for a smaller area like CSVFIA (Benedetti et al., 2015). Face-to-face interviews were conducted with the farmer, utilizing structured and pretested survey questionnaires.

Empirical Model

Production function and technical efficiency

The Cobb-Douglas production function was used to analyze the technical efficiency of rice production among the CSVFIA rice farmers. It has been used for the same purpose in several studies conducted in a number study areas in the Philippines (Dait, 2023; Mamiit et al., 2021; and Cañete and Temanel, 2017). The model allows for the estimation of constant elasticity of substitution between the inputs, which is especially relevant to the study area, where the assumption of diminishing marginal returns is frequently observed, consistent with the empirical findings of similar studies (Kazeem, 2020).

Additionally, the flexibility of the Cobb-Douglas model to incorporate different types of inputs—such as labor, land, and capital—further enhances its applicability in a wide range of agricultural contexts (Dait, 2003). Given these advantages, the adoption of the Cobb-Douglas production function in this study is employed by its theoretical soundness, empirical relevance, and practical utility in understanding agricultural production dynamics. Cobb-Douglas Production Function takes the form $Y = A \cdot K^\alpha \cdot L^{1-\alpha}$, where Y is the output, A is total factor productivity (TFP), K is the capital input, L is the labor input, and α is the output elasticity of capital, with $0 < \alpha < 1$.

According to Coelli et al. (2005), this specification incorporates an error term consisting of two components: one to accommodate random effects and the other to address technical inefficiencies. The aforementioned model can be formulated as:

$$Y_i = f(X_i; \beta) + \varepsilon_i \quad (1)$$

where: Y_i represents the output of the i -th farm, X_i is a vector consisting of functions that describe the actual input values used by the i -th farm. The vector β represents the parameters that need to be estimated, while the error term ε_i is a composite term defined as:

$$\varepsilon_i = v_i - u_i \quad (2)$$

where v_i captures the statistical noise which is assumed to be normally distributed while U_i is the random error associated with technical inefficiency and assumed to be $iidN^+(0, \sigma_U^2)$.

The observed production of the i -th firm, denoted as Y_i^* , has been adjusted to account for the stochastic noise captured by v_i .

$$Y_i^* = Y_i - v_i = f(X_i; \beta) - u_i \quad (3)$$

Equation 4 captures the farm-specific technical inefficiency in production. The terms δ_i and ω_i respectively denote parameters to be estimated and unobservable random variables assumed to be independently distributed.

$$u_i = \delta_j \sum_{j=1}^{12} Z_j + \omega_i \quad (4)$$

The Cobb-Douglas production function, which is linear in parameters upon logarithmic transformation, was estimated using MLE techniques. The form used for this study is specified as follows:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 D_6 + \varepsilon_i \quad (5)$$

where: Y is the farmer's output in kilogram per hectare (kg/ha); X_1 is seed quantity (kg/ha); X_2 is fertilizer amount (kg/ha); X_3 represents pesticide costs in Philippine Pesos per hectare (PhP/ha); X_4 indicates fuel and machinery rental costs (PhP/ha); and X_5 is labor input (man-days/ha). The dummy variable which was represented by D denotes hybrid rice utilization during the dry season (1 = hybrid, 0 = otherwise) and flooding during the wet season (1=affected by flood, 0=otherwise).

Global Moran's index (error) test and KNN parameter optimization

The Moran's Index (I) test was used to validate the existence of spatial interaction in the data sets. The significant Moran's I result suggests the necessity to further characterize and explain the specific characteristics of geographical dependency. The formula for the univariate Moran's I statistics is as follows:

$$I = \frac{n}{S_0} x \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2} \quad (14)$$

or in matrix form:

$$I = \frac{n}{S_0} x \frac{x'Wx}{x'x} \quad (15)$$

where:

x is an $(n \times 1)$ vector of observation x_i measured in deviation from the mean $\bar{x}$;

W is a weight matrix, which is a symmetric matrix with $(n \times n)$ element w_{ij} representing the distance or closeness of farm i with farm j ; and

S_0 is the sum of the elements of the spatial weight matrix.

The Euclidean distance formula, $d_{ij} = [(x_i - x_j)^2 + (y_i - y_j)^2]^{1/2}$, was used to measure the distance between a farm and its neighboring farm. The variables x_i and y_i represent the coordinates of the farmland. Thus, the study employed K-Nearest Neighbor (K-NN) to generate spatial weight matrices, which represented the spatial relationships between observations by determining the closest neighbors (k) for each given location in the dataset. This technique facilitated the creation of a spatial weights' matrix. By selecting a fixed number of k for each observation, the method effectively captured spatial dependencies for a particular community (Ahmed et al., 2023). Hence, Moran's I error test was used to analyze how different values of K affect the spatial clustering of the data. It aimed to look for the k -value that minimizes the error and maximizes the spatial coherence in the model. In terms of K-NN, spatial correlogram was used to identify significant points or values (thresholds) in the model that show spatial dependence of farmer's technical inefficiency. Moran's I test and spatial correlogram were done using R and MS excel, respectively. Furthermore, the study employed QGIS software to visually represent how farmers cluster through spatial patterns of rice productivity and inefficiency levels across farmland locations for both seasons.

Results and Discussion

Table 1 presents the summary statistics of the variables used in the stochastic frontier analysis (SFA) and technical inefficiency models for both the dry and wet season. For the production function, the dependent variable in the production frontier is rice yield (kg/ha). On average, rice yield is substantially higher during the dry season (2,499 kg/ha) compared to the wet season (1,692 kg/ha), suggesting more favorable production conditions during the dry months. Among the input variables, the average seed quantity used per hectare is also higher in the dry season (73 kg/ha) than in the wet season (59 kg/ha), which may reflect adjustments in seeding practices due to seasonal differences in water availability. The application of nitrogen fertilizer follows a similar pattern, with 116 kg/ha in the dry season and 93 kg/ha in the wet season. Pesticide expenses are notably higher during the dry season, likely due to increased pest pressure in drier conditions, averaging PhP 2,876/ha compared to PhP 2,297/ha in the wet season. Fuel and machinery rental costs, serving as a proxy for mechanization, are also greater in the dry season, averaging PhP 4,848/ha, contrary to PhP 3,880/ha in the wet season. Meanwhile, labor input is more intensive in the dry season (54 man-days/ha) compared to the wet season (43 man-days/ha), due to differences in land preparation and pest control requirements for each season.

In terms of dummy variables, about 33.63% of farmers used hybrid rice varieties, while the remaining 66.37% used inbred or other traditional varieties. Additionally, 51.75% of farmers reported experiencing flooding, indicating vulnerability to seasonal disruptions. The expected signs for production inputs such as seed, nitrogen, pesticide, fuel, and labor were positive, as increased input use is generally associated with higher yield. Likewise, hybrid rice adoption was expected to increase productivity. Flooding, however, was expected to have a negative impact on yield.

Table 1. Summary of the descriptive statistics for Cobb-Douglas production function

Variable	Unit and Description	Mean for Continuous Variables (Std. Dev.)		Dummy Variables		Expected Sign for Independent Variables
		Dry season	Wet season	Freq.	%	
Yield	Rice output in kilogram per hectare	2,499 (1,256)	1,692 (828)			
Seed quantity (kg)	Seed quantity in kilogram per hectare	73 (8)	59 (6)			+
Nitrogen quantity	Nitrogen amount in kilogram per hectare	116 (14)	93 (11)			+
Pesticide	Pesticide costs in Philippine Pesos per hectare (PhP/ha)	2,876 (1,712)	2,297 (1,364)			+
Fuel and Machinery	Fuel and machinery rental costs per hectare in Philippine Pesos (PhP/ha)	4,848 (3,186)	3,880 (2,538)			+
Labor input (man-days)	Man-days per hectare	54 (11)	43 (9)			+
Hybrid (1-hybrid:0-otherwise)						+
1: Hybrid rice farmer				38	33.63	
0: Non-hybrid rice farmer				75	66.37	
Flooding (1: Affected by flooding:0-otherwise)						–
1: Affected by flooding				59	51.75	
0: Not affected				55	48.25	

Table 2 shows the technical inefficiency model incorporating farmer and farmland-specific variables that may explain deviations from the production frontier. The average age of respondents is 56 years, and their average rice farming experience is 32 years, indicating a mature and experienced farming population. Farmers have completed an average of 6 years of formal education, which is slightly below high school level. In terms of gender distribution, the majority of respondents are male (85.09%), while females account for 14.91%. The average household monthly income is PhP 17,337.72, suggesting moderate income levels. Farmers reported seven contacts per year with agricultural technicians, which reflects access to extension services. However, variation is observed in network size, with farmers reporting an average of 22 peers in their agricultural network. Only 37.72% of farmers attended technical training, while the rest did not, highlighting a gap in formal skills upgrading. Regarding environmental and infrastructure variables, 68.42% of respondents experienced saltwater intrusion on their farms, while only 37.72% reported having adequate irrigation water supply.

Table 2. Summary of the descriptive statistics for technical inefficiency function

Variable	Unit and Description	Mean for Continuous Variables (Std. Dev.)	Dummy Variables		Expected Sign for Independent Variables
			Freq.	%	
Age	Age of farmer in years	56 (13)			+
Farming Experience	Rice farming experience of farmer in years	32 (14)			-
Education	Years of farmer's formal education	6 (3)			-
Gender (1: Male: 0-otherwise)					
1: Male			97	85.09	
0: Female			17	14.91	
Household Income	Total Household monthly income of farmer in PhP	17,338 (8,847)			-
Technical Advisory Support	Number of contacts with a technician in a year	7 (5)			-
Network	Number of friends in social network	22 (16)			-
Training (1- farmer attended technical training: 0- otherwise)					
1: attended training			43	37.72	

O: not attended	71	62.28	
Saltwater intrusion (1- farmer experienced soil salinity: 0-otherwise)			+
1: With saltwater intrusion on farmlands	78	68.42	
0: Without saltwater intrusion	36	31.58	
Access to irrigation system (1- farmer experienced adequacy in irrigation water: 0-otherwise)			-
1: Sufficiency irrigation water	43	37.72	
0: Insufficient irrigation water	71	62.28	

Results of Cobb-Douglas production function

Table 3 presents the results of the stochastic frontier analysis for both the production function and technical inefficiency models. The estimates were generated separately for the dry and wet seasons to account for seasonal differences in input use and farm conditions. In the dry season, key production inputs were found to significantly affect rice yield. The coefficient for seed input (0.349) was positive and statistically significant at the 5% level, indicating that increased seed use is associated with higher productivity. Fertilizer input also showed a significant positive effect (0.335, $p < 0.05$), suggesting its critical role in nutrient management during drier months. Most notably, the coefficient for machinery input was both large and highly significant (0.618, $p < 0.01$), underscoring the contribution of mechanized operations in enhancing production efficiency during the dry season. In contrast, during the wet season, only the quantity of seeds and nitrogen had a positive and significant effect on rice yield, indicating that higher application of these inputs will increase yield. On the other hand, the negative coefficient of flooding (-0.154 , $p < 0.05$) highlights the detrimental impact of excess water and flooding on rice yields.

On the other hand, technical inefficiency model showed several variables influencing the inefficiency of rice farmers. In the dry season, the frequency of contact with agricultural technicians significantly reduced technical inefficiency (-0.391 , $p < 0.01$), demonstrating the value of extension support in improving production decisions. Similarly, access to adequate irrigation water was associated with lower inefficiency (-1.506 , $p < 0.10$), emphasizing the importance of reliable irrigation infrastructure, particularly in dry season. In the wet season, the frequency of contact with agricultural technicians remained a significant and negative determinant (-0.507 , $p < 0.01$), reaffirming the role of extension services in both seasonal conditions. However, soil salinity worsens inefficiency (2.192, $p < 0.01$), which could be due to the adverse effects of saltwater intrusion during periods of elevated groundwater and rainfall, which are more common in the wet season (Dam, et al., 2019).

Table 3. Results of the stochastic production and technical inefficiency models using Cobb-Douglas production function

Variables	Cabusao=114			
	Dry		Wet	
	Mean S.D.	Standard Error	Coefficient	Standard Error
Production function				
Constant	1.7107	0.8395	8.3496***	1.3177
Seeds	0.3488 **	0.1490	0.1688	0.0388*
Fertilizer	0.3348**	0.1557	0.1966	0.1017*
Machinery	0.6177***	0.0671	0.0546	0.0625
Labor	-0.3778	0.1290	-0.0656	0.1663
Hybrid seeds	0.0572	0.0481	0.0614	0.0782
Flooding			-0.1543**	0.0679
Technical Inefficiency Function				
Constant	2.0285	7.0277	5.4839	5.4436
Age	0.0028	0.0336	0.0045	0.0270
Experience	0.0136	0.0304	-0.0153	0.0293
Education	0.3149	0.1031	-0.1224	0.0816
Gender	-0.0539	0.5482	-0.2641	0.5286
Household income	-0.2269	0.7562	-0.3345	0.5777
Size of social network	-0.0640	0.0798	-0.0008	0.0327
Frequency of contact with agricultural technicians	-0.3907***	0.1170	-0.5071***	0.1545
Trainings	0.2378	0.5051	0.0545	0.4311
Soil Salinity	0.8514	0.5768	2.1919***	0.7233
Irrigation water adequacy	-1.5064 *	0.8163	-0.1952	0.5615
Wald chi ²	161.67		112.79	
Prob chi ²	0.0000		0.0000	
Log likelihood	14.00		-93.97	

Note: *** statistical significance at $P \leq 0.010$ level, ** statistical significance at $P \leq 0.050$ level, and * statistical significance at $p \leq 0.10$ level.

Technical efficiency scores of rice farms

Technical efficiency of rice farms was examined to determine the capacity of farmers to produce maximum amount of output given the available bundle of inputs. During the dry season, there were 50 farmer-respondents whose technical efficiency score ranged from 0.90 to 0.99. It is also notable that there were 30 farmers in the wet season with lower technical efficiency level (0 to 0.49 range) than those in the dry season. The minimum TE in the wet season was 0.15, which is notably lower than the dry season's 0.31. The mean TE during the dry season was 0.81, which is significantly higher than the average of 0.69 as seen during the wet season.

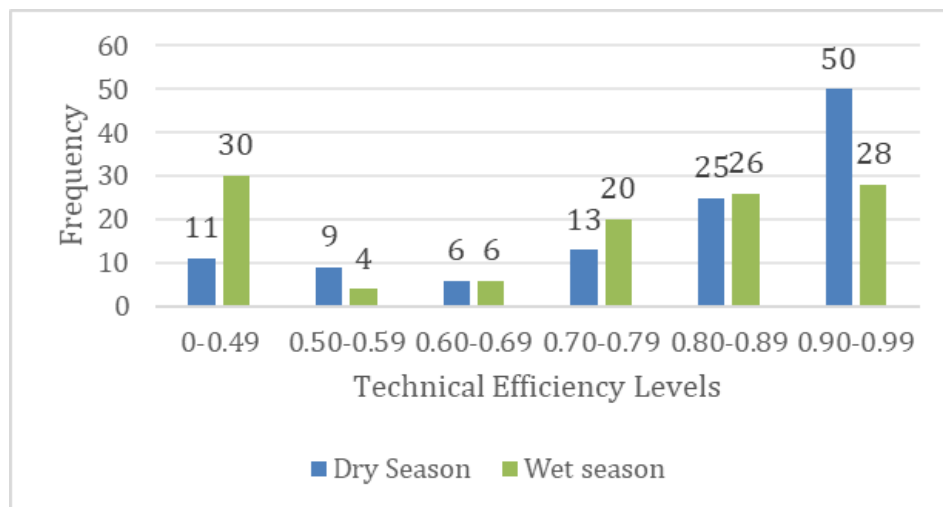


Figure 1. Illustration of technical efficiency levels across seasons

Moran's I and K-nearest neighbor

To ensure the robustness of neighborhood structure in the model, spatial weight matrices were generated using KNN method. By selecting a fixed number of nearest neighbors for each observation, the method effectively captured spatial dependencies for a small rice farming community, which were critical for analyzing variations in technical efficiency and productivity. The choice of spatial weight matrix plays a critical role in detecting the presence and strength of spatial autocorrelation wherein the number of neighbors (k) was varied from 1 to 20. The results consistently yielded statistically significant Z-scores for both dry and wet seasons, indicating strong spatial dependence across varying neighbor structures. Notably, the Z-scores peaked around $k = 11$ for the dry season ($Z = 8.82$ and at $k = 16$ for the wet season ($Z = 12.53$). These findings suggest that technical inefficiency among rice farmers exhibits strong spatial dependence, particularly when 16 nearest neighbors are considered.

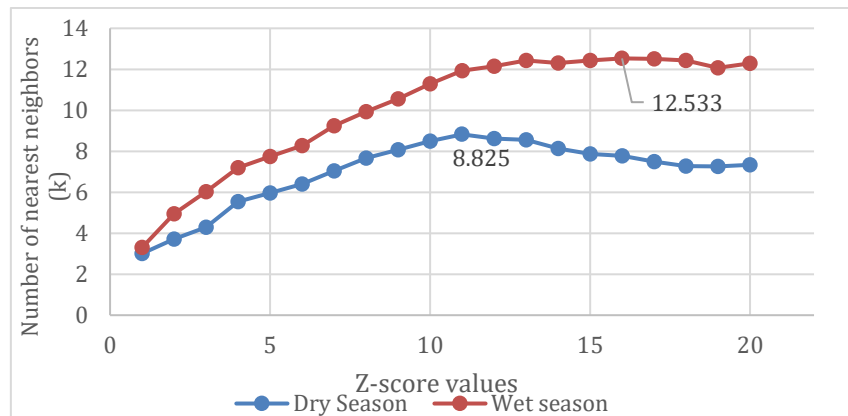


Figure 2. KNN and Moran's I Z-scores across seasons

Geospatial analysis of rice productivity and inefficiency scores

Figure 3 illustrates the interdependence and relationship of farmers using farmland's locations using the nearest neighbors of 16. The plot displays a complex network with interconnected lines and dots, which indicates a highly interconnected network of farmers or a strong spatial dependence. This means that each farmer's efficiency is influenced by that of their neighbor's. Efficient practices, innovations, and knowledge can spread easily through these connections, improving overall efficiency. When farmers are neighborhood, they are more likely to collaborate, share information about irrigation water management techniques, and discuss challenges they face, leading to the spillover effect of knowledge (Pede et al., 2018). This social interaction fosters mutual support among farmers where innovations, such as water-saving irrigation methods or crop management strategies, can be adopted more readily. This provides a good basis for crafting policy strategies in improving farmers' connectivity and efficiency.

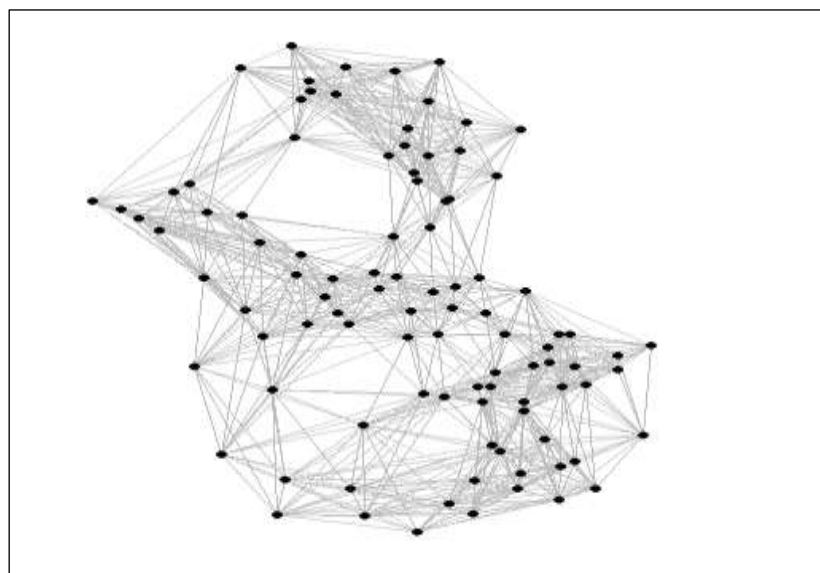


Figure 3. Visual illustration of 16-nearest neighbor

Rice productivity mapping analysis

Although $K = 16$ was confirmed as the most robust specification for spatial econometric analysis, $K = 4$ was selected for spatial visualization to ensure clearer and more explainable mapping of farmer interconnections. This simpler neighborhood structure minimizes visual clutter and enhances communicability of local spatial patterns. Figures 4.B and 4.B shows the spatial distribution and productivity levels of rice during the dry and wet seasons revealing notable differences in agricultural output across the irrigation canals and neighboring production areas.

In the dry season, the areas exhibiting the highest productivity levels (3,495–8,333 kg/ha, represented in deep pink) are more spatially widespread, notably concentrated around the intersections of Laterals C2A, C2B, and C1, and within the K-Nearest Neighbor clusters. These high-productivity zones are prominent in the central part of the irrigation system, where connectivity to the irrigation laterals appears denser and more structured. In contrast, low-yielding areas (500–1,704 kg/ha, shown in smaller pink points) are fewer and located mostly at the peripheries of the lateral systems, possibly indicating weaker irrigation access or suboptimal conditions. Conversely, areas situated near the swamp zone and at the periphery of Lateral C1X exhibit relatively lower productivity, indicating possible environmental constraints or limited access to resources. Conversely, areas situated near the swamp zone and at the periphery of Lateral C1X exhibit relatively lower productivity, indicating possible environmental constraints or limited access to resources.

Conversely, during the wet season, productivity significantly decreases, with the highest range (2,497–4,200 kg/ha) covering a much smaller area compared to the dry season. The distribution of productivity classes appears more fragmented, with larger portions of the area falling within the lower productivity ranges (350–1,496 kg/ha). The clusters near the swamp area and along Sinibaam Creek show consistently lower yields in the wet season, potentially due to flooding or excessive water retention, which hampers rice growth.



Figure 4.A. Rice productivity map in irrigated farmlands of CSVFIA, dry season

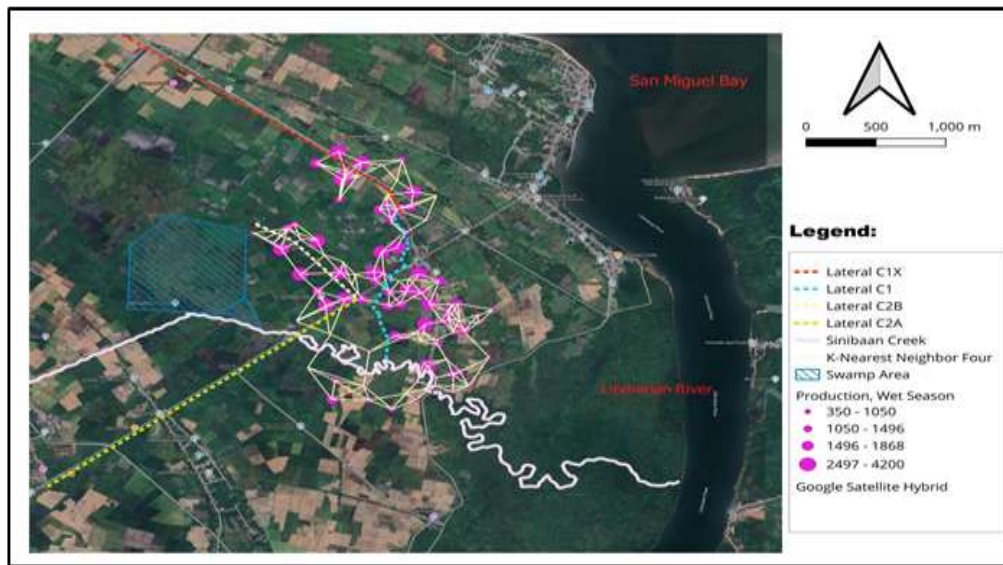


Figure 4.B. Rice productivity map in irrigated farmlands of CSVFIA, wet season

Technical inefficiency mapping analysis

Figures 5.A and 5.B illustrate spatial comparison of technical inefficiency scores revealing distinct seasonal disparities in production efficiency across seasons. During the dry season, the inefficiency levels ranged widely from 0 to 0.624, with clusters of higher inefficiency (0.285–0.624) appearing more prominently along Lateral C1 and C2A, particularly in farms adjacent to the swamp area and downstream of Sinibaan Creek. The spatial connectivity indicated by the KNN algorithm suggests that inefficiency may be spatially correlated, potentially due to shared access constraints or similar agronomic practices across neighboring farms. In contrast, farms along Lateral C2B and near the upper segment of Lateral C1X demonstrated notably lower inefficiency levels (0–0.074), suggesting more efficient practices or better-managed irrigation during the dry season. Similarly, in the wet season, more areas experienced moderate to high inefficiency (0.259 to 0.838 levels), particularly in farms located near Sinibaan Creek and farther south of the Libmanan River and western swamp area. This seasonal condition may reflect the influence of increased rainfall, flooding risks, and salinity during the wet months, affecting even previously efficient farms. Interestingly, central and northern clusters marked by lower inefficiency levels (ranging from 0.001 to 0.144), highlighting a consistent high productivity with the dry season. This suggests that stable environmental condition, access to adaptive technologies, and irrigation infrastructure significantly influence the seasonal efficiency of rice production. Identifying and targeting these spatial inefficiency hot spots for intervention could optimize resource use and improve year-round productivity (Mamiit,2022).



Figure 5.A. Technical Inefficiency map in irrigated farmlands of CSVFIA, dry season

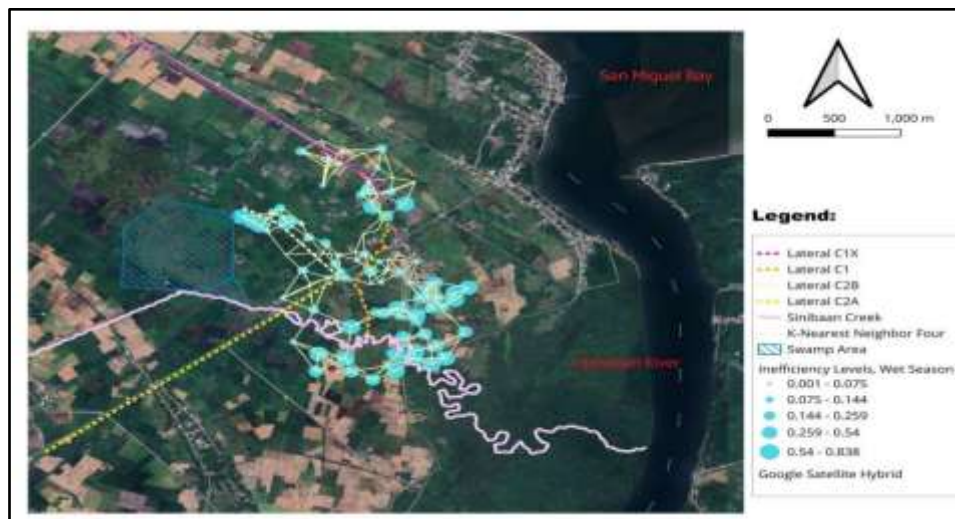


Figure 5.B. Technical Inefficiency map in irrigated farmlands of CSVFIA, wet season

Conclusion

This study investigated the determinants of rice production and technical inefficiencies among farmlands during the dry and wet cropping seasons using Cobb-Douglas production function. Comparative analysis of seasonal results suggests that the dry season offers more predictable responses to input use, with significant gains achievable through fertilizer application, seed quantity, and mechanization. Meanwhile, wet season inefficiency is more sensitive to environmental factors such as flooding and salinity. Notably, frequent engagement with agricultural technicians consistently emerged as a key factor in reducing inefficiency across both seasons. Geospatial productivity maps

show that rice yields are generally higher and more spatially widespread during the dry season, with production ranging from 500 to 8,333 kg/ha, compared to the wet season where yields range from 350 to 4,200 kg/ha, with a concentration in lower production clusters which reflect the underlying changes in efficiency patterns across seasons. This finding aligns with the observed spatial clustering of inefficiencies, which was influenced by irrigation canal networks and environmental conditions in the area. These findings imply that policies aimed at improving rice productivity should prioritize strengthening technical assistance support to enhance farmers' knowledge of farming technologies and investing in irrigation systems to ensure a reliable water supply throughout the year.

References

- Ahmed, M. S., N'diaye, M., Attouch, M. K., & Niange, S. D. (2023). K-nearest neighbors prediction and classification for spatial data. *Spatia1 Econometrics*, 4(12). <https://doi.org/10.1007/s43071-023-00041-2>.
- Benedetti, R., Piersimoni, F., & Postiglione, P. (2015). Sampling Spatial Units for Agricultural Surveys. *Springer Berlin Heidelberg*. <https://doi.org/10.1007/978-3-662-46008-5>.
- Bhatt, D., Kundu, A., Dey, A., Mall, R.K., & Raju, K.N.P. (2021). Water Resources Management for Irrigated Agriculture in Perspective of Geospatial Techniques. In: Adhikary, P.P., Shit, P.K., Santra, P., Bhunia, G.S., Tiwari, A.K., Chaudhary, B.S. (eds) *Geostatistics and Geospatial Technologies for Groundwater Resources*. Springer Hydrogeology. Springer, Cham., 551-566. https://doi.org/10.1007/978-3-030-62397-5_28
- Cañete, D. C., & Temanel, B. E. (2017). Factors Influencing Productivity and Technical Efficiency of Rice Farmers in Isabela, Philippines. *Journal of Advanced Agricultural Technologies*, 4(2). 10.18178/JOAAT.4.2.111-122.
- Coelli, T., Rao, D.S. P., O'Donnell, C. J., & Battese, G. E. (2005). An Introduction to Efficiency and Productivity Analysis (T. J. Coelli, Ed.; 2nd ed.). Springer. <https://dl.icdst.org/pdfs/files/3a67240be4e2274e4c95655ec16931de.pdf>
- Dait, J. M. G. (2023). A Panel Data Study on Factors Affecting Rice Production in the Philippines. *Universal Journal of Agricultural Research*, 11(3), 547-557. 10.13189/ujar.2023.110305.
- Dam, T. H. T., Babu, T. A., & Muller, K. (2019). Paddy in saline water: Analysing variety-specific effects of saline water intrusion on the technical efficiency of rice production in Vietnam. *Outlook on Agriculture*, 48(3), 237-245. <https://doi.org/10.1177/0030727019850841>.
- German, J. D., Redi, A. A. N. P., & Ilagan, J. B. (2022). Factors of Rice Productivity: A Case Study in Central Luzon, Philippines. WCSE 2022 Spring Event: 2022 9th International Conference on Industrial Engineering and Applications. 10.18178/wcse.2022.04.148.

- Kazeem, A. (2020). Economic Efficiency of Rice Farming: A Stochastic Frontier Analysis Approach. *Journal of Agribusiness and Rural Development*, 4(58), 423-435. doi: 10.17306/J.JARD.2020.01377.
- Inocencio, A. B., & Inocencio, A. D. (2020). Assessing the Resurgent Irrigation Development Programm of the Philippines: Synthesis Report. Discussion Papers DP 2020-21, Philippine Institute for Development Studies. <https://pidswebs.pids.gov.ph/CDN/PUBLICATIONS/pidsdps2021.pdf>.
- Mamiit R., Yanagida J., Miura T. (2021). Productivity Hot Spots and Cold Spots: Setting Geographic Priorities for Achieving Food Production Targets. *Frontiers in Sustainable Food System*, 5. doi: 10.3389/fsufs.2021.727484.
- Ozsahin, E., Sari, H., & M, O. (2022). Determination of suitable lands for rice cultivation in Edirne plain: GIS supported FAO limitation method. *Paddy Water Environ*, 325-338. <https://doi.org/10.1007/s10333-022-00895-6>.
- Pede, V., Areal, F., Singbo, A., Mckinley, U. (2018). Spatial dependency and technical efficiency: an application of a Bayesian stochastic frontier model to irrigated and rainfed rice farmers in Bohol, Philippines. *Agricultural Economics, International Association of Agricultural Economists*, 49(3), doi: 301-312. 10.1111/agec.12417.
- Philippine Rice Research Institute (PhilRice) (2024). *Profile of the Filipino Rice Farmer. The Rice Data Analytics Dashboard*. <https://www.philrice.gov.ph/ricelytics/profilemain>.
- Som-ard, J. (2020). Rice Security Assessment Using Geo-Spatial Analysis. *International Journal of Geoinformatics*, 16(1). https://www.researchgate.net/publication/339844815_Rice_Security_Assessment_Using_Geo-Spatial_Analysis
- Tobore, A., Senjobi, B., Ogundiyi, T., & Bamidele, S. (2021). Geospatial assessment of wetland soils for rice production in Ajibode using geospatial techniques. *Open Geosciences*, 13(1), 310-320. <https://doi.org/10.1515/geo-2020-0227>

Farmers' Understanding and Adapting: Cabbage Production and Weather Variation in Southern Shan State of Myanmar

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Abstract

Cabbage production in Southern Shan State, a vital part of Myanmar's vegetable supply, is vulnerable to fluctuating temperatures and rainfall. Without a clear understanding of how weather factors affect their crops, cabbage farmers would face significant losses. This study aimed to understand farmers' awareness and perception of temperature and rainfall changing over the past decade and their adaptation strategies to increase cabbage productivity. Total 150 cabbage farmers in Pindaya and Kalaw townships, Southern Shan State were individually interviewed during November to December 2024, by using purposive and simple random sampling methods. The collected data were analyzed using descriptive statistics and awareness index. According to the findings, majority of sample cabbage farmers recognized temperature and rainfall fluctuations along the decade, therefore, they had a high level of awareness. They particularly perceived about rising temperatures, frequent flooding, higher rainfall intensity, and an increase in the numbers of rainy days over the past ten years. Farmers identified that these weather variations particularly affected the vegetative, flowering and harvesting stages of cabbage production. Despite perceiving weather variations, about one-third of the sample cabbage farmers used adaptation strategies such as engaging in non-farming activities, changing cropping pattern, and adjusting cultural practices like growing different crop varieties, changing sowing dates and pesticide application rates. Therefore, enhancing educational initiatives supported by the public sector to improve farmers' knowledge of adaptation strategies will help increase their resilience to weather variations in cabbage production in the study area of Myanmar.

Keywords: awareness, adaptation strategies, cabbage, perception, Myanmar

JEL code: D24, Q54, Q56

SDG classification: SDG 12, SDG 13, SDG 15

Introduction

Myanmar being as a mainly agriculture-based country is extremely vulnerable to the effects of rising temperatures, erratic rainfall, and extreme weather events. Myanmar's agricultural sector encompassing crops, livestock and fishery sub sectors, contributed 23.7% of Gross Domestic Product (GDP), 28.79% of total export earnings in 2022-2023, and labor force participation rate, in general, was 61.13% of the total labor force (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2023). Because agriculture is one of the most climate dependent human activities and it relies on hydro-climatic conditions, it is particularly sensitive to extreme weather events, rising temperatures, and changes in precipitation (Yi et al., 2012; NAPA, 2012; Tun Oo et al., 2020).

During 2021-2022, more than 61 kinds of crops were cultivated under the different topography, climate and soil types of Myanmar. Cultivated crops included various kinds of cereals, oilseeds, pulses, industrial crops, culinary crops and fruits and vegetables. Total sown areas of Myanmar were about 19,756 thousand hectares and cereal crops took the largest share, 41.35% followed by shares of pulses and oilseed crops which were about 20% and 16.86% respectively among the country's total sown areas in 2022-2023. In addition, fruits and vegetables occupied about 15.06% of total sown areas while industrial crops and culinary crops shared very few percentages of total sown areas (MOALI, 2023).

Horticultural crops including fruit and vegetable production in Myanmar were promoted as a mean to increase farmers' incomes and to develop rural areas. Particularly productions of high yielding vegetable crops with short productive cycle were supported as means of increasing food and nutrition security and providing sustainable employment to a large number of farm families in both rural and urban areas. Production of vegetables could bring abundant economic and social benefits like the best resource for overcoming micronutrient deficiencies, providing farmers with higher incomes as well as creating more jobs per hectare than staple crops (Morris & Mar Lar Soe, 2021).

Vegetable crops are particularly sensitive to increasing temperatures, which can directly impact their yield. Recent studies conducted within the last decade around the world revealed that about 51% of vegetable productivity would be decreased due to climatic variations (Dumitru et al., 2023; Payen et al., 2015). Effects of weather and climatic factors on vegetable productions vary depending on the geographical context, type of vegetables and growing conditions (Eduard et al., 2023). Alterations in rainfall and temperature can impact the lifecycle of pests, yield and the quality of vegetables (Garrett et al., 2006). It is important to understand how weather and climatic factors could affect various types of vegetable crops (Smith & Olesen, 2010). Understanding vegetable crops' sensitivity to weather variations are crucial for adaptation strategies against future environmental challenges (Scheelbeek et al., 2010).

Myanmar's total vegetable cultivation in 2022-2023 reached 612,838 hectares, of which cabbage's sown areas representing as the third-largest portion of total vegetable' areas in Myanmar after tomato and mustard (Department of Agriculture [DOA], 2023). Cabbage belongs to the *Brassica* genus, it is an essential item on the Myanmar dining table and can be consumed fresh in salads or cooked in various dishes, both the outer green leaves and soft white heart (MOALI, 2023). Cabbage is an important vegetable crop in terms of its high production and consumption due to its ability to adapt to grow in different

climatic conditions and soil types. Regarding the fact that cabbage needs optimum agroclimatic conditions during growing period for better yielding results. In comparison with other vegetables, cabbage which could help in providing food, human nutrition and supporting local economies can be produced not only in highlands but also in lowland areas of Myanmar. Cabbage can be year-round cultivated in Shan State of Myanmar; however, it can also be grown in the lowlands particularly during winter season.

Growth, development, and productivity of cabbage are significantly influenced by weather factors, particularly temperature and rainfall (Bute et al., 2021; Erken & Yildirim, 2019; Silva et al., 2017; Soengas et al., 2018). Weather conditions and other factors are relating with yield of cabbage in Myanmar. Regional annual mean temperatures and precipitation are needed to take into consideration for production of cabbage (Medic-Pap et al., 2019). Extreme temperatures (exposure to cold and heat), water stress and amount of rainfall during the entire vegetation period affect cabbage yield and quality (Bute et al., 2021; Erken & Yildirim, 2019; Soengas et al., 2018). Optimum cabbage crop development occurs under more or less precisely determined environmental conditions. Unsuitable growing conditions cause stress and affect plant growth and productivity (Cervenskl, 2022). Water stress that exceeded 30% during cabbage production significantly decreased the yield and quality of cabbage. Weather conditions greatly affect cabbage production, primarily plant growth, occurrence and development of diseases, harmful insects, and weeds. Extreme temperatures (exposure to cold and heat) affect cabbage photosynthetic activity and yield (Soengas et al., 2018). To reduce weather vulnerability and adapt to changing weather factors, awareness and understanding of current weather trends are critical (Thant et al., 2022). The farmer's behaviour towards weather variations is likely shaped by their perception of observed weather and weather risk (Mertz et al., 2009). Therefore, understanding of farmers' awareness and perception of changing weather variations are correlating with the productions of the crops.

Cabbage production in Southern Shan State, a vital part of Myanmar's vegetable supply, is vulnerable to fluctuating temperatures and rainfall. If cabbage productions are adversely affected by temperature and rainfall, the farmers of this crop will be at risk. Without a clear understanding of how weather factors affect their crops, cabbage farmers would face significant losses. To respond to the adverse effects of weather variation, there is a need to apply the appropriate adaptation practices for enhancing productivity. The effectiveness of adaptation strategies highly depends on an understanding of the people's awareness and perception of weather variation in order to reduce their vulnerability and increase resilience. Therefore, this study aimed (1) to understand cabbage farmers' awareness and perception of temperature and rainfall changing over the past decade in Southern Shan State and (2) to investigate the adaptation strategies of cabbage farmers to increase cabbage productivity against changes in temperature and rainfall.

Methodology

Shan State in Myanmar was a leading cabbage producing region, with 9,161 hectares dedicated to the crop in 2022-2023. Of with, the Southern Shan State was the largest contributor, holding over half of the total area at 5,368 hectares (58.6%). It was followed by the Northern which covered approximately 2,529 hectares (27.61%) and the Eastern,

with about 1,264 hectares (13.8%) (DOA, 2023). Therefore, the study was carried out in the Southern Shan State. Pinlaung, Pindaya and Kalaw Townships occupied the top cabbage growing areas in Southern Shan State, the latter two were chosen in the study due to their large sown areas of cabbage and feasible conditions for data collection.

During November to December 2024, primary data collection with a total of 150 sample farmers was conducted in two designated townships, with 75 farmers chosen from each. The purposive sampling method was initially used to identify the cabbage farmers in each township, followed by simple random sampling among cabbage farmers. Each sample farmer was individually interviewed with a set of structured questionnaires to get demographic characteristics such as age, gender, education level, marital status, and family size; farm characteristics such as farm size, farming experience, sown area, yield and sources of weather information, farmers' awareness and perception of changes in temperature and rainfall on cabbage production.

To know about "do sample farmers recognize the change in temperature (changes in daytime and nighttime temperature), rainfall (changes in rainfall intensity, rainy days, rainfall pattern and duration of rainy day) and droughts or floods, individual sample farmers were interviewed firstly with "Yes or No" questions. Continuously, if the sample farmers answered as "Yes," she or he were also be asked whether their perception on changes in temperature and rainfall was increasing or decreasing or neutral conditions. Farmers were also asked to identify which growth stage among seedling, vegetative, flowering and harvesting stages was particularly affected by temperature and rainfall variations during the cabbage- growing season.

The existing adaptation practices of sample farmers such as adjustment of planting and harvesting dates, change in varieties, use of plastic house technology, mulching and shading, changes in use of amount of inputs (seed rate, fertilizer, weedicide and pesticide), change in irrigation methods, change in other crops and sown areas, and non-farm activities were also collected. Thereafter, farmers were identified into (i) farmers who adopted cultural practice strategy, (ii) farmers who adopted crop diversification and land management strategy, and (iii) farmers with livelihood diversification strategy based on their adaptation practices.

Demographic and farm characteristics, farmers' perception of change in temperature and rainfall, recognition of most affected crop growth stages, and adaptation strategies of cabbage farmers were analysed by using descriptive analysis. Awareness about changes in temperature and rainfall was calculated as an index score by using a set of statements based on the experiences of cabbage farmers along with 11 statements by five-point Likert scale. These statements were mentioned in Tables 1 and 2.

Table 1. Farmers' awareness of changes in temperature based on their experiences (within ten years)

No.	Statements
1	Temperature is changing
2	Temperature is increasing
3	Changes in temperature cause the incidence of pests in cabbage productions

- 4 Changes in temperature cause the incidence of diseases in cabbage productions
- 5 Changes in temperature lead to variations in quality of cabbage
- 6 Changes in temperature cause the reduction of quality of cabbage
- 7 Changes in temperature lead to variation in quantity of cabbage
- 8 Changes in temperature cause the reduction of quantity of cabbage
- 9 Changes in temperature lead to variation in ripening period of cabbage
- 10 Changes in temperature lead to variation in agronomic practices cabbage
- 11 Changes in temperature lead to decreasing in earnings from cabbage productions

Table 2. Farmers' awareness of changes in rainfall based on their experiences (within ten years)

No.	Statements
1	Rainfall is changing
2	The amount of rainfall is decreasing
3	Changes in rainfall cause the incidence of pests in cabbage productions
4	Changes in rainfall cause the incidence of diseases in cabbage productions
5	Changes in rainfall lead to variation in quality of cabbage
6	Changes in rainfall cause the reduction of quality of cabbage
7	Changes in rainfall lead to variation in quantity of cabbage
8	Changes in rainfall cause the reduction of quantity of cabbage
9	Changes in rainfall cause plants death and damage
10	Changes in temperature lead to variation in agronomic practices cabbage
11	Changes in temperature lead to decreasing in earnings from cabbage productions

Cronbach's alpha, a measure of internal consistency; that is, how close a set of items is related as a group was used to examine the strength of the interior flexibility and reliability of the awareness statements. The level of awareness on each given statement was scored as "5 point" for "Strongly agree", "4 point" for "Agree", "3 point" for "Neither agree nor disagree", "2 point" for "Disagree", and "1 point" for "Strongly disagree". Then the respondents' minimum, maximum possible and actual score and the awareness index were calculated by using the following formula developed by Hubert and Schultz (1976). Finally, three different ranges of awareness indices were categorized with frequency distribution as high awareness (0.70 to 1.00), medium awareness (0.35 to 0.69) and limited awareness (0.00 to 0.34).

$$\text{Awareness Index} = \frac{\text{Sum of scores} - \text{minimum possible score}}{\text{Differences between maximum and minimum possible score}}$$

Results and Discussion

Demographic and farm characteristics of sample farmers

Male dominated farming activities in the study areas were found because about 59% of sample farmers were male and the remaining 41% were female. The majority which was more than 90% of sample farmers were married, as shown in Figure 1.

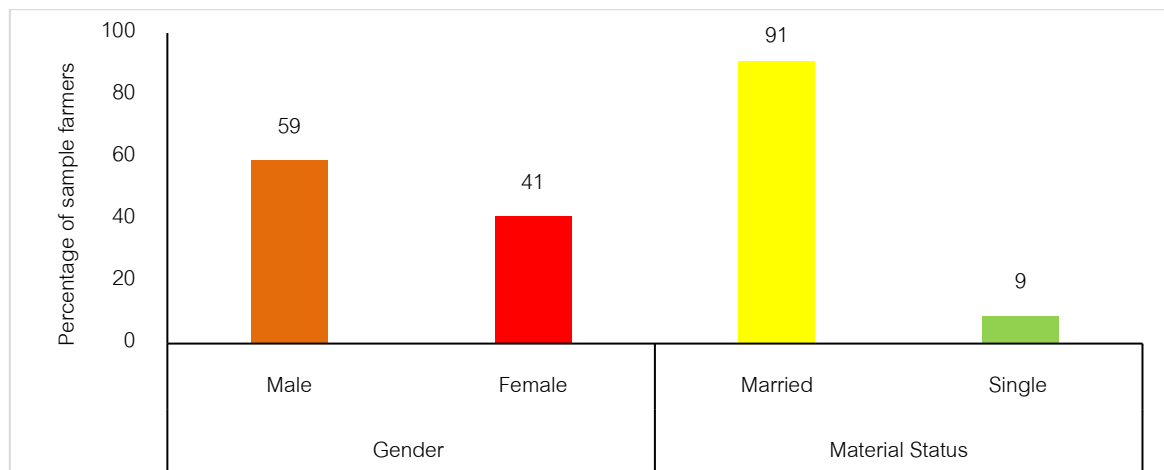


Figure 1. Proportions of gender and marital status of sample cabbage farmers (n=150)

Demographic characteristics of sample cabbage farmers were illustrated in Table 3. Average age of sample farmers was 44 years which indicated that they fell within active age for agricultural production. Sample farmers experienced an average of 23 years in farming, ranging from a minimum of 4 years to a maximum of 50 years. This implied that the farmers were anticipated to have high levels of local weather knowledge because most of them had been in the farming experience for more than half of their lives. Despite the education is directly related in understanding of new technology, the concept of weather changes, and the adoption of adaptation practices towards weather variation, the findings indicated that sample farmers had secondary education level with an average of 5 schooling years.

Table 3. Demographic characteristics of sample cabbage farmers (n=150)

Items	Unit	Average	Minimum	Maximum	SD
Age	Years	44	22	74	11.99
Education	Years	5	1	15	2.72
Farm experience	Years	23	4	50	11.13
Family size	No.	5	2	9	1.18

Sample cabbage farmers primarily owned the farm size averaging 1.96 hectares, ranging a minimum of 0.20 hectare and a maximum of 15.18 hectares. Share of upland ownership took the largest portion of total farm size. Sample farmers cultivated cabbage about 0.45 hectare in average within a range of minimum 0.20 hectare to maximum 2.02 hectares

in the study area. Average yield of cabbage per hectare of land was 5.09 MT within the lowest 2.37 MT and the highest 6.52 MT, as shown in Table 4.

Table 4. Farm characteristics of sample cabbage farmers (n= 150)

Items	Unit	Average	Minimum	Maximum	SD
Farm size	ha	1.96	0.20	15.18	
Upland	ha	1.79	0.20	10.12	4.50
Lowland	ha	0.17	0.00	4.86	1.28
Garden	ha	0.00	0.00	0.00	0.82
Cabbage farming					
Sown area	ha	0.45	0.20	2.02	0.24
Yield	MT/ha	5.09	2.37	6.52	0.90

Sources of weather information

Availability and accessibility of information on weather change are assumed to be key determinants of the extent of farmer awareness, understanding and knowledge of weather change impacts (Ajayi, 2014). Figure 2 showed that sources of weather information received by the sample cabbage farmers in the study areas. A significant portion which was about 43.33% of sample cabbage farmers received weather information through a combination of multiple sources including farmers-to-farmers, TV broadcasting channels, mobile phone and social media. The remaining 16.67%, 15.33% and 7.33% of sample farmers obtained weather information from a single source such as mobile phone, TV broadcasting channels, social media respectively. Despite farmers had accessibility of weather information from various sources, this study underlined the absence of sample farmers who got access to weather information from agricultural extension services.

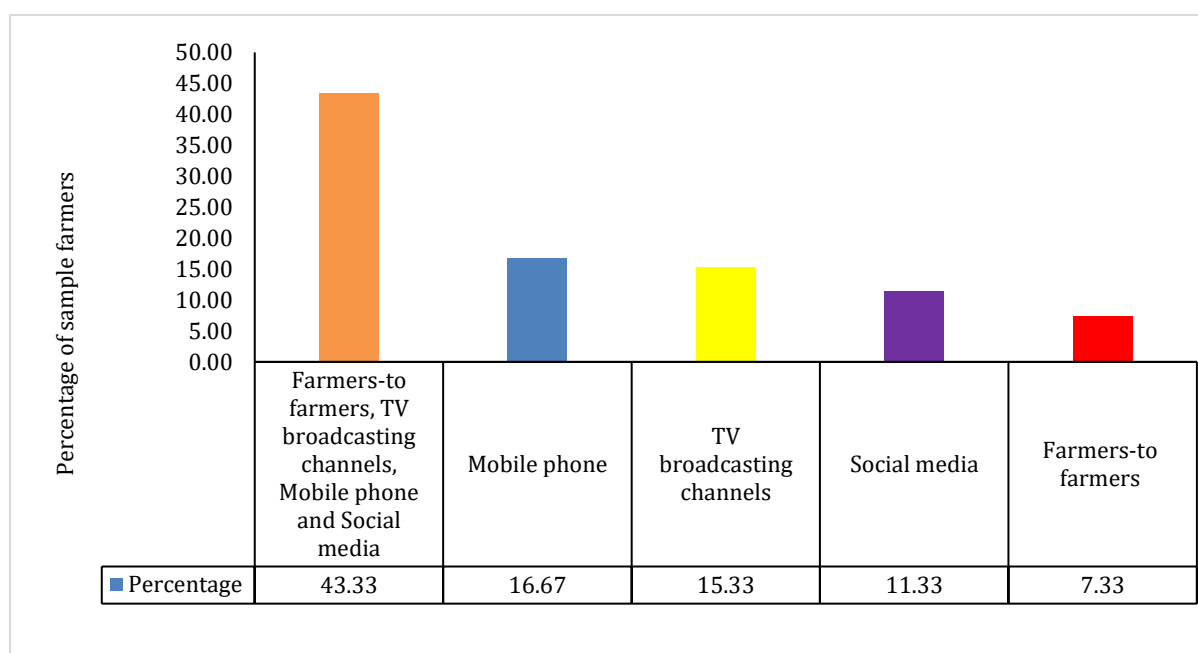


Figure 2. Source of weather information received by sample cabbage farmers (n=150)

Farmers' awareness of temperature and rainfall changes

The awareness of sample cabbage farmers on the temperature and rainfall changes during the last 10 years was shown in Table 5. Cronbach's alpha for the statements which measured the farmers' awareness of changes in temperature and rainfall were 0.71 and 0.80 respectively, indicating that the measurement was reliable and fit to continue the index calculation.

Table 5. Awareness of sample farmers on temperature and rainfall changes during the past 10 years (2014 to 2024) (n=150)

Item	Freq. (%)	Awareness Index		
		Average	Range	SD
Temperature				
Farmers with high awareness	144.00 (96.00)	0.87	0.70 - 1.00	0.86
Farmers with medium awareness	6 .00 (4.00)	0.64	0.69 - 0.35	0.54
Farmers with limited awareness	0.00	0.00	0.00 - 0.34	
Rainfall				
Farmers with high awareness	144.00 (96.00)	0.88	0.70 - 1.00	0.80
Farmers with medium awareness	5.00 (3.00)	0.63	0.69 - 0.35	0.63
Farmers with limited awareness	1.00 (1.00)	0.20	0.00 - 0.34	

The findings observed that almost all 96.00% of sample cabbage farmers had a high awareness level on changes in both temperature and rainfall, revealing their awareness indice 0.87 for temperature and 0.88 for rainfall in average. A very small percentages of farmers showed medium awareness (about 4.00% of sample farmers for temperature and 3.00% of sample farmers for rainfall), reporting the awareness indice, 0.64 and 0.63 for temperature and rainfall, respectively. Only about 1.00% of sample farmers had limited awareness on rainfall changes with an index value 0.20, while none of the sample farmers displayed limited awareness of temperature changes during a decade. The findings revealed that majority of sample cabbage farmers had strong understanding of temperature and rainfall changes over the past ten years, signifying a high degree of awareness.

Farmers' perceptions on changes in temperature and rainfall

As illustrated in Table 6, regarding farmers' perception of weather variability on their cabbage farming, most farmers perceived a substantial shift in temperature and rainfall distributions that had taken place over the past ten years.

Table 6 Farmers' perceptions of change in temperature and rainfall within the past 10-years (n=150)

Farmers' perception	Yes		Increased		Constant		Decreased	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Changes in daytime temperature	107	71.33	87	58.00	19	12.67	1	0.67
Flood events	104	69.33	84	56.00	19	12.67	1	0.67
Changes in rainfall intensity	103	68.67	86	57.33	12	8.00	5	3.33
Changes in nighttime temperature	102	68.00	72	48.00	26	17.33	4	2.67
Changes in rainy day	101	67.33	82	54.67	18	12.00	1	0.67
Changes in rainfall pattern	96	64.00	73	48.67	14	9.33	8	5.33
Drought events	86	57.33	53	35.33	28	18.67	5	3.33
Changes in duration of rainy day	81	54.00	62	41.33	16	10.67	3	2.00

Approximately 71.33% of sample farmers specifically noticed changes in daytime temperature, with about 58% of these reporting increases in daytime temperature during a decade. Similarly, around 68% of sample farmers perceived changes in nighttime temperature and about 48% of them recognized that there were increases in nighttime temperature during a decade. Furthermore, about 69.33%, 68.67% and 67.33% of sample farmers perceived more frequent flood events, altered rainfall intensity and changes in the number of rainy days in their areas during a decade. Notably, a majority of sample farmers indicated that flood events and rainfall intensity had increased, along with an increase in the numbers of rainy days over the past ten years. Moreover, about

64% and 54% of sample farmers perceived changes in rainfall pattern and duration of raining days within the past decade, with most observing an increasing trend. Similarly, about 57.33% of sample farmers perceived drought events, with majority of them reporting an increase in drought events during a decade. These findings suggested that the majority of sample farmers perceived an increasing trend in both temperature and rainfall over the last ten years.

Effects of temperature and rainfall variations on growth stages of cabbage

Rainfall variation affected more than half (over 55%) of sample farmers, whereas temperature changes impacted about 39.33% of sample farmers in their cabbage production. Notably, the vegetative stage of cabbage was most affected by temperature variations, as reported by roughly 53.13% of sample farmers. Moreover, about 29.69%, 10.94% and 6.25% of sample farmers indicated that temperature affected the seedling, flowering and harvesting stages of cabbage, respectively. Unlike temperature variations, changes in rainfall had the most significant impact on the flowering and harvesting stages, affecting 35.16% and 36.26% of sample farmers, respectively. The vegetative stage and the seedling stage were least damage from rainfall during the cabbage growth cycle, reporting 17.58% and 10.99% of sample farmers, respectively.

The findings revealed that sample cabbage farmers encountered the most significant temperature-related challenges during the vegetative stage and the biggest rainfall-related problems during the flowering and harvesting stages. This highlighted a considerable effect on both the plant's reproductive development of cabbage and its final yield.

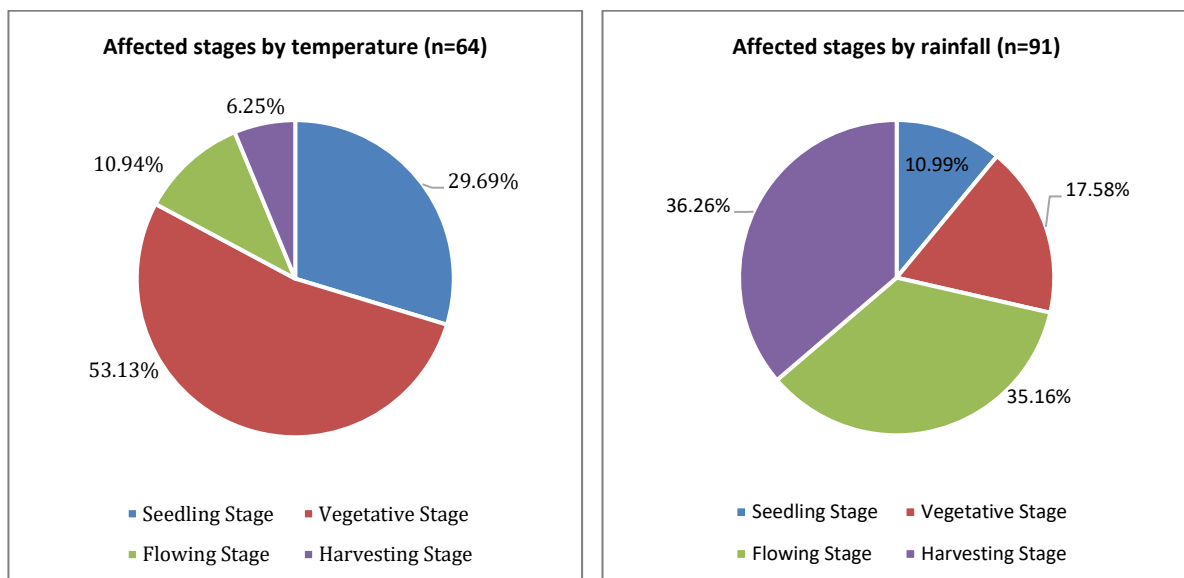


Figure 3 Various cabbage growth stages affected by temperature and rainfall changes during monsoon season of 2024-2025

Adaptation strategies for cabbage production to variability of temperature and rainfall

The three adaptation practices employed by sample farmers in response to changing temperature and rainfall: cultural practices, cropping system management, and livelihood diversification. Farmers were denoted as adopters of cultural practices if they employed two or more of the nine listed adaptation methods. Similarly, adoption of cropping system management strategy meant when sample farmers used at least one of the three specified adaptation practices. Farmers engaging in any non-farming activities were considered adopters of the livelihood diversification strategy.

One-third of the sample cabbage farmers implemented all three adaptation strategies. Specifically, adoption rates were 34% of sample farmers for cultural practices, 36% of sample farmers for cropping system management strategy, and 43% of sample farmers for livelihood diversification strategy. Among these three adaptation strategies, engaging in non-farming activities, changing cropping pattern, growing different crop varieties, altering sowing dates and pesticide application rates were the most prevalent practices adopted by cabbage farmers.

Table 9. Adaptation strategies of cabbage farmers against changes in temperature and rainfall (n=150)

Adaptation strategies	Farmers	
	Freq.	%
Adaptation of Cultural practices	51	34.00
Changes in used of varieties	46	30.67
Changes in sowing date	33	22.00
Changes in used of amount of pesticide	33	22.00
Changes in harvesting date	25	16.67
Changes in used of amount of fertilizer	21	14.00
Changes in used of irrigation methods	20	13.33
Changes in used of amount of weedicide	15	10.00
Changes in used of seed rate	10	6.67
Changes in used of plastic house technology/ mulching and3 shading technology		2.00
Adaptation of Cropping system management	54	36.00
Changes in other crops	45	30.00
Changes in sown areas	16	10.67
Lease out your own areas	12	8.00
Adaptation of Livelihood diversification	63	42.00
Working any non-farm activities along with cabbage farming	63	42.00

Conclusions

The sample farmers were predominantly male, with an active average age, substantial cabbage farming experiences and secondary education level. This demographic profile suggested a potential advantage in accessing information and enhanced opportunities for developing resilience against weather change. A significant proportion of cabbage farmers in the study areas accessed weather information through a combination of TV broadcasting channels, farmer networks, social media, and mobile phone. The lack of information dissemination from agricultural extension services underscored a potential weakness in formal agricultural support channel intended to enhance farmers' awareness and understanding of weather change.

The findings revealed that a high level of awareness regarding temperature and rainfall changes among the majority of sample farmers over the past decade. Most of sample cabbage farmers perceived significant changes in both temperature and rainfall patterns over the past decade, predominantly noting an increasing trend in daytime and nighttime temperatures, flood events, rainfall intensity, the number of rainy days, and drought occurrences. This widespread understanding and intense perception of recent weather variations within their farming community likely forms a crucial foundation for farmers' adaptation strategies and responses to ongoing environmental changes.

The findings also underscored the significant vulnerability of cabbage production in monsoon season of 2024-2025 to both temperature and rainfall variations. Regarding the temperature and rainfall variations across different growth stages of cabbage, over half of the sample cabbage farmers were most experiencing the temperature related issues during the vegetative growth stage. Conversely, about one-third of farmers were affected the rainfall-related issues during the flowering and harvesting stages. This indicated that a substantial proportion of sample cabbage farmers were affected by temperature and rainfall changes, highlighting the need for strategies to mitigate these effects and ensure stable productivity of cabbage in the study areas.

In response to weather-included changes, farmers have implemented various adaptation strategies to mitigate this effect. Notably, about one-third of sample farmers have adopted cultural practices, cropping system management, and livelihood diversification. The most common adaptation methods included engaging in non-farming activities, altering cropping patterns, adopting different crop varieties, adjusting planting schedules, and optimizing pesticide usage. These adaptation practices indicated that the sample cabbage farmers were proactively adapting to changing environmental conditions and to maintaining their productivity.

Cabbage farmers in the study areas were experiencing significant effects from temperature and rainfall variations, despite possessing considerable farming experience and awareness of weather changes. There is a clear need for improved access to reliable weather information, particularly from the public agricultural extension services, to enhance farmers' adaptive capacity. Therefore, to further strengthen their efforts, improve farmer's knowledge of adaptation strategies and mitigate the adverse effects of weather changes on sustainable cabbage productions, targeted extension services and resources such as enhancing educational initiatives and technologies advancements should be directly provided by the public sectors, especially in the study areas of Myanmar.

References

- Ajayi, J. O. (2014). Awareness of climate change and implications for attaining the Millennium Development Goals (MDGs) in Niger Delta Region of Nigeria. *Agris on-line Papers in Economics and Informatics*, 6(1), 3-11.
- Bute, A., Iosob, G. A., Antal-Tremurici, A., Brezeanu, C., Brezeanu, P. M., Cristea, T. O., & Ambăruș, S. (2021). The most suitable irrigation methods in cabbage crops (*Brassica oleracea* L. var. capitata): a review. *Scientific Papers. Series B. Horticulture*, 65(1).
- Cervenski, J., Vlajic, S., Ignjatov, M., Tamindzic, G., & Zec, S. (2022). Agroclimatic conditions for cabbage production. *Ratarstvo i povrtarstvo*, 59(2), 43-50.
- Department of Agriculture. (2023). Official data records from Ministry of Agriculture, Livestock and Irrigation (MOALI), Myanmar.
- Dumitru, E. A., Berevoianu, R. L., Tudor, V. C., Teodorescu, F. R., Stoica, D., Giuca, A., & Sterie, C. M. (2023). Climate change impacts on vegetable crops: a systematic review. *Agriculture*, 13(10), 1891.
- Erken, O. K. A. N., & Yildirim, M. (2019). Yield and quality compounds of white cabbage (*Brassica oleracea* L. cv. Capitata) under different irrigation levels. *Journal of Agricultural Science and Technology*, 21(5), 1341-1352.
- Garrett, K. A., Dendy, S. P., Frank, E. E., Rouse, M. N., & Travers, S. E. (2006). Climate change effects on plant disease: genomes to ecosystems. *Annu. Rev. Phytopathol.*, 44(1), 489-509.
- Hubert, L., & Schultz, J. (1976). Quadratic assignment as a general data analysis strategy. *British journal of mathematical and statistical psychology*, 29(2), 190-241.
- Medi-Pap, S., Cervenski, J., & Danojevic, D. (2019). Preventive measures as a tool for environment-friendly vegetable production in suburban areas. In *Proceedings, 23rd International Eco-Conference-13th Environmental protection of urban and suburban settlements, 25-27 September 2019, Novi Sad* (pp. 154-162). Novi Sad: Ecological movement of Novi Sad.
- Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental management*, 43, 804-816.
- Ministry of Agriculture, Livestock and Irrigation. (2023). Myanmar Agricultural sector in brief. 2023.
- Morris, S., & Mar Lar Soe. (2021). Myanmar's vegetable sector: opportunities and challenges for smallholder farmers. East-West Seed.
- National Adaptation Programme of Action (NAPA). (2012). The Myanmar National Adaptation Programme of Action (NAPA) to climate change, Nay Pyi Taw, Myanmar. Received from: <http://unfccc.int/resource/docs/napa/mmr01.pdf>
- Payen, S., Basset-Mens, C., & Perret, S. (2015). LCA of local and imported tomato: an energy and water trade-off. *Journal of Cleaner Production*, 87, 139-148.

- Scheelbeek, P. F., Moss, C., Kastner, T., Alae-Carew, C., Jarmul, S., Green, R., & Dangour, A. D. (2020). United Kingdom's fruit and vegetable supply is increasingly dependent on imports from climate-vulnerable producing countries. *Nature food*, 1(11), 705-712.
- Silva, R. S., Kumar, L., Shabani, F., & Picanço, M. C. (2017). Assessing the impact of global warming on worldwide open field tomato cultivation through CSIRO-Mk30 global climate model. *The Journal of Agricultural Science*, 155(3), 407-420.
- Smith, P., & Olesen, J. E. (2010). Synergies between the mitigation of, and adaptation to, climate change in agriculture. *The Journal of Agricultural Science*, 148(5), 543-552.
- Soengas, P., Rodriguez, V. M., Velasco, P., & Cartea, M. E. (2018). Effect of temperature stress on antioxidant defenses in Brassica oleracea. *ACS omega*, 3(5), 5237-5243.
- Thant, P. S., Espino, A., Soria, G., Myae, C., Rodriguez, E., Barbon, W. J., & Gonsalves, J. (2022). Myanmar local food systems in a changing climate: Insights from multiple stakeholders. *Environmental and Sustainability Indicators*, 14, 100170.
- Tun Oo, A., Van Huylenbroeck, G., & Speelman, S. (2020). Measuring the economic impact of climate change on crop production in the dry zone of Myanmar: A Ricardian Approach. *Climate*, 8(1), 9.
- Yi, T., Hla, W. M., & Htun, A. K. (2012). *Drought Conditions and Management Strategies in Myanmar; Report Prepared for United Nations-Water; Department of Meteorology and Hydrology: Yangon, Myanmar, 2012; 9p.*

Crop Diversification as a Response to Market and Climate Risks in Ilocos Norte, Philippines

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Abstract

Farming systems are vulnerable to climate change evident through extreme heat that cause declining water level availability for irrigation. Also, market uncertainties such as abrupt price fluctuations cause much losses to farmers. Therefore, farmers are encouraged to diversify crop production. This study aimed to determine crop combinations that will yield high profit for farmers and economical utilization of natural resource endowments during dry season in selected towns in the province of Ilocos Norte, Philippines. The equi-marginal principle was employed to analyze the marginal or incremental benefit in producing each crop. Optimization through linear programming revealed that the dry season farmers should adjust their crop diversification management to maximize their profit. Considering resource constraints, it is profitable to produce garlic and onion in Badoc and garlic and tomato in Vintar, Ilocos Norte. It is recommended that there should be more support in the agriculture sector in terms of weather forecasting, planning and programming of crop production, and market linkaging. The water conservation practices such as recommended duration of irrigating and the quantity thereof should also be determined and disseminated through extension services to assist farmers. Appropriate local pricing policies and strategic provision of farm input subsidies to minimize expenses should also be implemented.

Keywords: climate resilience, crop diversification, multiple cropping, off-season farming, vegetables

JEL code: M11, Q12, Q13

SDG classification: SDG 11, SDG 12, SDG 13

Introduction

The rice-based farming systems are predominant in Ilocos Norte, Philippines. During dry season, farmers produce variety of vegetable crops. In the past few years, climate change greatly affected farming systems in terms of extreme drought. Its occurrence lowers water level needed for irrigating the crops. Therefore, this affects plant growth, level of production, quality of produce and pricing thereof. To address adverse hazards which farming systems are vulnerable to, farmers are encouraged to take measures such as integrated and sustainable farming system. In turn, this will also benefit them in terms of aversion of market risks due to abrupt fluctuations in pricing of their produce. However, crop selection and minimal support from the government pose issues that make dry season crop production highly risky for farmers. To maximize production benefits, the most profitable crop combinations for diversification is very essential.

This study aimed to determine the most profitable crop diversification practices during dry season in selected towns in the province of Ilocos Norte, Philippines. Specifically, the study aimed to do ascertain what crops are suitable for dry season production in Ilocos Norte, estimate the profitability of producing various crop combinations per production period; and come up with results-based policy recommendations that would support the enhancement of income of the farmers from off-season crops. This study will mainly benefit farmers in various villages sharing similar characteristics. This aims to increase the benefits they derive from their vital roles in the food systems.

Theoretical Framework

The neo-classical economists' equi-marginal principle of resource allocation (to consumption and production activities) is well-known in economics. It demonstrated that this principle implies an efficient and linear optimal allocation (Mishra, 2017).

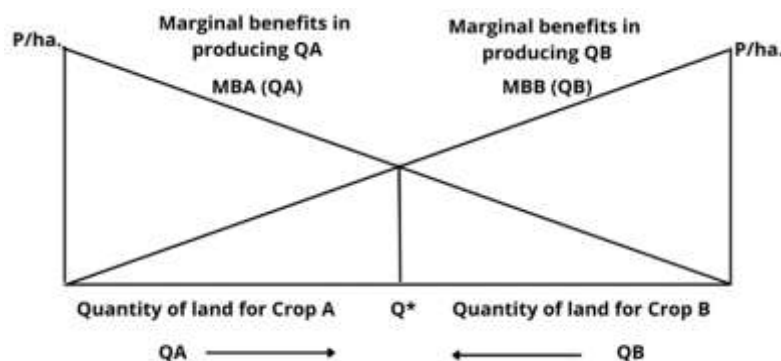


Figure 2. Quantity of land available for crop production = Q^*

Figure 2 depicts the model of optimal cropland allocation utilizing a simple example wherein there are only two potential productive uses—crop A and crop B. It is assumed that all areas for either use is employed for production. The width of the horizontal axis (Q^*) shows the total land area in a specific period. It is assumed that this is a "static" one-period problem for simplicity. The land area cannot be saved for the next period (i.e., use it or lose it), so the issue is how to utilize it in its best use during the period. The vertical

axis on the left-side measures the benefit of producing crop A while the vertical axis on the right-side measures the benefit of producing crop B. The values per unit of land are expressed as PhP/ha. The MBA(QA) curve represents the marginal or incremental benefit in producing per unit of crop A measured from left to right on the horizontal axis. On the other hand, the MBB (QB) curve represents the marginal or incremental benefit in producing per unit of crop B measured from right to left.

In this one-period case, the land uses are mutually exclusive (e.g., each land unit is not a public good that can be enjoyed by more than one user at a time). Thus, the constraint is that the combined land use for the two crop production options must not exceed the total available land area:

$$Q_A + Q_B \leq Q^* \quad (1)$$

When all the available land is utilized and the two marginal benefit curves cross (i.e., the marginal benefits are equal in both lands), the ideal land allocation is illustrated by the land usage combination of Q_A^* and Q_B^* , such that:

$$MBA(Q_A^*) = MBB(Q_B^*) \quad (2)$$

$$Q_A^* = Q - Q_B^* \quad (3)$$

The entire combined value of the land for the two purposes is maximum at this optimal allocation (e.g., the total area under the two marginal benefit curves is maximized). This also describes the equi-marginal principle, which states that the optimal allocation of a scarce resource will be made when the marginal benefits of competing uses are equal.

The opportunity cost of land use is a key trade-off concept for land valuation that is highlighted in one-period optimization. Utilizing a unit of land for one crop means giving up the advantages of utilizing that land for another crop when land uses are mutually exclusive, as they are in this case. The opportunity cost is the value of this forgone benefit. Subsequently, the marginal benefit of land use for producing crop A (e.g., MBA) is the marginal opportunity cost of land use for producing crop B. If there are greater than two alternative land uses, the marginal opportunity cost of land use for one crop is equal to the maximum marginal benefit of land use in any of the other crops that can be produced.

The data were taken from both primary and secondary sources. The secondary data were gathered from official reports of government agencies (e.g., PSA, DA, OPAG and LGUs) and journal articles from scientific research. Moreover, the crop suitability and groundwater availability maps of the Department of Agriculture were used as reference. For the primary data, surveys were conducted. An informed consent were secured prior to surveys. The translated questionnaires were used for the farmers for more accurate data gathering. Request letters to gather the needed data were forwarded to the concerned office heads of the provincial government and LGUs. The location of the participants were determined through coordination with the local government authorities.

The optimal allocation of croplands were determined through surveys to gather quantitative data from the farmers in the study areas. The information gathered from the farmers include their sociodemographic profile, farm size, crop production system, yields, quantity of production inputs and costs (such as capital, pesticides and fertilizer, labor requirements), and other relevant data. Linear programming was employed for the quantitative data analysis. Furthermore, profitability analysis was performed to determine

the magnitude of benefits that the crop producers can derive between alternatives to come up with logical conclusions and sound policy recommendations. The Microsoft Excel software's Solver was used as analysis tool.

The stratified random sampling method was used in this study. The farmers from the identified major producing towns were the primary participants. Using the Cochran's formula, about 81 farmers (49 from Vintar and 32 from Badoc) were targeted as participants in this study. Those who practice simultaneous production of the three crops was the inclusion criteria while those that practice monocropping during dry season was the exclusion criteria for the participants in the study.

Methodology

The study was conducted from January to March 2025 in the towns of Vintar and Badoc in the province of Ilocos Norte, Philippines. These were selected because there are high volume of crops produced in the areas, particularly garlic, onion, and tomato. According to the latest data from the High-Value Commercial Development Program (HVCDP) of the Province of Ilocos Norte, these three crops belong to the top ten crops with the greatest number of producers. Furthermore, such crops are included in the government investment priorities, specifically indicated in the Provincial Commodity Investment Plan of the Philippine Rural Development Project.



Figure 1. Map of the province of Ilocos Norte, Philippines

Model formulation

This section includes mathematical notations for optimization using the Microsoft Excel Software since it is user-friendly yet it can generate reliable results. Table 1 contains the description of the variables and subscripts.

Table 1. Description of the variables and subscripts

Variable/ subscript	Meaning	Measurement
T	Area of land for planting tomato	Hectare (ha.)
G	Area of land for planting garlic	Hectare (ha.)
S	Area of land for shallot onion	Hectare (ha.)
B	Area of land for planting crop 2	Hectare (ha.)
D	Area of land for planting crop 3	Hectare (ha.)
c	Production cost per hectare planted with crop	US Dollars (\$)
C	Total crops production cost	US Dollars (\$)
w	Volume of irrigation and cost per hectare planted with crop	Millimeter (mm)
W	Total volume of water and cost for crops irrigation	Millimeter (mm)
m	Yield per crop per hectare	Metric tons (mt)
M	Maximum attainable yield for all crops produced	Metric tons (mt)
a	Land area for crop production	Hectare (ha.)
A	Total land area available for crop production	Hectare (ha.)

Behavioral objectives and constraints

Farmers are assumed to have the following objectives: maximize profit (Π), minimize input cost (I), and maximize food production (F). These are mathematically expressed as follows:

Maximize Profit (4)

$$\text{Max } \Pi = y_1 T_1 + y_2 B_2 + y_3 D_3$$

Subject to:

$$c_1 T_1 + c_2 B_2 + c_3 D_3 \leq C \quad (\text{Financial Constraint})$$

$$w_1 T_1 + w_2 B_2 + w_3 D_3 \leq W \quad (\text{Environmental Constraint})$$

$$m_1 T_1 + m_2 B_2 + m_3 D_3 \leq M \quad (\text{Economic Constraint})$$

$$\text{Max } \Pi = y_1 G_1 + y_2 B_2 + y_3 D_3 \quad (5)$$

Subject to:

$$c_1 G_1 + c_2 B_2 + c_3 D_3 \leq C \quad (\text{Financial Constraint})$$

$$w_1 G_1 + w_2 B_2 + w_3 D_3 \leq W \quad (\text{Environmental Constraint})$$

$$m_1 T_1 + m_2 B_2 + m_3 D_3 \leq M \quad (\text{Economic Constraint})$$

$$\text{Max } \Pi = y_1 S_1 + y_2 B_2 + y_3 D_3 \quad (6)$$

Subject to:

$$c_1 S_1 + c_2 B_2 + c_3 D_3 \leq C \quad (\text{Financial Constraint})$$

$$w_1 S_1 + w_2 B_2 + w_3 D_3 \leq W \quad (\text{Environmental Constraint})$$

$$m_1 T_1 + m_2 B_2 + m_3 D_3 \leq M \quad (\text{Economic Constraint})$$

The profit maximization involves determining the profit from producing tomato, garlic and shallot onion subject to constraints such as limited capital and water for irrigation. Further, there is also a maximum attainable yield given a specific variety of seed, technology and technical efficiency level. The crops produced on-farm are valued at the farm-gate prices. However, the profit will be calculated through computing the difference between the total revenue less total cost incurred from crop production. The total income should be enough to cover production expenses.

Results and Discussion

It was found that most of the farmers in the two areas plant the combination of garlic and onion. Farmers prefer onion due to its short production period, which is 45 days, and it is easy to maintain.

Table 2. Crop mix choices of farmers in Ilocos Norte, Philippines.

Crop Mix	Badoc		Vintar	
	Frequency (n=31)	Percentage (%)	Frequency (n=49)	Percentage (%)
Garlic, Onion, Tomato	4	12.90	14	28.57
Garlic and Onion	14	45.16	30	61.22
Garlic and Tomato	1	3.23	1	2.04
Onion and Tomato	12	38.71	4	8.16

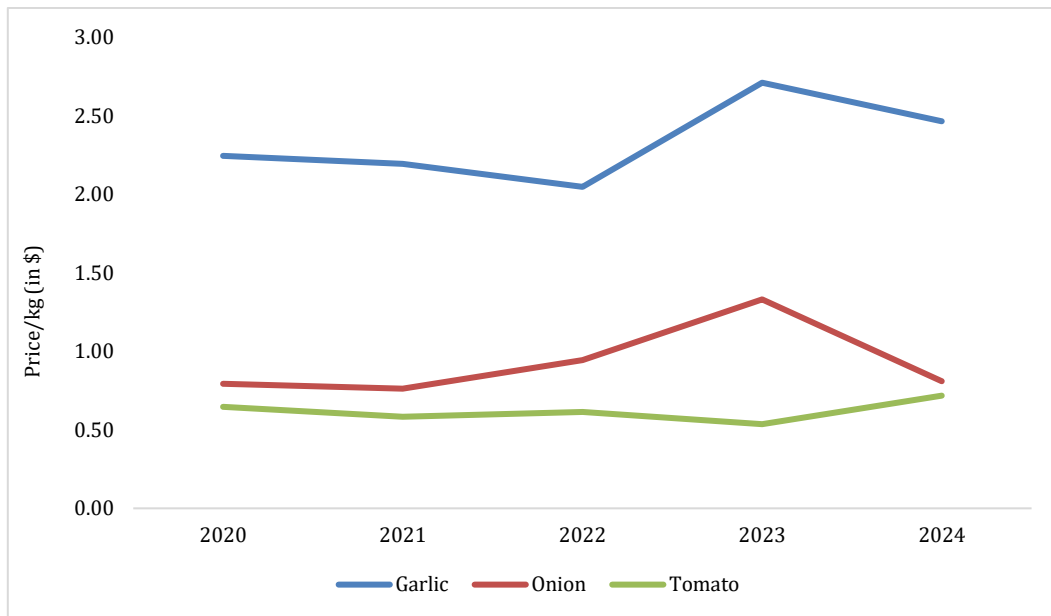


Figure 2. Price/kilogram of garlic, onion, and tomato for the last 5 years (2020-2025) in Ilocos Region, Philippines

Data Source: Philippine Statistics Authority and Bangko Sentral ng Pilipinas

Considering market, onions have lower prospect of high profit due to more production from other provinces and low market and bargaining power. Onion requires less irrigation, but they diversify due to high profit expectation, they copy the plants of neighbors, and it is their traditional crop with sure market. In both municipality, water level is declining, and it was reported as a problem.

Conclusion

The conclusion should be explained clearly with suggestions/recommendations placed after it which can be of use to readers/consumers.

- i. Crop diversification is a good practice, however, consider irrigation problem, there should be more support from the government to regulate markets and provide more irrigation support and price of inputs.
- ii. Timely input provision
- iii. Planning, programming or crop production
- iv. Irrigation conservation
- v. Cropping calendar thru coordination between weather and climate experts for projections with farmers.

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References

- Adebayo, T. S. (2020). New insights into export-growth nexus: Wavelet and causality approaches. *Asian Journal of Economics, Business and Accounting*, 15(2), 32-44.
- Bernanke, B., Gertler, M., & Gilchrist, S. (1999). *The financial accelerator in a quantitative business cycle framework* (NBER Working Paper 6455). Cambridge, MA: National Bureau of Economic Research.
- Ayadi, R., Arbak, E., Naceur, S.B., & Groen, W.P.D. (2015). Determinants of financial development across the Mediterranean. In R. Ayadi, M. Dabrowski, & L. D. Wulf (Eds.), *Economic and social development of the southern and eastern Mediterranean countries* (pp. 159-181). Cham: Springer International Publishing.
- Todaro, M. P., & Smith, S. C. (2020). *Economic development* (13th ed.). London: Pearson.

Developing A Highland Community's Sustainable Indicators Under the Operation of Royal Project Foundation, Thailand

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Abstract

This study develops sustainable indicators for highland communities under the Royal Project Foundation in Thailand, aligning with the Sustainable Development Goals (SDGs). The research employs a systematic approach involving a literature review, stakeholder consultations, and field testing in two pilot areas: Pang Da Royal Agricultural Station and Mae Hae Royal Project Development Center. As a result, 51 indicators were identified and categorized into four dimensions: economic, social, environmental, and infrastructure, along with 20 sub-dimensions. Each indicator is assessed using predefined evaluation criteria, classifying community sustainability into four levels: A (very good), B (good), C (fair), and D (poor). The findings reveal challenges in data collection, particularly for economic and environmental indicators, which require substantial resources and technical expertise. This proposed framework serves as a practical tool for the Royal Project Foundation to systematically assess community development, enabling the identification of areas and issues requiring strategic development, and ensuring that highland development aligns with both the Sufficiency Economy Philosophy and global sustainability goals. Given the resource-intensive nature of data collection, the study recommends conducting periodic assessments every three to five years rather than an annual assessment to ensure efficiency and feasibility. Additionally, the indicators should be periodically reviewed and modified to reflect the evolving socioeconomic and environmental realities of highland communities.

Keywords: sustainable development goals, sustainability indicators, highland communities, sufficiency economy philosophy, community development evaluation

JEL code: Q01, R58, I32

SDG classification: SDG 1, SDG 11, SDG 15

Introduction

The UN Sustainable Development Cooperation Framework 2022–2026 was signed by the UN Country Team and the Royal Thai Government in January 2022, marking the beginning of the Sustainable Development Goals (SDGs) in Thailand (United Nations in Thailand, 2023). Their collaborative efforts are guided by the principles of human rights, gender equality, sustainability, resilience, and leaving no one behind. Furthermore, the 13th National Economic and Social Development Plan draft and Thailand's 20-Year National Strategy also adhered to the SDGs. For the main plan to be successful, government agencies and relevant entities must implement policies and strategies that align with the SDGs.

Over the past fifty years, His Majesty King Rama IX has founded the Royal Project Foundation with the goals of reducing poverty in highland regions, reducing opium production areas, and restoring watershed forests. The "understanding, empathy, and development" tenet forms the foundation of the Royal Project Model, which operates according to the "King's Philosophy" or Sufficiency Economy Philosophy. Additionally, their development plan aligns with both the United Nations Sustainable Development Goals (SDGs) and the 20-year national strategy (Royal Project Foundation, 2021). To ensure that the development indicators created by the Royal Project are suitable for gauging the degree of development in highland communities, they must be developed in a way that harmonizes with the SDGs' development indicators.

The problem is that most people who reside in highland areas are impoverished and have limited access to public services. As such, the spatial data needed to analyze each indicator is necessary for the assessment of the sustainability of highland communities. Next, criteria for each indicator were developed to compare and aggregate the index values between communities outside and within highland areas. Because of the work being done by the Highland Research and Development Institute, Royal Project Foundation, and other integrating agencies, several highland settlements in the northern area are currently growing and enjoying a higher standard of living. To accomplish community sustainable development goals in a timely and appropriate manner, community sustainability assessment is crucial to their growth.

To address this issue, we developed a framework that makes it possible to methodically analyze or choose indicators for gauging and tracking the performance of communities with the SDGs through key steps: Organizing, classifying, and choosing criteria and selection indicators for the sustainable development of highland villages through cooperative meetings including the research team, academics, experts, and representatives of the Royal Project. Pang Da Royal Agricultural Station and Mae Hae Royal Project Development Center are two distinct pilot regions where the assessment guide is also tested and exhibited.

The study's findings will help the Royal Project choose and rigorously assess SDG indicators for communities in the highlands. The development of an operational framework for the Royal Project that is in line with the SDGs will be greatly aided by these metrics. State the objectives of the work and provide an adequate background, avoiding a summary of the results. Explain how you addressed the problem and clearly state the aims of your study.

Methodology

This study's methodology consisted of 4 primary steps as follows: the Methodological Approach for developing the conceptual framework, A Systematic Review that compiles all of the research that is currently accessible using a Curation and Categorization of criteria list for selecting indicators and criteria that are appropriate for evaluating the indicators of highland communities, as well as the testing and demonstration of the evaluation guide through illustrative scenarios (Gebara et al, 2024).

Methodological approach

The methodological approach was utilized in the development of a Highland community's sustainable indicators to create the framework for creating, assessing, and choosing SDG indicators and criteria as well as to obtain the guidelines for the Highland community's sustainable evaluation (Fig 1).

A systematic review

A Systematic review of the literature. Sufficiency Economy Philosophy, the international production Indicators, the Development Indicators of Different Organizations, the Sustainable Development Goals, and the Royal Project Model are the categories into which the production of indicators and indices is separated. Thus, the basis for categorizing the indicators and criteria is based on 4 dimensions namely, economic, social, environmental, and infrastructure (Fig 2).



Figure 2. Four aspects of sustainable development for highland communities

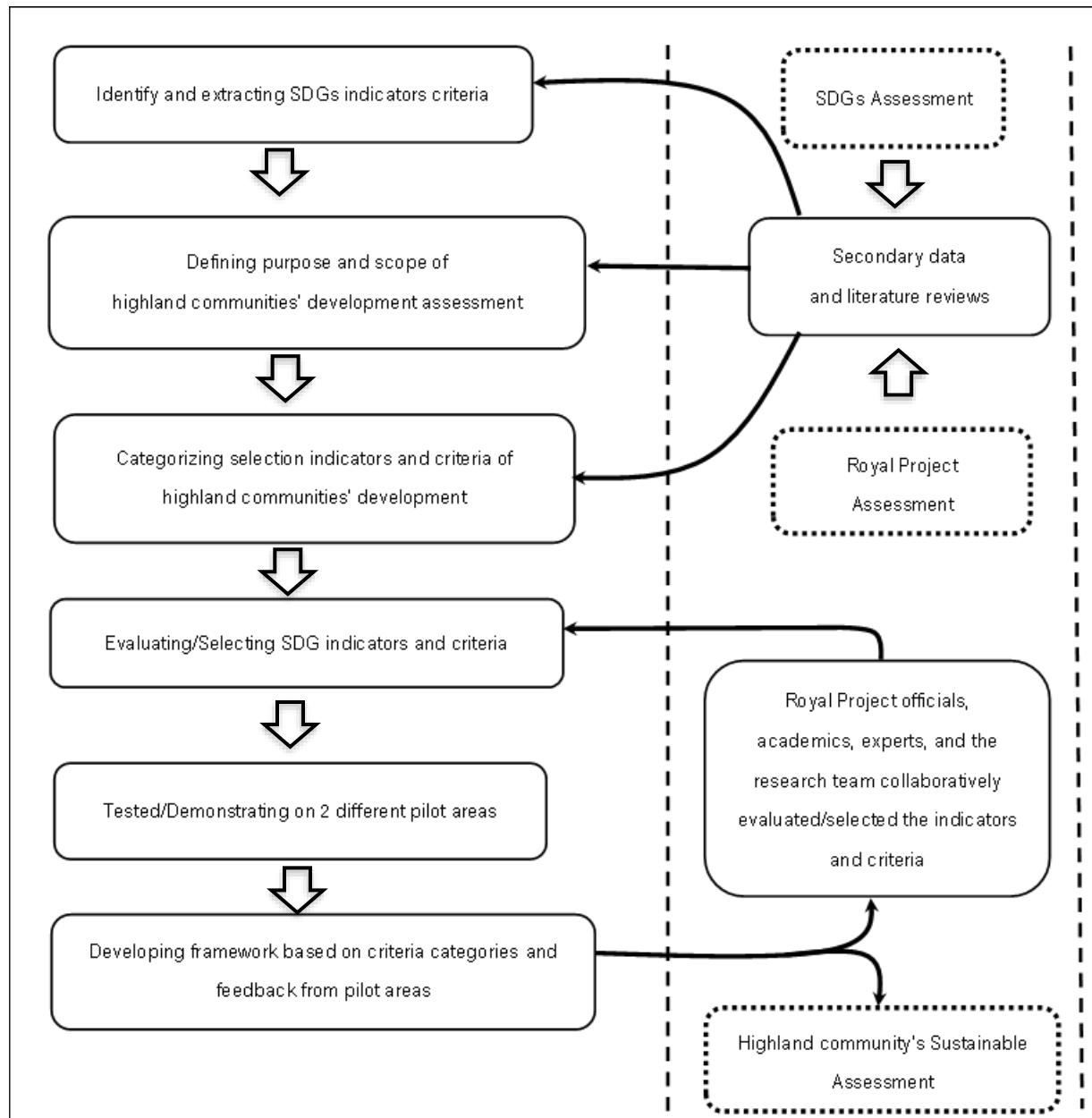


Figure 1. Conceptual framework

Curation and categorization of criteria list

Based on secondary data gathered by associated government institutions, including the Royal Project Foundation, the criteria were categorized. The Royal Project Foundation, government agencies, and associated international organizations gathered secondary data, which was used to categorize the criteria. It is important to note that the indicators chosen should accurately reflect the situation, and the criteria chosen should be appropriate for assessing the indicators of highland communities.

Illustrative cases

Pang Da Royal Agricultural Station and Mae Hae Royal Project Development Center are 2 pilot areas where the assessment guide is tested and demonstrated. Data was collected by questionnaires for household members, community leaders, and the Sub-District Administration Office.

The analysis employed household-level data obtained from questionnaires distributed at random to all households in each location, including both Royal Project participants and non-participants. Data from community leaders and sub-district administrative organizations was also utilized to provide a broad overview of the locations. Furthermore, secondary data was utilized, namely for social and environmental aspects, from relevant agencies.

Results and Discussion

As a tool for tracking and assessing development in alignment with the Sustainable Development Goals and the Royal Project Model, the sustainable development indicators of highland communities have been developed. There are 4 primary dimensions, 20 sub-dimensions, and 51 indicators in the collection of developmental indicators.

Table 1. Dimension overview, sub-dimensions and indicators

Dimensions	Sub-Dimensions	Indicators
1. Economic	1.1 poverty, assets, and liabilities	income above poverty line, poverty gap, income distribution or Gini index, household assets, and debt situation
	1.2 employment	unemployment
	1.3 access to a funding source	capital access, savings
	1.4 marketing channels	marketing channels, market opportunities from production standards
	1.5 food security	income above the food poverty line, malnourished people
2. Social	2.1 strength community	community networks, participation, strength communities that apply the sufficiency economy, community development plans,

Food Systems, Consumption, and Nutrition

Dimensions	Sub-Dimensions	Indicators
		community peace, drug-resistant villages, culture and local wisdom conservation
	2.2 social equality	citizen rights, female leader
	2.3 inclusive education	basic literacy and numeracy, compulsory education, lifelong learning
	2.4 having good basic health	child mortality rate, basic health care access and vaccinations, health insurance
3. Environment	3.1 environmentally friendly land use	environmentally friendly agricultural systems, using land legally, using community land use and land map, soil erosion
	3.2 restoring and conservation of forests and biodiversity	community forest area, land use change from agricultural to forest area, agroforestry, afforestation, fires forest area
	3.3 sustainable water management	community water management plans and prevent drought problems, developed water source in agricultural areas
	3.4 household waste management	household garbage separation, waste management without burning in open area, household having sanitary toilets, and manage waste from farms without burning
	3.5 community climate change adaptation	community having a risk management plan form natural disasters and their impacts, community having climate change knowledge
4. Infrastructure	4.1 transportation	all year convenient road to the village and agricultural plots
	4.2 water consumption	households having clean drinking water and water to use throughout the year
	4.3 electricity	the households have electricity
	4.4 internet and telecommunications	household access to information
	4.5 community good basic health	garbage disposal points and community waste management
	4.6 accessing basic services	basic health services and basic education services access

Furthermore, standards for assessing each indicator's degree of community sustainability have been developed. There are 4 categories for the community's sustainability: A (very good), B (good), C (fair), and D (poor). For instance, the indicator of income over the poverty line (unit: percentage of families). This indicator demonstrates that a household has enough money to spend at least on food and nonfood expenses. It is based on the

proportion of the community's households with total incomes above both food and non-food of the poverty line. The poverty line considered in this indicator is the sum of the food and non-food poverty lines. This indicator is in line with SDG Goal 1: reducing poverty. Table 2 provides a full description of the criteria used to evaluate community sustainability when it is divided into 4 levels.

Table 2. Criteria for evaluated community sustainability based on income above the poverty line

Level A (very good)		Level B (good)		Level C (fair)		Level D (poor)	
Households have incomes above the poverty line	100 percent	Households have incomes above the poverty line	90-99 percent	Households have incomes above the poverty line	80-89 percent	Households have incomes above the poverty line	80 percent

Based on the collection of sustainable highland community development indicators in the pilot areas, it was found that:

Economic indicators: Household questionnaires were used to collect data on indicators such as income above the poverty line, poverty gap, income distribution, debts, and assets. Particularly, the analysis of the food poverty line required data on the gender and age of all household members to calculate the necessary protein and calorie costs per month, as well as various household expenses. These expenses were categorized into sections such as food, clothing and footwear, housing-related costs, medical expenses, transportation, communication, and education. This data was then used to calculate the non-food poverty line for each household annually. Data collection in this area was time-consuming and detailed, potentially causing confusion for both interviewers and respondents. Therefore, interviewers must be trained in using communication questions to ensure the accuracy of the data collected. Additionally, this data collection must be systematically planned, especially if it is to be used in evaluating all operational areas of the Royal Project. For instance, it should be determined that household-level data collection occurs every three years since it requires significant resources for both data collection and analysis and does not need to be conducted annually.

Social indicators: This includes indicators such as community group and network formation, participation, community development planning, community peace, and the preservation of local culture and wisdom. Data in this area was collected using community leader questionnaires. Indicators for the application of the Sufficiency Economy Philosophy, drug-free villages, health and wellness, access to basic health services, vaccination, and health insurance were evaluated by relevant government agencies and data collected. In some areas, sub-district administrative organization questionnaires were used, while in others, data had to be directly requested from relevant agencies. Coordination is needed to understand the required data for accurate data collection and preparation. For example, defining which community activities will be evaluated for community participation, and having community leaders regularly collect this data to ensure its accuracy. For indicators of strong communities applying the Sufficiency Economy Philosophy in development and drug-free villages, the Royal Project must coordinate with the responsible agencies (the Community Development Department and

the Narcotics Control Operations Center) for evaluation or to use their questionnaires in the Royal Project areas. Household questionnaires were used to collect data on indicators of literacy, compulsory education, and citizenship rights.

Environmental indicators: This includes indicators such as environmentally friendly agricultural systems, legal land use, parcel-based land use planning, soil erosion, community forest areas, and wildfire areas. Currently, this data cannot be evaluated at the community level due to the lack of community-specific land maps. Spatial boundaries for each village should be defined if environmental assessment at the village level is required. Data analysis should be conducted according to specific indicators, such as the area affected by wildfires or land conversion from agriculture to forest. The Royal Project needs to clearly communicate with GIS data analysis agencies regarding the required type and level of data. If certain indicators cannot be implemented, it is necessary to adjust and find new suitable indicators. Community leader or sub-district administrative organization questionnaires can be used to collect data on indicators such as water management plans, agricultural areas with water source development, disaster risk management plans, and climate change awareness. Household questionnaires can be used to collect data on indicators such as waste management, the availability of hygienic toilets, and the management of farm residues without open burning.

Infrastructure indicators: This includes indicators such as transportation to farmers' plots, access to water for consumption, clean drinking water, year-round sufficient water supply, electricity access, and information access, collected through household questionnaires. Indicators for transportation to villages, community waste management, and access to basic services in education and health were also evaluated. The accessibility of basic services can be assessed based on travel time from home to basic service units. Given the context and operational plans of the Royal Project Foundation, the consensus was to evaluate the presence or absence of service units in the community and the convenience of accessing nearby service units. Data was collected using community leader questionnaires and information from sub-district administrative organizations.

The study results from two pilot areas of Pang Da Royal Agricultural Station and Mae Hae Royal Project Development Center.

Economic dimension: Communities in the Pang Da Royal Agricultural Station demonstrated higher economic sustainability with 83.33 - 100% of households having income above the poverty line (levels A-C) and stronger food security (level A). Despite lower average household assets (447,015 THB/household) compared to Mae Hae, they showed better access to capital and savings participation. Communities in the Mae Hae Royal Project Development Center showed lower economic sustainability with 71.43 - 82.14% of households above the poverty line (levels C-D) and moderate food security (levels B-C). Although they possessed higher average household assets (521,500 THB/household), most communities in both areas required development in market channel diversity and agricultural production standards.

Social dimension: Communities in both areas showed similar social indicators with established community groups and cultural preservation practices. Pang Da communities demonstrated higher participation in community activities (levels A-B) while Mae Hae communities had stronger network structures with more diverse groups, including youth organizations (level A). The most notable challenges across both areas were in

educational attainment, particularly compulsory education completion and lifelong learning promotion (level D), despite generally good basic health indicators.

Environmental dimension: Both pilot areas faced similar environmental challenges, including limited environmentally friendly agricultural practices (level D, <25% of agricultural land) and insufficient climate change knowledge dissemination. Pang Da maintained higher forest coverage (65.61%) with minimal soil erosion, while Mae Hae experienced more severe erosion issues (level C) and climate impacts. Both areas showed good waste management practices with over 70% of households separating waste and managing it without open burning, though community-level land use planning remained underdeveloped.

Infrastructure dimension: Infrastructure was generally well-developed across both areas (level A), with universal electricity coverage and information access. Most communities had good transportation networks and access to clean drinking water (>80% of households), though specific communities in both areas required improvements in road access or water supply systems. Access to basic health and education services was adequate, with most communities able to access services in nearby areas, though some communities needed development in waste management systems.

Conclusion

To develop community sustainable development indicators under any agency's operational plans, sustainable development indicators from all relevant sectors including both domestic and foreign agencies, should be obtained to create community sustainable development indicators under any agency's operational plans. This procedure should also include linking the evaluation indicators and criteria with the organizations that use them, such as the Royal Project Foundation. It is essential to review the applicability of the indicators and criteria in the context of highland regions, and the feasibility and appropriateness of collecting this data for evaluation. The evaluation results indicate that the Royal Project should focus on developing and promoting those communities with low or somewhat poor sustainability in specific aspects to improve sustainable development in such areas. If the data required to evaluate the indicators is not accessible, they must be altered, or new, appropriate ones must be found to reflect the actual operations or development. This will allow for a complete analysis of community sustainability in highland areas utilizing the indicators and values of the community sustainability index. The conclusion should be explained clearly, with suggestions/recommendations placed after it, which can be of use to all stakeholders.

Acknowledgement

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References

- Chakrabartty, S. N. (2017). Composite index: Methods and properties. *Journal of Statistical Theory and Practice*, 11(3), 400-423. <https://doi.org/10.1080/15598608.2017.1295833>
- Ebert, U., & Welsch, H. (2004). Meaningful environmental indices: A social choice approach. *Journal of Environmental Economics and Management*, 47(2), 270-283. <https://doi.org/10.1016/j.jeem.2003.09.001>
- Ekasingh, B., Kramol, P., Teerakul, N., & Kaewmanee, P. (2016). Changes in Highland communities' quality of life. Highland Research and Development Institute. <https://research.hrdi.or.th/public/upload/o19o698i3b.pdf>
- Ekasingh, B., Promburom, P., Puntiya, P., & Bhumiprapat, P. (2013). Multi-dimensional Highland development indicators and indices for sustainability. *Journal of Science and Technology Mahasarakham University*, 32(2), 171-183.
- Gebara, C. H., Thammaraksa, C., Hauschild, M., & Laurent, A. (2024). Sustainable production and consumption. *Elsevier Ltd on behalf of Institution of Chemical Engineers*. <https://doi.org/10.1016/j.spc.2023.12.004>
- Royal Project Foundation. (2021). Royal Project model. <https://royalproject.org/pageeng/model/>
- Taitaemthong, B., Intaruccomporn, W., Chalermphol, J., Na Lampang, D., & Prapatigul, P. (2019). Development sustainable indicators of Highland community under Highland development project using Royal Project system. *Khon Kaen Agriculture Journal*, 47(Suppl. 1), 435-440.
- United Nations Thailand. (2023). Our work on the Sustainable Development Goals in Thailand. <https://thailand.un.org/en/sdgs>

Factors Influencing the Transition to Modern Agricultural Practices

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Abstract

The agricultural sector is vital to economic and social development, providing income for many people while ensuring food security and supplying raw materials to various industries. In recent years, advanced technology has significantly enhanced agricultural production by improving resource efficiency, increasing farmers' income, and reducing costs and environmental impacts. However, the agricultural sector is experiencing a labor shortage, as more than half of agricultural households depend on an aging workforce, which limits productivity. This study conducts a comprehensive literature review of academic research published between 2016 and 2024 to identify the key factors influencing the adoption of modern agricultural practices. This study identifies 16 key factors into five primary dimensions, which are economic, technological, farm-related, institutional, and personal. The identified factors include age, education and knowledge, experience, gender, innovativeness, cost, income, financial conditions, household assets, farm size, government support and credit constraints, compatibility, complexity, resource availability, and infrastructure. In addition, the results also highlight that the factors of farmer education, farm size, government support, and credit constraints are the most frequently discussed and influential in accelerating agricultural transformation. Addressing these key factors through targeted policy interventions can enhance agricultural productivity, resilience, and sustainability, ultimately fostering the modernization of agricultural sector.

Keywords: agricultural development, factor, sustainability, technological adoption

JEL code: O33, Q10, Q12

SDG classification: SDG 2, SDG 9

Introduction

The agricultural sector is considered a highly important part of world economy and society. Agriculture is not only the main source of income for the country's population, but also a fundamental basis for food security and a source of raw materials for other industrial sectors. Therefore, the development of agricultural sector is crucial for economic sustainability and the quality of life of farmers in the developing country.

At present, technology plays a significant role in enhancing agricultural production through the use of modern technologies such as automation systems, big data analytics (Pakorn et al., 2021), online platforms, and the use of sensors to monitor the farming environment. These technologies enable farmers to improve production efficiency, reduce costs, and enhance the quality of agricultural products. They also contribute to more efficient resource management, cost reduction, market expansion, improved livelihoods for farmers, and minimized environmental impacts.

However, the agricultural sector is facing a labor shortage problem. More than half of farming households rely on elderly workers who are unable to upgrade production and cultivation practices (Attavanich et al., 2019). These farmers often face limitations in accessing modern knowledge and technologies, as well as lack of capital, skills, and support. Most importantly, the absence of adequate assistance and promotion from relevant agencies hinders farmers' ability to adopt technologies that align with their capacities.

To address these challenges, this study aims to explore the key factors influencing the advancement of farmers, particularly in relation to their adoption of agricultural technologies. Understanding these factors will help improve the design of policies and support systems tailored to farmers' needs.

This research consists of three main parts: the methodology, which explains the research design and analysis; the results and discussion, which highlights key findings and their implications; and the conclusion.

Methodology

This study aims to identify and analyze the key factors influencing the advancement of farmers, with a particular focus on the adoption of modern agricultural technologies. A systematic literature review was conducted on academic publications from 2016 to 2024, using databases such as Scopus, Web of Science, and ScienceDirect. The search employed key terms including "technology adoption," "precision agriculture," "innovation in agriculture," and "digital farming."

Articles were selected based on their relevance to technology adoption in agriculture, with emphasis on both enablers and barriers affecting smallholder farmers, especially in developing countries. A total of 16 recurring factors were identified and grouped into five primary dimensions: personal, economic, farm-related, institutional, and technological. Each factor was assessed based on frequency of mention, cross-study consistency, and practical influence on decision-making. The analysis aimed to provide a comprehensive understanding of how these factors interact and influence farmers' readiness and capability to adopt agricultural technologies.

Results and Discussion

Based on the systematic literature review outlined in the methodology section, 16 key factors influencing the advancement of farmers were identified and categorized into five primary dimensions: economic, technological, farm-related, institutional, and personal, see Table 1. These dimensions represent the multifaceted nature of agricultural transformation, where individual capabilities, access to resources, institutional support, and technology influence farmers' decisions.

Table 1. Factors influencing the transition to modern agricultural practices

Dimension	Key factors	Authors
Economic	Cost	Bahari et al. (2024); Ammann et al. (2022)
	Income	Bontsa et al. (2023); Vollaro et al. (2019)
	Financial conditions and household assets	Suprehatin (2021); Dibbern et al. (2024)
Technological	Innovativeness	Aubert et al. (2012); Li et al. (2024)
	Compatibility	Hoang Nguyen et al. (2022); Geng et al. (2024)
	Complexity	Giua et al. (2022); Li et al. (2024)
Farm	Farm size	Tamirat et al. (2017); Ahmed & Ahmed (2023)
	Resource availability and Infrastructure	Feder et al. (1985); Suprehatin (2021) Dibbern et al. (2024)
Institutional	Government support	Chuang et al. (2019); Bahari et al. (2024); Giua et al. (2022); Suprehatin (2021); Aubert et al. (2012)
	Credit constraints	Dibbern et al. (2024)
Personal	Age	Hoang Nguyen et al. (2022); Suprehatin (2021)
	Education and knowledge	Caffaro & Cavallo (2019); Bontsa et al. (2023)
	Experience	Giua et al. (2022); Ahmed & Ahmed (2023)
	Gender	Geng et al. (2024); Chuang et al. (2019)

Within the economic dimension, four major factors were consistently highlighted: cost, income, financial conditions, and household assets. These factors play a critical role in determining farmers' capacity and willingness to adopt new technologies in their production activities. That also reflects access to financial resources, the ability to manage economic risks, as well as the income structure and household assets of farmers.

Firstly, cost is one of the key considerations when adopting new technologies, especially those that are complex, such as IoT or smart farming systems, which often require high initial investments. These costs may include procurement of equipment, system installation, training, and maintenance expenses, all of which represent financial burdens for farmers (Bahari et al., 2024; Ammann et al., 2022). Therefore, cost assessment becomes crucial in evaluating whether a given technology is cost-effective and appropriate for a specific farm context. If the cost exceeds the farmer's affordability, even technologies with high efficiency or productivity potential may not be adopted, ultimately reducing opportunities for agricultural development.

In the same vein, the income level of farming households is directly linked to their ability to access and accept new technologies, particularly digital technologies that require ongoing investments, such as internet connectivity or regularly updated sensor systems (Bontsa et al., 2023). Farmers with sufficient income or diversified sources of income beyond agriculture are more likely to adopt and experiment with new technologies, as they can better absorb potential risks of failure. Vollaro et al. (2019) emphasized that income enhances investment capacity and reflects a more efficient farm management level, which influences long-term technology planning. Conversely, technologies that demonstrate clear potential to increase income or reduce costs serve as a powerful incentive for farmers to adopt them (Ammann et al., 2022).

Moreover, financial conditions and household assets, in addition to income, represent the overall financial stability of a farming household. These include accumulated assets such as land, buildings, machinery, or savings, all of which strengthen the household's ability to manage the risks associated with investing in new technologies (Suprehatin, 2021; Dibbern et al., 2024). Farms with greater asset holdings tend to have more flexibility in managing costs and can allocate resources effectively. For example, farms that own their land are more secure in making long-term plans than those renting land. Therefore, they are more likely to invest in irrigation systems or other long-term technologies with extended payback periods (Suprehatin, 2021).

With regard to the **technological dimension**, three factors emerged as particularly influential: innovativeness, compatibility, and complexity. The readiness and specific characteristics of the technologies offered to farmers play a crucial role in both the acceptance and actual adoption of technology in agriculture. Technological factors reflect external attributes—such as compatibility, complexity, or infrastructure availability—and also encompass perceptual aspects, including ease of use and contextual suitability for the farmers.

Compatibility refers to the ability of technology to seamlessly integrate with the existing production systems that farmers already use. That includes compatibility with current agricultural tools, coordination with various farming activities, and alignment with the lifestyle and skill levels of farm laborers (Aubert et al., 2012; Hoang Nguyen et al., 2022; Bahari et al., 2024). Technologies that can be used alongside familiar tools and processes are more likely to be accepted, as they do not require farmers to make major changes to their operations. In contrast, technologies that involve substantial changes—such as requiring complete equipment replacement or reconfiguring production practices—may be perceived as overly burdensome or risky. Geng et al. (2024) emphasized that technologies should be designed to align with the environmental

and contextual realities of farmers, including land characteristics, crop types, and farming systems.

On the contrary, complexity is negatively associated with technology adoption. The more complex a technology is in terms of usage or installation, the lower the likelihood that farmers will adopt it (Giua et al., 2022; Hoang Nguyen et al., 2022; Li et al., 2024). Complexity may arise from various aspects, such as complicated system setups, the need for IT knowledge, advanced data analysis, or integration with unfamiliar systems. It becomes incredibly challenging in rural areas or among farmers with limited technology experience, where complexity becomes a significant "barrier" that hinders access—even if technology holds great potential.

In relation to the **farm-related dimension**, farm size, resource availability, and infrastructure significantly influenced adoption. The unique characteristics of individual farms constitute another group of critical factors that directly influence the decision to adopt agricultural technologies, particularly in terms of farm size, type of agricultural practice, land tenure, and household structure.

Farm size is a significant factor affecting technology adoption, especially for technologies requiring high initial investments. Larger farms generally have an advantage in terms of economies of scale—that is, the larger the area or production volume, the lower the average cost per unit of using a technology. That makes technology adoption more cost-effective and viable (Tamirat et al., 2017; Vollaro et al., 2019; Ahmed & Ahmed, 2023). In addition, larger farms tend to have more financial resources and labor availability, enabling easier investment in advanced technologies. Ammann et al. (2022) and Giua et al. (2022) reported that larger, more integrated farms along the supply chain are more likely to adopt smart farming systems and IoT technologies.

In contrast, smaller farms often face financial constraints and may lack the capacity to bear the risks associated with new technology failures (Caffaro & Cavallo, 2019; Ahmed & Ahmed, 2023). Furthermore, the benefits of technology adoption in small-scale farms may not be as apparent, or the technologies may not be fully utilized. For instance, sensor systems designed for large areas or automated systems requiring continuous power supply may not be suitable or effective on small farms. As a result, the full potential of such technologies might not be realized in these settings (Aubert et al., 2012; Tamirat et al., 2018).

Equally important, resource availability and infrastructure are directly affecting farmers' ability to access and utilize technology (Hoang Nguyen et al., 2022; Dibbern et al., 2024). For example, even if a farmer is knowledgeable and motivated to use a crop monitoring application, the absence of reliable internet connectivity in the area renders the technology ineffective. Another critical issue is the availability of supporting tools and equipment—such as sensors, surveillance cameras, or data logging systems. If these are not affordably priced or available through local distributors, farmers may perceive the technology as "out of reach" or unnecessary for their production system. Therefore, resource availability is a "basic condition" for technology acceptance, even when farmers have a positive attitude or strong motivation toward its adoption.

Turning to the **institutional dimension**, this refers to the role of external organizations, whether from the public sector, private sector, financial institutions, or technology providers—that influence farmers' decisions to accept and adopt agricultural technologies.

Government support is vital in encouraging farmers to gain confidence and take the initiative to adopt new technologies. This support may come in the form of policy formulation, strategic direction-setting for digital agricultural development, investment in technological infrastructure, as well as organizing training programs for farmers and relevant stakeholders (Chuang et al., 2019; Hoang Nguyen et al., 2022; Bahari et al., 2024). Such support mechanisms help reduce the financial burden placed solely on farmers, thereby lowering the risks associated with the adoption of technology. Additionally, the government can further incentivize adoption through tax measures, subsidies, or facilitating access to credit specifically for agricultural technology investments.

At the same time, credit constraints represent another major barrier to technology adoption, especially for technologies that are expensive or require long-term investments. Farmers who lack access to formal financial systems often face difficulties in deciding to invest in technology, even when they recognize its potential benefits (Dibbern et al., 2024). Therefore, strategies such as low-interest credit schemes, state-backed loan guarantees, or special-purpose grants provided by agricultural financial institutions are essential measures that governments and related agencies can implement to overcome financial access limitations and ensure fairer access to technology for smallholder farmers.

Lastly, the **personal dimension** included age, education and knowledge, experience, and gender. The experience of farmers, particularly their past experiences with technology, significantly influences their ability to analyze situations and select technologies that best suit their farm context (Giua et al., 2022; Suprehatin, 2021). Farmers who have previously experimented with or used innovations tend to have higher confidence in adopting new technology, as they have learned from past experiences and understand how to reduce risks and avoid failure. Additionally, experience enhances the ability to access information and share knowledge with others, an important mechanism for spreading technology adoption at the community level (Vollaro et al., 2019). However, in some cases, highly experienced farmers may become attached to traditional methods that previously worked well, creating resistance to change and hindering adaptation to modern technology (Ahmed & Ahmed, 2023).

In addition, gender is important in access to resources, information, and decision-making regarding technology adoption. Typically, male farmers are more accepted and supported in accessing financial resources, technologies, and services, allowing them to apply digital technologies more than their female counterparts (Geng et al., 2024). Chuang et al. (2019) also reported that young male farmers are more likely to use IoT technologies in farm management than females of the same age group, highlighting the inequality in opportunity within agricultural systems across regions.

To conclude, innovativeness refers to a personality trait reflecting a willingness to try new things, self-confidence in one's potential, and the ability to identify opportunities through change (Aubert et al., 2012). Farmers with high innovativeness tend to recognize the benefits of technology, such as productivity gains, cost reductions, and minimized

environmental impacts. As a result, they are more willing to adopt technology than their peers (Hoang Nguyen et al., 2022; Li et al., 2024).

Conclusion

This study explored and synthesized the key factors influencing the advancement of farmers, particularly in relation to their adoption of modern agricultural technologies. Through a systematic review of academic literature from 2016 to 2024, sixteen critical factors were identified and categorized into five main dimensions: economic, technological, farm-related, institutional, and personal.

The findings reveal that technology adoption in agriculture is not determined by a single factor, but rather by the interplay between individual characteristics, farm structure, financial conditions, institutional support, and the technological environment. For example, farmers with sufficient income, innovative attitudes, and previous experience with technology are more likely to adopt new systems. Meanwhile, structural barriers such as credit constraints, lack of infrastructure, or complex technological requirements remain significant challenges.

To promote inclusive and sustainable agricultural transformation, it is essential for policymakers, technology developers, and supporting institutions to design interventions that consider these multidimensional factors. This includes improving access to finance, delivering localized training programs, enhancing infrastructure in rural areas, and promoting gender-equitable innovation policies. Future research should also explore how these factors evolve over time and how digital platforms can be tailored to match the needs and capacities of diverse farming communities.

Future research should develop practical tools to study how important each factor is for farmers. The sixteen factors identified will be used to develop questionnaires or surveys to understand farmers adopting technology.

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References

- Ahmed, H., & Ahmed, M. (2023). Influencing factors on adoption of modern agricultural technology in developing economy countries. *Developing Country Studies*, 13(2), 1–15.
- Ammann, J., Umstätter, C., & Benni, E. N. (2022). The adoption of precision agriculture enabling technologies in Swiss outdoor vegetable production: A Delphi study. *Precision Agriculture*, 23(4), 1354–1374.
- Attavanich, W., Chantararat, S., Chenphuengpaw, J., Mahasuweerachai, P., & Thampanishvong, K. (2019). Farms, farmers and farming: A perspective through

- data and behavioral insights (No. 122). Puey Ungphakorn Institute for Economic Research.
- Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, 54(1), 510–520.
- Bahari, I., Arpaci, I., Der, O., & Akkoyun, F. (2024). Driving agricultural transformation: Unraveling key factors shaping IoT adoption in smart farming with empirical insights. *Sustainability*, 16(5), 2129.
- Caffaro, E., & Cavallo, F. (2019). The effects of individual variables, farming system characteristics and perceived barriers on actual use of smart farming technologies: Evidence from the Piedmont Region, Northwestern Italy. *Agriculture*, 9(5), 111.
- Chuang, J.-H., Wang, J.-H., & Liang, C. (2019). Implementation of Internet of Things depends on intention: Young farmers' willingness to accept innovative technology. *International Food and Agribusiness Management Review*, 23(2), 253–266.
- Dibbern, T., Romani, S. A. L., & Massruh, S. F. M. S. (2024). Main drivers and barriers to the adoption of digital agriculture technologies. *Smart Agricultural Technology*, 8, 100459.
- Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, 33(3), 255–298.
- Geng, W., Liu, L., Zhao, J., Kang, X., & Wang, W. (2024). Digital technologies adoption and economic benefits in agriculture: A mixed-methods approach.
- Giua, C., Materia, V. C., & Camanzi, L. (2022). Smart farming technologies adoption: Which factors play a role in the digital transition? *Technology in Society*, 68, 101869.
- Khan, W., Khan, S., Dhamija, A., Haseeb, M., & Ansari, S. A. (2023). Risk assessment in livestock supply chain using the MCDM method: A case of emerging economy. *Environmental Science and Pollution Research*, 30(8), 20688–20703.
- Le Hoang Nguyen, L., Halibas, A., & Quang Nguyen, T. (2023). Determinants of precision agriculture technology adoption in developing countries: A review. *Journal of Crop Improvement*, 37(1), 1–24.
- Li, L., Min, X., Guo, J., & Wu, F. (2024). The influence mechanism analysis on the farmers' intention to adopt Internet of Things based on UTAUT-TOE model. *Scientific Reports*, 14(1), 15016.
- Suprehatin. (2021). Determinants of agricultural technology adoption by smallholder farmers in developing countries: Perspective and prospect for Indonesia. *Jurnal Penelitian dan Pengembangan Pertanian*, 40(1), 21–30.
- Tamirat, T. W., Pedersen, S. M., & Lind, K. M. (2018). Farm and operator characteristics affecting adoption of precision agriculture in Denmark and Germany. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, 68(4), 349–357.

Vollaro, M., Raggi, M., & Viaggi, D. (2019). Innovation adoption and farm profitability: What role for research and information sources? *Bio-based and Applied Economics*, 8(2), 179–210.

Farmers' Participation in Rice Certified Seed Production in Myanmar: SWOT Analysis

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Abstract

Usage of quality certified seed is the most dominant factor for increasing rice productivity. Rice accounts for the largest area of crops grown area in Myanmar and certified rice seed productions are mainly produced by seed producer farmers, private seed companies and public seed farms. Hence, comprehensive research on Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of rice seed production is critically important. Main objective of the study was to know the current situations of seed producing in Mandalay Region. A total of 86 seed producer farmers were interviewed using structured questionnaires during February 2025. The results show that the main strengths factors were getting higher rice yield, getting the knowledge about the seed production technologies disseminated by DOA and getting more income. However, the major weaknesses were weak market linkage for selling certified rice seeds, labor scarcity of roughing and also limited investment. As the opportunity, seed producer farmers can get easily register seeds from DOA seed farms, income earning opportunity for the local community and farmers can use certified rice seeds with the affordable price. Meanwhile there were three main threats as limited awareness of local farmers to use the quality certified rice seeds, the high prices of agricultural inputs and limited irrigation water were also main constraints. Public sector should encourage for giving intensive trainings for local field workers to understand well the roughing practices, providing agricultural loan for the seed producer farmers via development of certified rice seed production towards improved rice industry in Myanmar.

Keywords: certified rice seeds, Mandalay region, seed producer farmers, SWOT analysis

JEL code: D24, Q54, Q56

SDG classification: SDG 12, SDG 13, SDG 15

Introduction

In Myanmar, rice (*oryza sativa*) is the primary crop, followed by maize, pulses, oil seeds and it is major export income earning by export of the surplus production. In 2021-2022, a total of over 7.05 million ha of rice was cultivated which comprising 6.09 million ha under monsoon rice and 1.08 million ha under summer rice. National average yield of rice is 3.90 MT/ha and it is still lower than the national targeted yield 5.15 MT/ha in Myanmar. The shortage of good quality seed is frequently identified as a major constraint for increasing crop production in Myanmar and rice accounts for the largest area of crops grown area in Myanmar and therefore the necessary of certified rice seeds are highly demanded throughout the country. The Ministry of Agriculture, Livestock and Irrigation encourages seed grower associations, private companies and collaborating farmers for seed industry development (MOALI, 2022).

Seed is the most dominant factor for increasing rice productivity in both specifications and effective use of quality and certified seeds improves the rice productivity and profit (Sabai Aye, 2022). Rice seed productions are done by seed producer farmers, private seed companies and government seed farms of public sector in Myanmar. According to the secondary data, Bago Region is the highest rice seed production area (10,697.70 ha) followed by Mandalay Region, the second highest seed producing area (4,475.52 ha) and Ayeyarwady Region, the third highest seed producing area (3,793.20 ha) (Rice Division, 2024). To produce certified rice seeds, seed producer farmers buy the register seeds from the Department of Agriculture (DOA) seed farms and grow in their fields with the seed production technologies which are trained by the help of DOA extensions. In this paper, SWOT analysis of rice seed production by seed producer farmers in Mandalay Region were studied.

There are also a limited number of studies in Myanmar that addresses the current situations of rice seed producing by seed producer farmers to develop rice industry. This study was conducted with the objective of determining the strengths, weaknesses, opportunities and threats of the seed producing farmers in the study area, Mandalay Region. The study on SWOT analysis of certified rice seed production in Mandalay Region will expose all possible constraints and solutions to enhance the productivity of certified rice seed of local farmers in Myanmar. This study also can provide understanding to policymakers for policy formulation that can support the rice seed producing and the development and potential of rice industry. A sound and good policy implementation for rice seed production sector would directly contribute to seed producer farmers to increase farmers income which participation in rice seed producing and this can also vital role of using quality certified rice seeds in rice growing area for rice industry development.

Methodology

Amarapura Township and Patheingyi Township in Mandalay Region were purposively selected as the research area because most of the rice seed production farms are located in those Townships. Simple random sampling was used to select 86 seed producer farmers in which farmers were producing certified rice seeds in their fields which are non-contracted with the seed companies. This research was conducted in collaboration with Department of Agriculture Amarapura Township and Patheingyi Township manager

offices. The primary data of seed production were collected through personal interview using structured questionnaire during November 2024 to February, 2025. The certified rice seeds were producing and selling to the rice growing farmers by seed producer farmers. Therefore, it would be required to identify internal contexts (strengths and weaknesses) and also external contexts (opportunities and threats) to explore the current situations, to suggest the possible policy formulation and to find out critical intervention areas by SWOT analysis.

SWOT analysis is a simple framework for generating strategic alternatives from a situation analysis. Thompson et al. (2007) stated that SWOT analysis is a simple but powerful tool for sizing up an organization's resource capabilities and deficiencies, its market opportunities, and the external threats to its future. SWOT matrix provides a framework for identifying and formulating strategies by matching key internal and external factors. SWOT matrix helps managers or policy makers in developing four types of strategies, namely strengths-opportunities (S-O) strategies, weaknesses-opportunities (W-O) strategies, strengths-threats (S-T) strategies, and weaknesses-threats (W-T) strategies (Weihrich, 1982). The survey data were analysed by SWOT analysis to point out current situation of seed producer farmers by investigating internal strengths and weaknesses as well as external opportunities and threats. Then, using SWOT matrix to develop the possible specific policy options from an external-internal analysis and identify the suggestions in the rice seed production for future development of rice industry.

Results and Discussion

Demographic characteristics of the selected respondents in the study areas

The demographic characteristics of the selected respondents are presented in Table 1. The average household size was 4.46 in the study area. It was also found that average farming experience was nearly 29 years, minimum farming experiences was 9 years and maximum farming experience was 55 years. The average seed production experience was 6.21 years and minimum seed production experiences was 2 years with the maximum seed production experiences was found 12 years. Average land ownership was 3.68 hectare of the sample households and the maximum land ownership was 13.77 hectare. Average certified rice seed producing area was 3.57 hectare that the minimum 0.81 hectare and the maximum was 12.15 hectare.

The information about age group and education level of sample farms household heads were described in Table 2. The eldest age of household heads was 78 years old and the youngest age was 27 years while the average age of household heads was 50.2 years. The household heads education levels were grouping into four levels: primary, secondary, high school and graduate level. Majority of household heads had secondary school level (48.84%) followed by high school level (30.23%). No household head was found illiterate and 8 household heads were found graduate level (9.30%) among selected respondents. The most seed producer farmers are selling their rice seeds to neighbour farmers and six of the selected respondents are selling their certified rice seeds with the brand names for marketing to other regions of Myanmar.

Table 1. Demographic characteristics of the selected respondents in the study areas (n=86)

Items	Unit	Average	Range	SD
Household size	Number	4.46	1 - 8	1.27
Working experience of farming	Year	29	9 - 55	11.30
Rice seed production experience	Year	6.21	2 - 12	3.20
Family farm labour	Number	1.92	0 - 7	1.35
Land ownership	Ha	3.68	0.81 - 13.77	3.98
Rice seed production area	Ha	3.57	0.81 - 12.15	2.62

Source: Own survey, 2024

Table 2. Age group and education level of sample farm household heads in the study areas (n=86)

Items	Frequency	Percent	SD
Age group (year)			
21 - 30	2	2.32	
31 - 40	12	13.95	
41 - 50	32	37.21	
51 - 60	27	31.40	
Over 60	13	15.12	
Average	50	50.20	10.31
Range		27 - 78	
Education Level			
Primary	10	11.63	
Secondary	42	48.84	
High school	26	30.23	
Graduate	8	9.30	

Source: Own survey, 2024

According to results of SWOT analysis in seed producer farmers, it had a number of internal strengths and external opportunities that help to achieve the development and internal weaknesses. There are also external possible threats that destructive for further development of rice seed production as shown in Table 3. The key strength factors of

certified rice seed production were getting the knowledge about certified rice seed production technologies disseminated by DOA, higher rice yield by growing registered seed (RS) for certified rice seed, more income from certified rice seed producing than normal grains producing, less infestation because of systematic cultivation and farmers can sell their rice seeds with the market price up to farmers' decision. These results are in consistent with the previous findings that the farmers are getting higher yield and higher income from using of certified seeds in their rice fields (Akanbi et al., 2024; Awotide et al., 2012). On the other hand, weakness factors of certified rice seed production were labour scarcity for rouging the off-type in seed producing rice field, limited market information and weak market linkage for selling certified rice seeds, limited investment for certified rice seed production to be stored for at least 5 to 6 months for selling, having difficult for storage infrastructure of warehouse and necessary of separate combine harvester only for seed producing fields. These results are in consistent with the previous findings that development countermeasures of Jiangxi rice seed industry based on SWOT analysis (Yu et al., 2020; Mesfin and Zemedu, 2015).

However, there were opportunities for the seed producer farmers such as seed producer farmers can get easily the register rice seeds from DOA seed farms with the cheap price, income earning opportunity for the local community, local farmers can use certified rice seeds with the affordable price and mutual helps between seed producers. Register seeds were sufficiently available for seed producer farmers that studied in this research and it was stated that the main purpose of early generation seed multiplication is to ensure the regular supply of high quality pre-basic and basic seed (certified seeds) for the entire seed program (Atilaw et al., 2016). However, in the study area limited irrigation water for producing certified rice seed, less awareness of local farmers to use certified rice seeds, high prices of agricultural inputs for producing certified rice seed and necessary of seed dryer to reduce the rice seed moisture especially to be stored long time were threatened to development of the rice seed production according to the study results. Our finding is also in agreement with the findings of the previous study that poor drying techniques, insecure storage facilities, and very high relative humidity and temperature contribute to the development of moulds, increased insect activity and faster respiration in stored grain (Rickman and Aquino, 2004).

According to the data analysis of the 86 respondents of rice seed producer farmers, Figure 1 indicates that the majority of respondents (76.7%) response that they were getting knowledge about the seed production technologies disseminated by DOA followed by farmers were getting higher yield by growing register seeds for certified seeds (75.6%) of the respondents and getting more income from seed producing business (65.1%). Figure 2 shows about the weaknesses, there are 5 weaknesses facing by seed producer farmers. According to the responses of samples, labour scarcity for rouging in seed producing (70.9%), limited market information and weak market linkage for selling certified rice seeds (65.1%) and limited investment for seed producing (61.6%) were identified as major weaknesses.

The opportunities of certified rice seed production are shown in Figure 3. The most important factors that support the opportunities were seed producer farmers can get register seed easily from the DOA seed farms with the cheap price (90.7%), income earning opportunity for local community (72.1%) and local farmers can use the quality certified seeds to get high yield (69.8%). As shown in Figure 4, it was stated that most

of the respondents (84.9%) are experiencing the limited irrigation water for their rice fields, less awareness of local farmers to use certified rice seeds (73.3%) and high price of agricultural inputs (66.3%).

Table 3. Internal and external contexts of the certified rice seed production in Mandalay

Internal Contexts		External Contexts	
Strengths	Weaknesses	Opportunities	Threats
1. Getting the knowledge about certified rice seed production technologies disseminated by DOA	1. Labor scarcity for rouging the off-type in seed producing rice field	1. Seed producer farmers can get easily the RS rice seeds from DOA seed farms with the cheap price	1. Limited irrigation water for producing certified rice seed
2. Higher rice yield by growing Registered Seed for certified rice Seed	2. Limited market information and weak market linkage for selling certified rice seeds	2. Income earning opportunity for the local community	2. Less awareness of local farmers to use certified rice seeds
3. Getting more income from certified rice seed producing than normal grains	3. Limited investment for certified rice seed production to be stored for selling	3. Affordable certified rice seed for local farmers	3. High prices of agricultural inputs for producing certified rice seed
4. Less infestation because of systematic cultivation	4. Having difficult for storage in ware house	4. Mutual helps between seed producer farmers	4. Necessary of seed dryer for moisture control of rice seeds
5. Farmer can sell their rice seeds with the market price up to farmers' decision	5. Necessary of separate combine harvester only for seed producing fields		

Source: Own survey, 2024

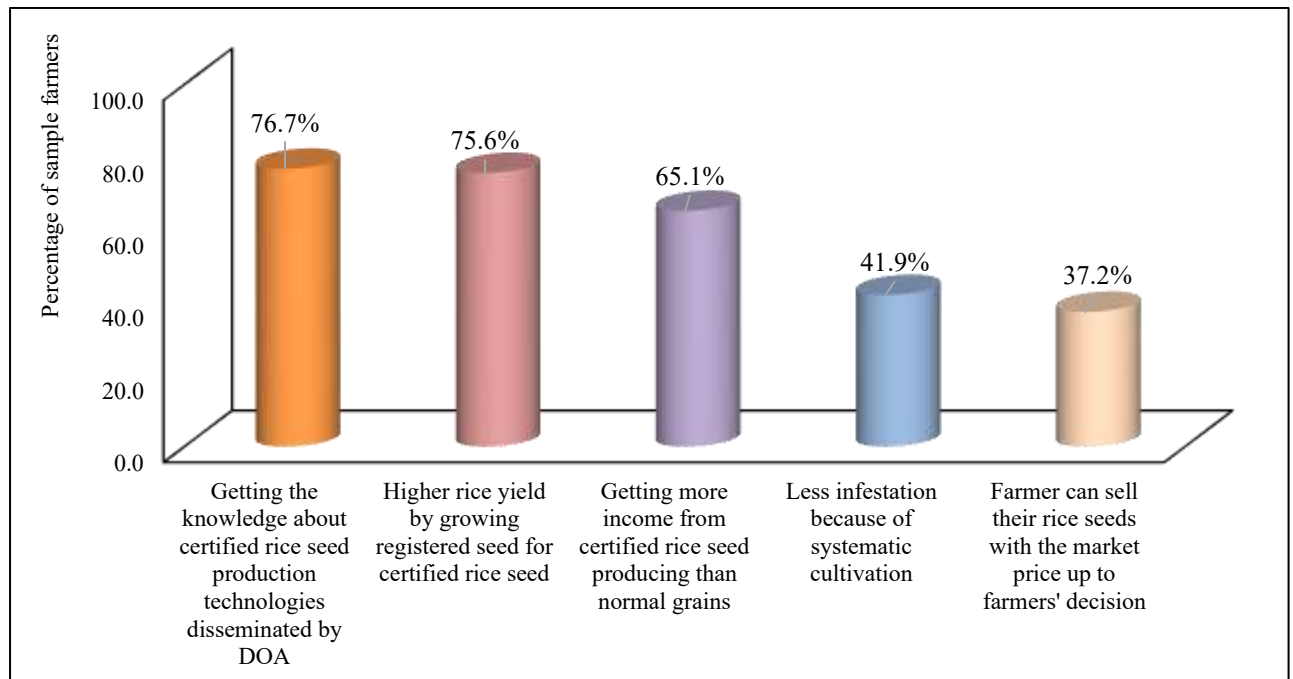


Figure 1. Strengths of certified rice seed producer farmers in Mandalay (n=86)

Source: Own survey, 2024

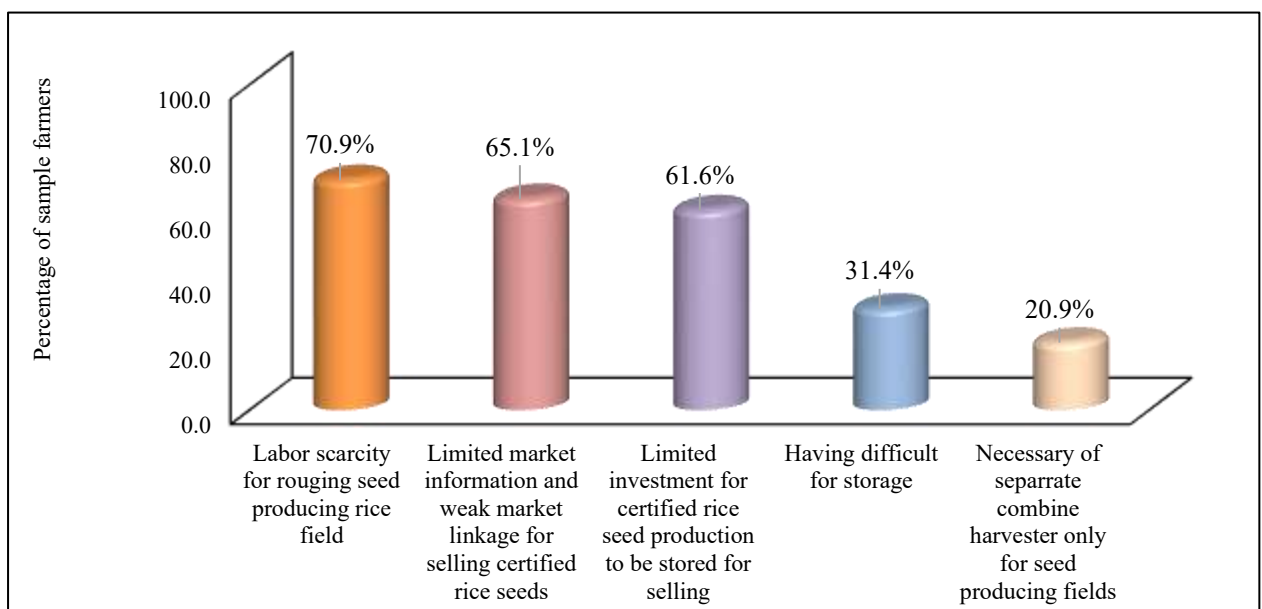


Figure 2. Weakness of certified rice seed producer farmers in Mandalay (n=86)

Source: Own survey, 2024

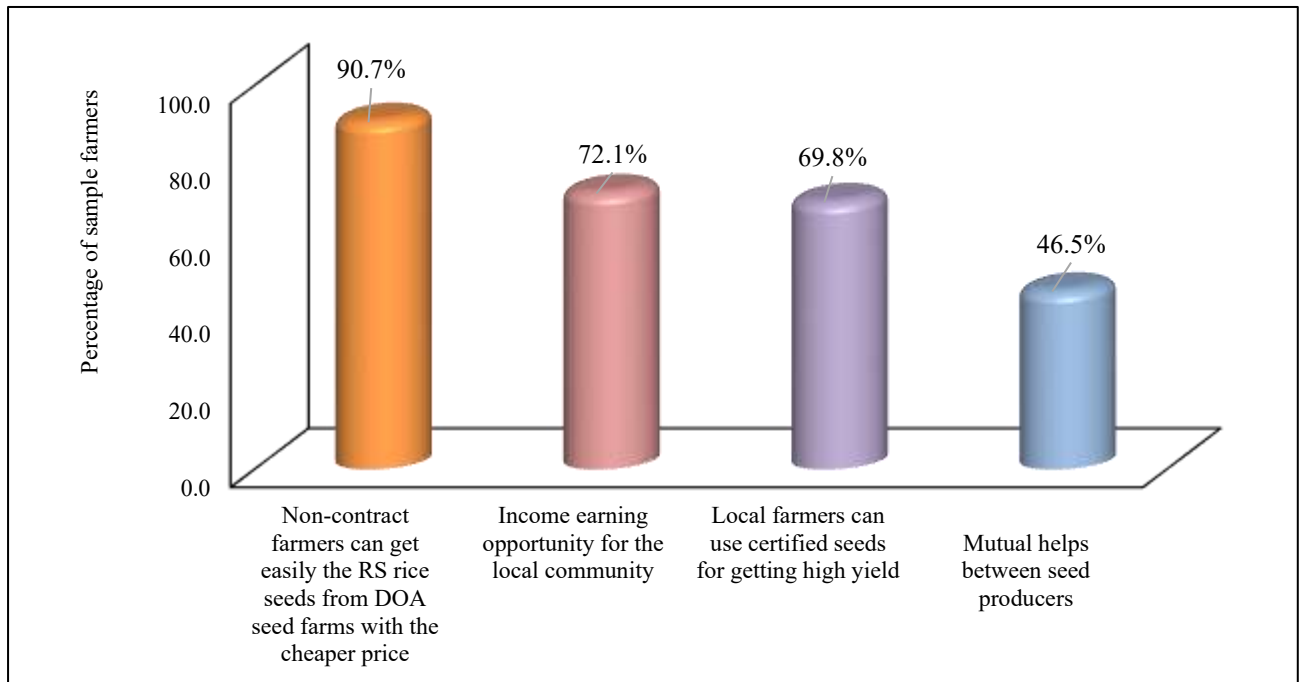


Figure 3. Opportunities of certified rice seed producer farmers in Mandalay (n=86)

Source: Own survey, 2024

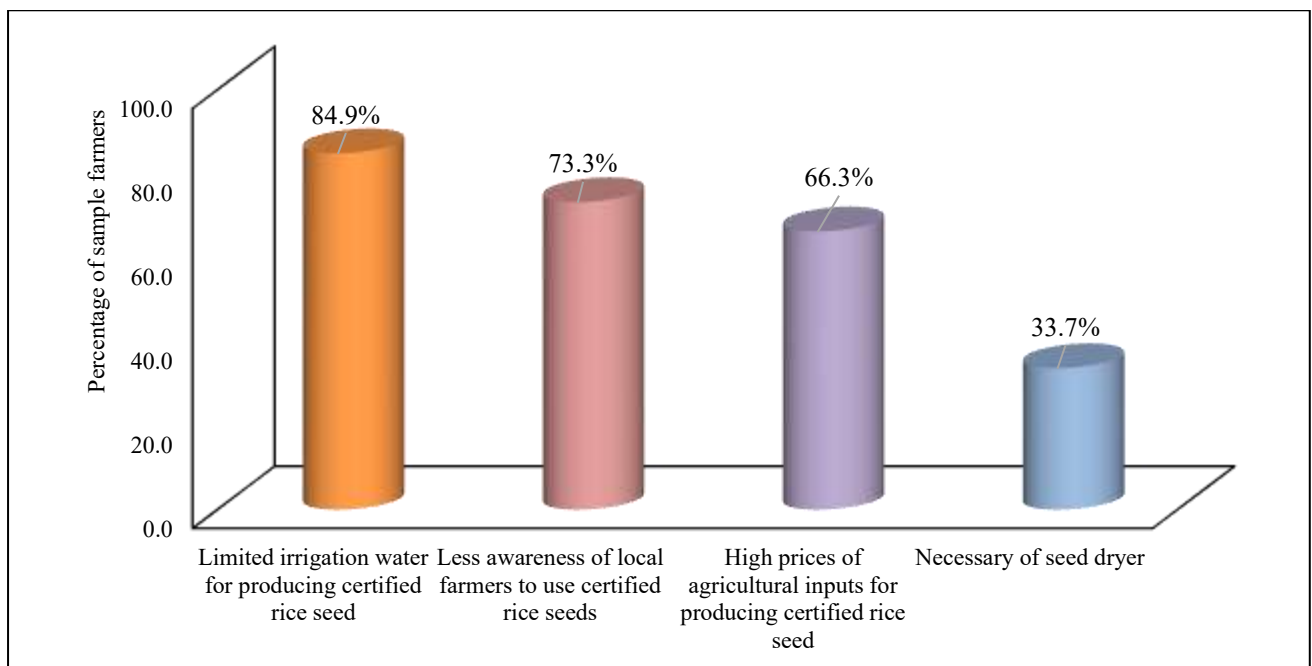


Figure 4. Threats of certified rice seed producer farmers in Mandalay (n=86)

Source: Own survey, 2024

Figure 5 presents possible strategies matrix for the certified rice seed production of this study. After analysing the SWOT of according to the methodology, possible specific strategies for seed production sector were formulated by a combination of SWOT factors using strategies matrix. S-O strategies identified the ways to use strengths factors to maximize the opportunities of organization or company. S-T strategies identified the way to use strengths factors to minimize the possible threats factors of organization or company. W-O strategies that identified the opportunities to develop strategies that would be minimized the weaknesses of organization or company. W-T strategies identified the opportunities to develop strategies that would be avoided or escaped from threats of organization or company.

Internal factors External factors	Strengths (S)	Weaknesses (W)
	S1. Getting the knowledge about certified rice seed production technologies disseminated by DOA S2. Higher rice yield by growing Registered Seed in certified rice seed production S3. Getting more income from certified rice seed producing than normal grains S4. Less infestation because of systematic cultivation S5. Farmer can sell their rice seeds with the market price up to farmers' decision	W1. Labor scarcity for rouging the off-type in seed producing rice field W2. Limited market information and weak market linkage for selling certified rice seeds W3. Limited investment for certified rice seed production to be stored for selling W4. Having difficult for storage in ware house W5. Necessary of separate combine harvester only for seed producing fields
Opportunities (O)	↓ ↓	
	S-O Strategies (Using internal strength to take advantage of external opportunities)	W-O Strategies (Taking advantages of opportunities to offset internal weaknesses)
O1 Seed producer farmers can get easily the register rice seeds from DOA seed farms with the cheaper price O2 Income earning opportunity for the local community O3 Affordable certified rice seed for local farmers O4 Mutual helps between seed producers	S1O2- Promote the rice seed production with seed producing technologies to create job opportunities for local community S2O1- Using register seeds from DOA seed farms for getting high yielding S3O4- More income of seed producer farmers to expand the seed business with the mutual helps of farmers associations	W1O2- Support technical training to local farmers for rouging in seed producing fields W2O3- Support market information and provide strong market opportunities for selling certified rice seeds and usage of certified rice seeds for local farmers with the affordable price W3O3- Facilitate loans and financial programs on rice seed producer farmers W5O4- Provide to farmers for using separate combine harvester especially for seed producer farmers to get good quality certified rice seeds for local farmers with the affordable price

Threats (T)	S-T Strategies (Using internal strength to mitigate or minimize external threats)	W-T Strategies (Strategies that minimize both internal weakness and external threats)
T1. Limited irrigation water for producing certified rice seed	S2T2- Improve the farmer's awareness and knowledge on the effects of using quality seed in their rice growing fields for getting high yield	W1T2- Provide on job training in seed production farms for local workers and awareness of farmers to use certified rice seed
T2. Less awareness of local farmers to use certified rice seeds	S3T4- Encourage to provide the seed dryer for seed producer farmers with the help of local government	W2T2- Provide market information for seed producer farmers to enhance the selling of rice seeds to the local farmers
T3. High prices of agricultural inputs for producing certified rice seed	S2T3- Provide the agricultural inputs by the helps of the relevant department for getting more income for seed producer farmers	W4T4- Provide the seed dryer to reduce the moisture of the seeds and also the seed storage area with helps of government warehouse
T4. Necessary of seed dryer		

Figure 5. Possible strategies matrix for the certified rice seed production

Source: Author's compilation based on own survey

Conclusion

The present study deals with SWOT analysis of certified rice seed production in Mandalay Region and suggests a critical intervention area to improve the certified rice seed production through strategies matrix. According to the results of the study, a number of SWOT elements such as seed production technologies, higher yield, higher income and job opportunity for local community are main contribution points. Meanwhile, limited technical training for local workers to practice as a job training in government seed farms and also relevant department need to educate the rice farmers for the awareness of using of certified seeds for getting higher yield than that of using grain seed in their rice growing. Special agricultural loans and financial support for seed producer farmers in contrast of grain producing farmers that the seed producer farmers need the loan at the seed storage time instead of planting time are major constraints to rice seed production in the study area. The strategies in order to exploit the strengths and opportunities and to elucidate the weaknesses and threats will help to improve the productivity of rice seed production. Therefore, the findings of the study provide policy options in terms of critical intervention areas for the Farmers' Participation in Rice Certified Seed Production in Myanmar sector in Myanmar. Public sector should encourage to upgrade the seed production technologies for the seed producer farmers, to give intensive trainings for local field workers to understand well the roughing practices off-types in seed production

and to provide agricultural loan for the seed producer farmers via development of certified rice seed production towards improved rice industry in Myanmar.

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References

- Akanbi, S. U. O., Mukaila, R., & Adebisi, A. (2024). Analysis of rice production and the impacts of the usage of certified seeds on yield and income in Cote d'Ivoire. *Journal of Agribusiness in Developing and Emerging Economies*, 14(2), 234-250.
- Atilaw, A., Alemu, D., Kifle, T., Bishaw, Z., & Karta, K. (2016). Early Generation Seed Production and Supply: Status, Challenges and Opportunities. *Agricultural Research for Ethiopian Renaissance*.
- Awotide, B. A., Awoyemi, T. T., & Diagne, A. (2012). Access to certified, improved rice seed and farmers' income in Nigeria. *Journal of Crop Improvement*, 26(4), 558-579.
- Mesfin, A. H., & Zemedu, L. (2015). Improved rice seed production and marketing: challenges and opportunities; the case of Fogera district of Ethiopia. *Journal of Agriculture and Environmental Sciences*, 1 (2), 1-21.
- Ministry of Agriculture, Livestock and Irrigation (MOALI). (2022). Myanmar Agriculture Sector in Brief. Nay Pyi Taw. Myanmar.
- Rice Division, Department of Agriculture (DOA). (2024). Seed Producing Area, Yield and Production of Rice Certified Seeds by States and Regions. Nay Pyi Taw. Myanmar.
- Rickman, J. F., and Aquino, E. U. G. E. N. E. (2004). Appropriate technology for maintaining grain quality in small-scale storage. 2007, 149-157.
- Sabai Aye, M., Nomura, H., Takahashi, Y., Stringer, L. C., & Yabe, M. (2022). Improving rice production efficiency in Myanmar by controlling for environmental production factors. *Journal of Agricultural Science (Toronto)*.
- Thompson, A. A., Strickland, A. J., & Gamble, J. E. (2007). *Crafting and Executing Strategy- Concepts and Cases*, (15th Edition), USA: McGrawHill/Irwin.
- Weihrich, H. (1982). The TOWS matrix-A tool for situational analysis. *Long range planning*, 15(2), 54-66.
- Yu, Y. F., Yin, J. H., & Peng, L. L. (2020). Development countermeasures of Jiangxi rice seed industry based on SWOT analysis.

Analysis of Nutritional Content and Heavy Metals of Suckermouth Catfish (*Pterygoplichthys spp.*) in Selangor Malaysia

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Abstract

Suckermouth catfish (*Pterygoplichthys spp.*) is a species of freshwater fish recognized as an invasive alien species in Malaysia. According to the Malaysian Ministry of Fisheries (2019), these urban fish pose a threat to local fish populations, primarily by consuming aquatic plants that are vital for the survival of indigenous fish species. Research conducted on *Pterygoplichthys spp.* in the Puchong River, where their population is notably high and continues to grow, indicates that this species is becoming increasingly dominant in the ecosystem. The negative impacts of this species are significant, and no effective solutions have been identified to eliminate them. Therefore, it is essential to explore alternative uses for suckermouth catfish, such as processing them into food products. To facilitate their use as raw materials for food processing, it is necessary to conduct studies assessing their nutritional value and heavy metal content. Analysis has shown that the levels of crude protein, ash, and crude fat in suckermouth catfish are 63.9%, 20.4%, and 6.1%, respectively. Furthermore, the concentrations of heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) in *Pterygoplichthys spp.* are below the contamination limits established by the Malaysian Food Act of 1983 and the Food Regulations of 1985. Consequently, this fish can be classified as safe for consumption and has the potential to be processed into various economically valuable livestock and fishery products.

Keywords: suckermouth catfish, freshwater, urban fish, heavy metal content, crude protein, crude fat

JEL code: Q10, Q51

SDG classification: SDG 1, SDG 2, SDG 6, SDG 8

Introduction

Suckermouth catfish (*Pterygoplichthys*) is a species of fish that originates from the Amazon River in South America (Armbruster 2004). This fish belongs to the Loricariidae family, which encompasses 122 genera and 963 species globally (Fishbase 2021). According to the compilation in The Global Invasion of the Suckermouth Armored Catfish Genus *Pterygoplichthys* (Siluriformes: Loricariidae), there are 15 recognized species, including *Pterygoplichthys disjunctivus*, *Pterygoplichthys pardalis*, *P. multiradiatus*, *P. anisitsi*, *P. joselimaianus*, *P. lituratus*, *P. ambrosetti*, *P. parnaibae*, *P. xinguensis*, *P. punctatus*, *P. zuliaensis*, *P. scrophus*, *P. undecimalis*, and *P. gibbiceps* (Orfinger and Goodding 2018). In Malaysia, the *Pterygoplichthys* species found in local lakes are not fully utilized by the surrounding communities, either as a food source or as raw material for fish feed. This contrasts with the utilization of suckermouth catfish in the Ciliwung River, Indonesia, where local residents make otak-otak (a fish meat and spice cake), fish balls, shu may (a dim sum-like dish made from fish meat and spices), and fish crackers (Ernawati 2014). The popularity of this fish is largely due to its affordability and availability (Elfidasari *et al.* 2019). Conversely, in Bangladesh and some other countries, suckermouth catfish are underutilized because of the high levels of ash and heavy metals in their flesh, which limits their use primarily to fertilizer (Hossain *et al.* 2018).

Pterygoplichthys spp. are considered appropriate for the development of fishmeal alternatives for various aquatic species (Sumanasinghe and Amarasinghe, 2014; Abesinghe *et al.*, 2020) and serve as protein sources for poultry, including chickens (Intawicha *et al.*, 2020) and ducks (Indarsih *et al.*, 2016). The processing of *Pterygoplichthys* spp. into fishmeal may effectively contribute to controlling their populations in natural water bodies (Mengumphan and Saengkrachang, 2008; de Fonseca and Radampola, 2022). The meal derived from *Pterygoplichthys* spp. contains adequate nutrients to support fish growth (Abarra *et al.*, 2017). High-quality feed is characterized not only by its protein content but also by the presence of essential amino acids that enhance growth performance (Arsad *et al.*, 2019). These amino acids significantly affect the growth rates, reproductive success, and overall development of both fish and chickens.

Supplementing with methionine has been shown to improve protein synthesis in fish, as evidenced by studies on blackhead seabream (17.25%) (Harpaz, 2005), and to enhance growth performance in various fish species, including common carp (*Cyprinus carpio*) (Alissianto *et al.*, 2019) and channel catfish (*Ictalurus punctatus*) (Cai and Burtle, 1996). Additionally, methionine supports the antioxidant system (Elango, 2020) and boosts energy metabolism by facilitating the synthesis of cysteine and glutathione through the trans-sulfuration pathway (Wang *et al.*, 2021). Cysteine, a semi-essential amino acid, plays crucial roles in protein synthesis, structure, and function, and an imbalance between methionine and cysteine can negatively impact the growth of broiler chicks. The study aims to assess the levels of heavy metals and nutritional content to evaluate the potential of these fish as raw materials for livestock and fishery products.

Methodology

Samples of *Pterygoplichthys spp.* were collected from gill net fishermen operating in the Puchong River in February 2025. A total of 100 fish samples were gathered, and their lengths were measured, revealing a range from 39.3 cm to 54.5 cm. The fish flesh was subjected to proximate analysis, amino acid profiling, and heavy metal content assessment. The determination of heavy metal levels in the suckermouth catfish samples was performed using the Atomic Absorption Spectrophotometer (AAS) method, adhering to established quality standards. Nutritional content analysis, specifically the proximate analysis, was conducted at the Animal Nutrition Laboratory within the Animal Science Department of the Faculty of Agriculture at Universiti Putra Malaysia. This proximate analysis included evaluations of protein, ash, fat, and energy content, while amino acid analysis was executed using High-Performance Liquid Chromatography (HPLC).

Results and Discussion

Nutrient content

Proximate analysis was conducted to assess the levels of protein, fat, ash, and energy present in *Pterygoplichthys spp.* The results of this analysis are presented in Table 1. The chemical composition of *Pterygoplichthys spp.* reveals a crude protein content of 63.9%, crude fat of 6.1%, and ash content of 20.4%. According to Nurjannah *et al.* (2005), the protein content in *Pterygoplichthys spp.* is classified within the freshwater fish category that exhibits high protein levels, defined as greater than 20%. Conversely, Elfidasari *et al.* (2018) indicated that a protein content below 15% is considered low, while a range of 15%-20% is deemed moderate, and anything above 20% is classified as high protein, with the maximum protein content in fish reaching 50.05%. The crude protein levels identified in this study are consistent with the findings of Panase *et al.* (2018), which reported a protein content of 54.8% in *Pterygoplichthys pardalis*. Additionally, Payungsuk *et al.* (2020) noted that the chemical composition of *Pterygoplichthys pardalis* in Thailand included 62.28% crude protein, 6.40% lipids, and 3900 kcal g⁻¹ of gross energy. The unexpectedly high protein levels in *Pterygoplichthys spp.* observed in this study are noteworthy. The considerable size of the *Pterygoplichthys spp.* specimens collected is quite remarkable and differs from other fish species, likely influencing the unique nutrient composition.

Variations in the protein content of *Pterygoplichthys spp.* meat can be attributed to the fish's age and body size; generally, longer fish exhibit higher protein levels. This correlation arises because larger fish possess an enhanced capacity for optimal protein synthesis. However, the presence of heavy metals in *Pterygoplichthys spp.* meat can impair physiological functions related to protein synthesis, leading to a reduction in overall protein content (Elfidasari *et al.* 2018). The crude protein content of *Pterygoplichthys pardalis* is 62.2% greater than that of the suckermouth catfish (*Hypostomus plecostomus*), which has a protein content of 37.1% and is widely found in Indonesia (Asnawi *et al.*, 2015). The proximate composition of *P. multiradiatus* meal closely resembles that of *Pterygoplichthys spp.* in Malaysia, with values of 69.5 ± 0.04% crude protein, 4.5 ± 0.05% crude lipid, 6.0 ± 0.2% moisture, and 10.6 ± 0.2% ash content (de Fonseka and Radampola, 2022). Test results indicate that the fat content of *Pterygoplichthys spp.* is 6.1%, classifying the suckermouth catfish as a high-fat fish.

According to Murray and Burt (2001), fish are considered low-fat if their fat content is 1% or less, while those with fat content exceeding 5% are categorized as high-fat fish.

Table 1. Proximate test result *Pterygoplichthys spp*

Parameters	Content (mg/kg)
Dry Matter (%)	90.0 ± 0.02
Ash level (%)	20.4 ± 0.137
Crude protein (%)	63.8 ± 0.02
Crude fat (%)	6.1 ± 0.036
Energy J/g	17,411

Amino acid

The analysis of the amino acid was shown in Table 2. The levels of methionine and cysteine found in *Pterygoplichthys spp.* in this research are 5.242 and less than 0.001, respectively, in comparison to *P. disjunctivus*, which has methionine at 3.81% ± 1.37% and cysteine at 0.19% ± 0.02% (Wang *et al.*, 2023). Methionine is essential for protein synthesis and plays a significant role in various metabolic processes, including the production of other amino acids and the creation of antioxidants. In the context of fish nutrition, methionine is frequently a limiting amino acid, particularly when alternative protein sources that do not include fishmeal are utilized. Therefore, the substitution of cysteine for methionine is vital, as it can lower methionine levels in the diet without adversely affecting growth (He *et al.*, 2016). Additionally, the leucine content in this study is measured at 3.150, which is significantly lower than the 15.15 reported for *P. disjunctivus* in a study conducted in Kolkata, India (Bimal *et al.*, 2017). Leucine serves a therapeutic function in conditions such as burns, trauma, and sepsis, and is also crucial for muscle protein synthesis (Bandt and Cynober, 2006; Etzel, 2004).

Table 2. Analysis of amino acid content of *Pterygoplichthys spp*

Amino acids	Content (g/g)
Leucine	3.150 ± 0.02
Cysteine	<0.001 ± 0.91
Methionine	5.242 ± 1.37

Heavy metal content

The quality and safety of fishery products, particularly fish, are significantly affected by the presence of various elements and compounds within them. Assessing the levels of heavy metals in *Pterygoplichthys spp.* aims to evaluate the safety and suitability of these fish species for human consumption, as well as their economic potential. The findings from the Atomic Absorption Spectrophotometer (AAS) analysis are presented in Table 3. The AAS results indicated the following heavy metal concentrations in the samples: Cadmium (Cd) at <0.002 g/g, Mercury at 0.023 g/g, and Lead (Pb) at 0.002 g/g. In Malaysia, the Malaysian Food Act of 1983 and the Food Regulations of 1985 set the

allowable limits for heavy metals in food products. These regulations define maximum permissible levels for contaminants such as lead (Pb) and cadmium (Cd), thereby safeguarding food safety for consumers. Specifically, the allowable concentration of lead in food is 0.0002 g/g, while cadmium is limited to 0.0001 g/g. The presence of heavy metals in aquatic environments can significantly impact the organisms inhabiting these waters. Fish serves as a significant food source for humans. However, if fish become contaminated, they can pose health risks to individuals (Orfinger and Goodding 2018). While the levels of heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) in the meat of *P. pardalis* are below the maximum allowable limits, continuous consumption of heavy metal-laden foods can adversely affect health (Chavez *et al.* 2006). Lead can enter fish through the food chain and respiratory processes, including gill absorption and skin diffusion (Suprpto *et al.* 2019). The presence of heavy metals in fish organs is significantly affected by environmental conditions, the degree of water pollution, the duration of exposure to contaminants, and the dietary habits of the fish.

As a predator, the suckermouth catfish tends to accumulate higher levels of toxic metals in its tissues, as these metals can build up within organisms and be transferred up the food chain (Winiarska-Mieczan *et al.* 2018). The relatively low concentration of Pb in Lake Puchong is attributed to its less polluted environmental conditions, resulting in heavy metal levels in *Pterygoplichthys spp.* meat remaining below safety thresholds. The interaction between heavy metals and proteins may influence the immune response in fish. When exposed to foreign substances like metals, the immune system activates and produces increased amounts of proteins; however, this does not lead to a long-term rise in the fish's protein content as it is not directly linked to growth. Furthermore, the relationship between heavy metals and protein may reflect a physiological adaptation of *Pterygoplichthys spp.* to their environmental conditions. Such adaptive mechanisms are crucial for the survival of fish, as their cells respond to significant threats, particularly toxic pollutants like Pb. *Pterygoplichthys spp.* can generate stress-induced proteins in response to these threats (Elfidasari).

Table 3. Analysis of heavy metal content of *Pterygoplichthys spp*

Heavy metals	Content (mg/kg)	Limit for health supplement products (mg/kg) ¹
Cadmium (Cd)	<0.002	0.0002
Mercury (Hg)	0.023	0.1
Lead (Pb)	<0.002	0.0002

Conclusion

Researchers and management authorities in Malaysia have the opportunity to evaluate the potential of *Pterygoplichthys spp.* for the production of fishmeal. This initiative could significantly diminish reliance on conventional protein sources for fish feed. Furthermore, it may enhance the utilization of the invasive *Pterygoplichthys spp.* present in Malaysia.

References

- Abarra, S.T., Velasquez, S.F., Guzman, K.D.D., Felipe, J.L.F., Tayamen, M.M., Ragaza, J.A. 2017. Replacement of fishmeal with processed meal from knife fish *Chitala ornata* in diets of juvenile Nile tilapia *Oreochromis niloticus*. *Aquaculture Reports* 5:76–83.
- Abesinghe, A., Sudasinghe, H., Amarasinghe, A., Fareed, F., Senavirathn, T., Meegaskumbura, M. 2020. The identity of the exotic *Pterygoplichthys* sailfin catfishes in Sri Lanka (Teleostei:Loricariidae). *Zootaxa* 4852:145– 150. <https://doi.org/10.11646/zootaxa.4852.1.10>
- Asnawi S., Sudjowo O, Suyadi. E. (2015) Potency of sapu-sapu fish (*Hypostomus plecostomus*) as feed supplement for local ducks. *Int. J. Poult. Sci.*, 14. pp. 240-244
- Alissianto YR, Sandriani ZA, Rahardja BS. The effect of amino acid lysine and methionine addition on feed toward the growth and retention on mud crab (*Scylla serrata*). In *IOP Conference Series: Eart Environ Sci.* 2018; 137(1): 012059
- Armbruster J. 2004. Phylogenetic relationships of the suckermouth armoured catfishes (Loricariidae) with emphasis on the Hypostominae and the Ancistrinae. *Zool J Linn Soc* 14: 1-80. DOI: 10.1111/j.1096-3642.2004.00109. x.
- Arsad SC, Stavrakakis V, Turpin P, Rossa Y, Risjani LA, Sari FS, et al. *IOP Conference Series: Eart Environ Sci.* 2019; 236, 012044 [[Google Scholar](#)]
- Bimal, P.M., Satabdi, G., Arabinda, M., Tandrima, M., Laduram, M., Sanjay, B., Samir, K.P and Basanta K.D. (2017). Nutritional composition of the invasive *Pterygoplichthys Disjunctivus* from East Kolkata Wetland India., *J. Inland Fish. Soc. India*, 49 (2) : 48-54.
- Cai Y, Burtle GJ. Methionine requirement of channel catfish fed soybean meal-corn-based diets. *J Ani Sci.* 1996;74(3):514–21. doi: 10.2527/1996.743514x
- Chávez JM, De La Paz RM, Manohar SK, Pagulayan RC, Carandang JR (2006) New Philippine record of SouthAmerica sailfin catfis
- de Fonseka, R., Radampola, K. 2022. Feasibility of using sailfin catfish meal as an alternative to commercial fishmeal in the diets of juvenile guppy (*Poecilia reticulata*). *Journal of Fisheries* 10:101203–101203.
- De Bandt JP, Cynober L(2006) Therapeutic use of branched chain amino acids in bur
- Elango R. Methionine nutrition and metabolism: insights from animal studies to inform human nutrition. 2020. *J Nutr.* 150; 2518–2523. doi: 10.1093/jn/nxaa155
- Ernawati Y. 2014 The analysis of the concentration of heavy metals cadmium, mercury and lead in the flesh of suckermout catfish (*Pterygoplichthys pardalis*) in Ciliwung River, Indonesia. *AACL Bioflux* 7 (1): 33-42.
- Elfidasari D, Ismi LN, Shabira AP, Sugoro I. 2018. The correlation between heavy metal and nutrient content in *Plecostomus* (*Pterygoplichthys pardalis*) from Ciliwung River in Jakarta. *Biosaintifika* 10 (3)
- Etzal MR (2004) Manufacture and use of dairy protein fractions *J Nutr*134(4):996S-1002S

- Harpaz Sheenan. L-Carnitine and Its Attributed Functions in Fish Culture and Nutrition. *Aqua*. 2005;3–21. doi: 10.1016/j.aquaculture.2005.04.007
- He J. Y., Han B., Tian L. X., Yang H. J., Zeng S. L., Liu Y. J., 2016 The sparing effect of cystine on methionine at a constant TSAA level in practical diets of juvenile Nile tilapia *Oreochromis niloticus*. *Aquaculture Research* 47(7):2031-2039.
- Hossain M, Vadas R, Ruiz-Carus R, Galib SM. 2018. Amazon sailfin catfish *Pterygoplichthys pardalis* (Loricariidae) in Bangladesh: A critical review of its invasive threat to native and endemic aquatic species. *Fishes* 3: 14. DOI: 10.3390/fishes3010014.
- Indarsih, B., Asnawi, A., Purnamasari, D.K. 2016. Sapu-sapu fish (*Hyposarcus pardalis*) as a single protein source for laying mojosari ducks. *Journal of Indonesian Tropical Animal Agriculture* 41:117–124.
- [Intawicha, P., Wanaporn, T and Montri, P. 2020.](#) *International Journal of Poultry Science* 19 (8): 380 - 384 , 2020
- Panase, P, Saenphet, S and Saenphet, K. 2018. *Aquaculture Reports*. 11:17-23.
- Mengumphan, K., Saengkrachang, J. 2008. Production of generation-2 Mekong giant catfish (*Pangasinodon gigas*) cultured with *Spirulina* sp. *Maejo International Journal of Science and Technology* 2:559–567
- Murray J, Burt JR. 2001. *The Composition of Fish*. FAO, Rome, Italy.
- Nurjannah, Nitibaskara, R., & Madiha, E. (2005). Pengaruh penambahan bahan pengikat terhadap karakteristik fisil otak-otak ikan sapu-sapu (*Liposarcus pardalis*). *Buletin Teknologi Hasil Perikanan*, 1-11.
- Orfinger AB, Goodding DD. 2018. The global invasion of the suckermouth armored catfish genus *Pterygoplichthys* (Siluriformes: Loricariidae): Annotated list of species, distributional summary, and assessment of impacts. *Zool Stud* 57: e7. DOI: 10.6620/ZS.2018.57- 07.
- Payungsuk I., Wanaporn, T and Montri P. 2020. Suckermouth Armored Catfish (*Pterygoplichthys pardalis*) as a Replacement for Fish Meal in Thai “Pradu Hang Dam” Native Chicken Diets. *International Journal of Poultry Science*.
- Sumanasinghe, H.W., Amarasinghe, U. S. 2014. Population dynamics of accidentally introduced Amazon sailfin catfish, *Pterygoplichthys pardalis* (Siluriformes, Loricariidae) in Pologolla reservoir, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 18:37–45
- Suprpto H, Arief M, Ermawati L, Hakim HZ, Hidayati N. 2019. Toxicity and severe stress of lead (Pb) to hematology responses of java barb (*Barbonymus gonionotus*). *Intl J Fish Aquat Stud* 7 (6): 26-30.
- Wang W, Yang P, He C, Chi S, Li S, Mai K, et al. Effects of dietary methionine on growth performance and metabolism through modulating nutrient-related pathways in largemouth bass (*Micropterus salmoides*). *Aqua Rep*. 2021; 20:100642.
- Winiarska-Mieczan A, Florek M, Kwiecien M, Kwiatkowska K, Krusinski R. 2018. Cadmium and lead content in chosen commercial fishery products consumed in Poland and

risk estimation on fish consumption. Biol Trace Elem Res 182: 373-380. DOI: 10.1007/s12011-017-1104-1.

Maximizing The Potential of Philippine Pigmented Maize in Nutrient-Dense Snack Development

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Abstract

Food and nutrition security continues to be a major challenge in the Philippines, contributing to the persistent issue of malnutrition. With protein-energy malnutrition and macronutrient deficiencies being prevalent among children under five, the government has prioritized the development of complementary food blends to address these nutritional gaps. This study aimed to develop a ready-to-eat (RTE) snack using pigmented maize (APN 408), a locally available ingredient recognized for its nutritional value due to the presence of secondary metabolites like flavonoids, anthocyanins, and phenolic acids. Snack crackers were made using 30% mungbean flour (control), known for its high protein content, along with different formulations of cornstarch and pigmented maize. Five formulations were produced using the process done in keropok production, followed by drying, then deep frying. Sensory evaluation revealed that the addition of 7.5% pigmented maize to the cornstarch and mungbean were preferred by most panelists. This formulation was subjected to proximate and physicochemical analyses. Results showed that snack crackers with added pigmented maize had significantly higher crude protein and carbohydrate content than those made solely with mungbean and cornstarch, offering a more nutrient-dense option that helps children aged 3 to 5 years old meet their recommended macronutrient intake. Overall, the incorporation of pigmented maize in snack crackers presents a promising solution to improve food and nutrition security by providing an affordable, accessible, and nutritionally superior alternative to traditional complementary food blends.

Keywords: complementary food blends, nutrient enrichment, keropok production, corn-based snacks

JEL code: L66, Q19, Q16

SDG classification: SDG 2

Introduction

Over the years, the Philippines' battle against malnutrition has seen little to no progress, continuing to affect Filipino children nationwide, especially those situated in rural areas. With the persistence of the problem, the government has made nutrition investments to address the pressing concerns about the impact of malnutrition and its effects on children's development and growth. Specifically, the launch of the Department of Science and Technology - Package for the Improvement of Nutrition of Young Children (DOST - PINOY) introduces complementary food production to selected priority regions offering both technical assistance and adoption of the developed products for free.

According to reports, approximately 70% of Filipino children consume snacks once a day, with afternoon snacks being the most prevalent choice (Serafico et al., 2023). Given their regular consumption, snacks possess a substantial potential for delivering the essential nutrients in children to meet their dietary needs. For instance, snack products contribute to 31.2% of the total energy among children aged 3-5 years old (Serafico et al., 2023) which is significant in addressing malnutrition in the country.

This research aims to improve the current available Rice-Mongo crunchies (RMC) of DOST - FNRI by incorporating pigmented maize. The development of this snack takes advantage of pigmented maize's protein content which is seen as a better alternative to rice which is seen to potentially address protein-energy malnutrition and achieve food and nutrition security among children.

This study aimed to develop ready-to-eat (RTE) healthy snacks made from pigmented maize (APN 408), mungbean, cornstarch, with the objective of providing a nutritious and convenient snack option. While the specific objectives are:

- 1) Determine the physicochemical properties and proximate composition of the developed RTE maize-based snack
- 2) Evaluate the sensory properties and general acceptability of the product; and
- 3) Compute for the nutritional composition of the formulated product

Methodology

Time and place of study

The procurement of raw materials, dough preparation, and sensory evaluation were conducted at the Food Chemistry laboratory of the Institute of Food Science and Technology, University of the Philippines Los Baños (UPLB), College, Laguna from February 2024 to May 2024. While, cabinet drying of the developed snack crackers was done at Lakay Manufacturing, Sta. Rosa, Laguna. The pigmented maize flour (APN 408) was sourced from Institute of Plant Breeding while other raw materials were acquired from the local market in Los Baños. The proximate analysis was conducted at SentroTek Corporation, Mandaluyong City, Metro Manila in May 2024.

Preparation of mixture formulation

The mixture formulation was prepared following the method of Tuhumury et al. (2020). Mungbean flour was maintained at 30% concentration. Pigmented maize (APN 408) flour and cornstarch in dry powder form were weighed using an analytical balance and mixed together in the specified ratios below. Then, a 1:1 dry mixture-to-water ratio (100g:100 mL) was steamed cooked over a medium heat for 45 minutes, then cooled for 1 - 2 hours. The cooled mixture was kneaded into dough, molded into blocks, boiled for 60 minutes, cooled again, sliced into 1.5 mm pieces, and dried using a cabinet dryer at 80 °C for 3 hours. After cooling, the slices were deep-fried in coconut oil at 180 °C for 3–5 seconds. Finally, the snack crackers were flavored with a 60:40 cheese to kalabasa powder mix per 100g of crackers.

Table 1 presents the different formulations with F1 being the control group, having no pigmented maize flour added. The mungbean flour has a controlled concentration of 30% based on the formulation of Rice-Mongo Crunchies of DOST – FNRI.

Table 1. Formulation of snack crackers

Formulations					
Main Ingredients	F1	F2	F3	F4	F5
Mungbean flour (g)	300g	300g	300g	300 g	300g
Pigmented maize flour (g)	0	75g	150g	225g	300g
Cornstarch (g)	700g	625g	550g	475g	400g

Note: F1: no added pigmented maize flour; F2: with 25% pigmented maize in reference to mungbean flour; F3: with 50% pigmented maize flour in reference to mungbean flour; F4: with 75% pigmented maize flour in reference to mungbean flour; F5: with 100% pigmented maize flour in reference to mungbean flour

Sensory evaluation

The sensory evaluation was conducted at the Conference Room of the Institute of Food Science and Technology (IFST), UPLB. The snack cracker formulations were evaluated by 50 experienced panelists from the UPLB, all have taken the FST 151 (Sensory Evaluation) subject. A 9-point hedonic scale rating was used to score the samples for appearance, taste, aroma, texture (crunchiness), and overall acceptability, with 9 being the most preferred quality and 1 as least preferred quality. The sensory scores were as follows 1 (Dislike Extremely), 2 (Dislike), 3 (Dislike Moderately), 4 (Dislike Slightly) 5 Neither like 26 nor Dislike), 6 (Like Slightly), 7 (Like), 8 (Like Very Much), and 9 (Like Extremely).

To ensure food safety, all utensils were washed prior to the sensory evaluation to reduce possible contamination of microorganisms. Five cups with different formulations, including the control, were arranged randomly for each panelist based on a master list. After evaluation, score sheets were collected, summarized, and analyzed using Student's t-test. The formulation with the highest overall acceptability score for each parameter was considered the most preferred. All leftover samples were disposed of properly, following sanitary protocols.

Proximate analysis

Proximate analysis was conducted using standard AOAC (2010) methods to determine the nutritional composition of the sample.

Moisture content was measured using the hot air oven method. Approximately 1 gram of the sample was placed in a pre-weighed crucible, dried at $100 \pm 5^\circ\text{C}$ until a constant weight was achieved, and then cooled in a desiccator before final weighing

$$\% \text{ MC} = \left(\frac{\text{loss in weight}}{\text{weight of sample}} \right) \times 100 = \left(\frac{w_2 - w_3}{w_2 - w_1} \right) \times 100 \quad (1)$$

where

w_1 = initial weight of empty crucible

w_2 = weight of crucible + sample before drying

w_3 = weight of crucible + sample after drying

Ash content was determined by dry ashing, where about 5–10 grams of the sample was incinerated in a muffle furnace at 550°C for two hours. The residue was then cooled in a desiccator and weighed.

$$\% \text{ Ash} = \left(\frac{\text{weight of residue}}{\text{weight of sample}} \right) \times 100 = \left(\frac{w_2 - w_3}{w_2 - w_1} \right) \times 100 \quad (2)$$

where

w_1 = initial weight of empty crucible

w_2 = weight of crucible + sample before ashing

w_3 = weight of crucible + sample after ashing

Crude fat content was analyzed using the Soxhlet extraction method. Around 1 gram of the dried sample was extracted with petroleum ether for 16 hours, then dried at 50°C until no traces of solvent remained.

$$\% \text{ Crude fat} = \frac{\text{weight of fat}}{\text{weight of sample}} \quad (3)$$

Crude protein was quantified through the Kjeldahl method, involving acid digestion with sulfuric acid and a selenium catalyst, followed by distillation with sodium hydroxide and titration with hydrochloric acid. The percentage of nitrogen obtained was multiplied by a protein conversion factor to calculate crude protein.

$$\% \text{ N} = \frac{(\text{Sample-Blank})_{\text{vol HCl}} (\text{Normality}_{\text{HCl}}) (1.4)}{\text{weight of sample}} \quad (4)$$

$$\% \text{ Crude Protein} = (\% \text{ Nitrogen}) (\text{Protein Factor}) \quad (5)$$

Crude fiber was assessed by defatting the sample with petroleum ether, boiling it sequentially in 1.25% sulfuric acid and 1.25% sodium hydroxide, filtering and washing, then drying and ashing the final residue to determine weight loss.

$$\% \text{ Crude fiber} = \left(\frac{\text{loss in weight}}{\text{weight of sample}} \right) \times 100 \quad (6)$$

Carbohydrate content was calculated by difference, subtracting the sum of the measured moisture, protein, fat, fiber, and ash contents from 100.

$$\% \text{ Carbohydrate} = 100 - (\% \text{MC} + \% \text{Protein} + \% \text{Fat} + \% \text{Fiber} + \% \text{Ash}) \quad (7)$$

Energy content was computed using the Atwater system, which multiplies the grams of protein, fat, and carbohydrate by 4, 9, and 4 kcal/g respectively, and includes alcohol at 7 kcal/g if present.

$$\begin{aligned} \text{energy (kcal)} = & \left(4 \frac{\text{kcal}}{\text{g}} \text{ protein} \times \text{g protein} \right) + \left(9 \frac{\text{kcal}}{\text{g}} \text{ fat} \times \text{g fat} \right) + \\ & \left(4 \frac{\text{kcal}}{\text{g}} \text{ carbohydrate} \times \text{g carbohydrate} \right) + \left(7 \frac{\text{kcal}}{\text{g}} \text{ alcohol} \times \text{g alcohol} \right) \end{aligned} \quad (8)$$

Percent Daily Value (%DV) was calculated based on the US FDA (2023) guidelines for a 2,000-calorie diet, where values less than 5% are considered low and values above 20% are high. Percent Recommended Energy and Nutrient Intakes (%RENI) was calculated using PDRI values, specifically the male reference values for children aged 3–5 years, to assess the nutritional adequacy of the food samples.

Physicochemical analysis

Only the selected snack cracker formulations with the highest general acceptability were subjected to physicochemical analyses.

Linear expansion was measured following Cheow et al. (2004), by tracing five lines across each dried cracker slice and comparing their lengths before and after frying. The percentage of linear expansion was calculated based on the change in length.

$$\text{Linear expansion} = \frac{\text{length after frying} - \text{length before frying}}{\text{length before frying}} \quad (9)$$

Water activity was determined using a water activity meter, which measures the ratio of the vapor pressure of the food sample to that of pure water, yielding a value between 0.0 and 1.0.

Color measurement was conducted using the CIE Lab color space system under standard illuminant D65. Each sample was measured ten times—five at the front and five at the back—to calculate the mean and standard deviation of Lab* values.

Hygroscopicity was assessed using the method of Igual et al. (2021) as cited by Sotelo-Díaz et al. (2023), where 0.5 grams of extrudate sample were stored at 25 °C and 81% relative humidity in an airtight container with Na₂SO₄ for seven days. The weight gain was used to determine the amount of water absorbed per 100 g of dry solids.

Water Solubility Index (WSI) and Water Absorption Index (WAI) were evaluated based on Singha et al. (2018). Ground extrudate samples were mixed with distilled water, centrifuged, and measured for dissolved solids and sediment. WSI was calculated as the weight of dissolved solids in the supernatant relative to the dry weight, while WAI was determined by the ratio of sediment weight to the dry sample.

$$\text{WSI (\%)} = \frac{\text{weight of dissolved in supernatant}}{\text{weight of dry solids}} \times 100 \quad (10)$$

$$\text{WAI} \left(\frac{\text{g}}{\text{g}} \right) = \frac{\text{weight of sediments}}{\text{weight of dry solids}} \quad (11)$$

Data analysis

This study used Student's T-test to compare the means of the two formulations with highest overall acceptability. The two formulations were treated as independent groups, with the Shapiro-Wilk test used for assessing normality and Levene's test used for evaluating homogeneity. All analyses will be done in triplicates and presented in means $\pm$ SD, with data analyses being done using SPSS.

Results and Discussion

Preliminary trials on development of snack crackers

Figure 1 shows the different formulations of snack crackers. Using the formulation of Rice-Mongo Crunchies developed by DOST-FNRI, a 30% mungbean flour concentration was followed, which was maintained on all five formulations. Rice flour was substituted with cornstarch, as the texture of keropok is typically achieved through starch gelatinization, a process where starch and water are subjected to heat.

In this study, varying combinations of mungbean flour, pigmented maize flour (APN 408), and cornstarch were used to determine which formulation would yield the highest overall acceptability. The incremental 25% addition of pigmented maize was based on the mungbean flour concentration. After frying, the snack crackers have a moisture content of 3- 4% which aligns the typical moisture content range for crackers (3 - 5%) as noted by Lu (2016).



Figure 1. Different formulations of snack crackers.

Sensory evaluation of the developed snack crackers

Figure 2 presents the median values for each sensory attribute of the snack crackers. As shown, formulation 1 (F1) received the highest median scores across all sensory attributes, indicating a strong consumer preference. While formulation 2, which includes 7.5% pigmented maize flour, followed with a moderate acceptability (median score of 6). Based on the ratings, it is evident that increasing the concentration of pigmented maize

results in a decreased preference for appearance due to color changes from Maillard reaction and reduced crunchiness. Hence, formulations with higher concentrations of pigmented maize were less favored. Despite this, some panelists emphasized that formulation 2 could be improved with better crunchiness, making it the most promising among all the formulations with added pigmented maize flour.

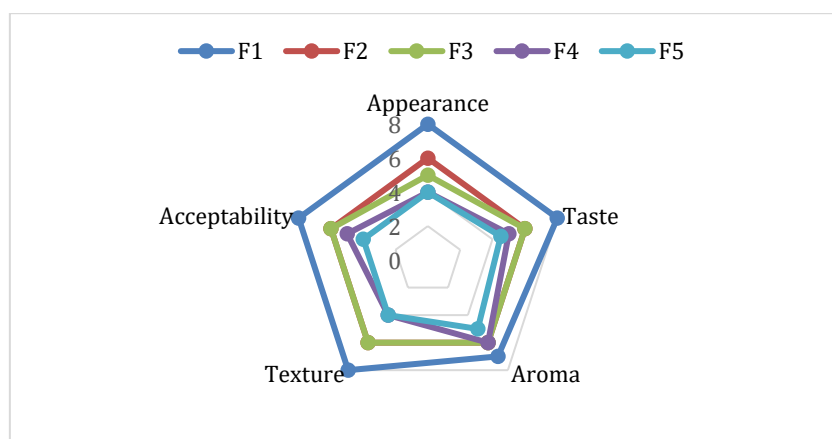


Figure 2. Spiderweb diagram of median values for each sensory attribute of the snack crackers

F1: no added pigmented maize flour; F2: with 25% pigmented maize in reference to mungbean flour; F3: with 50% pigmented maize flour in reference to mungbean flour; F4: with 75% pigmented maize flour in reference to mungbean flour; F5: with 100% pigmented maize flour in reference to mungbean flour

Physicochemical analysis of the developed snack crackers

The data for the physicochemical properties of the snack products are shown in Table 2. The physical quality of the products depends on raw materials, such as its initial composition, formulations, and the pre-processing treatments (Oikonomou & Krokida, 2011). All treatments showed significant differences with each other, indicating a p-value less than 0.05. This suggests that the addition of pigmented maize flour affects the quality of the final product.

Formulation 1 demonstrated highest values for linear expansion, hardness, lightness, water activity, and water absorption index (WAI), making it the most preferred formulation despite being harder due to its crispiness. Its higher linear expansion (67.14 ± 8.78) is linked to better starch gelatinization and water retention, contributing to texture and volume. On the other hand, formulation 2 exhibited reduced expansion, hardness, and lightness due to the addition of pigmented maize flour, as increasing the protein content leads to a less expanded extrudate with higher bulk density and a more compact texture (Korkerd et al. (2015).

Formulation 2 also showed higher hygroscopicity and water solubility index (WSI), suggesting it is more prone to moisture absorption and has better starch digestibility. Formulation 1 exhibited a higher water activity value of 0.38 ± 0.01 , whereas formulation 2 had a water activity of 0.33 ± 0.01 , which implies that the former has more available

water, making it more prone to spoilage and contamination by bacteria, molds, and yeasts. However, since their water activity values fall within the safe range of (<0.85 aw), both formulations are classified as low moisture foods. Moreover, the color analysis revealed that formulation 1 appeared lighter and more uniform, wherein the addition of pigmented maize led to darker shade as it imparts a golden hue color, deviating from the lighter color produced by using mungbean flour only.

Table 2. Physicochemical analysis of the snack crackers

	F1	F2
		
Linear expansion, %	67.14 ± 8.76^a	54.34 ± 7.94^b
Water activity, Aw	0.38 ± 0.01^a	0.33 ± 0.01^b
Hardness, N	7.29 ± 1.30^a	4.93 ± 0.77^b
Color		
L*	66.46 ± 1.45^a	58.29 ± 0.64^b
a*	10.86 ± 0.47^a	8.07 ± 0.37^b
b*	35.61 ± 1.47^a	25.26 ± 1.04^b
Hygroscopicity, %	14.00 ± 1.19^b	15.23 ± 1.34^a
Water absorption index, (g/g dry solid)	4.42 ± 0.03^b	3.16 ± 0.02
Water solubility index, %	16.28 ± 0.63^b	18.68 ± 0.23^a

Note: Means $\pm$ SD with different superscripts are significantly different at 5% level of significance. F1 is the control group without pigmented maize flour. F2 is the formulation with 25% pigmented maize flour with reference to mungbean flour concentration.

Proximate composition of the developed snack crackers

Table 3 shows the proximate analysis of the snack crackers, with formulation 2 having pigmented maize flour added. Comparing the two formulations, it can be observed that the mean values for each component of the proximate analysis differ, with formulation 1 having higher values except for ash content and protein content. Since the two formulations are treated as independent groups, Student's t-test was used to compare the means of the samples. The values obtained from the Shapiro-Wilk test indicated that the assumption for normality for both groups was satisfied. Furthermore, the results obtained from Levene's test indicated that the assumption for homogeneity of variances was satisfied.

Table 3. Proximate analysis of the developed snack crackers

Sample	Moisture Content (%)	Ash (%)	Content	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)	Nfe (%)
F1	3.760 ± 0.026 ^a	0.882 ± 0.004 ^b	+	6.180 ± 0.121 ^b	15.503 ± 0.030 ^a	2.107 ± 0.101 ^a	71.630 ± 0.159 ^b
F2	3.137 ± 0.067 ^b	1.208 ± 0.003 ^a	±	7.367 ± 0.0412 ^a	10.404 ± 0.005 ^b	1.863 ± 0.101 ^b	76.021 ± 0.183 ^a

Note: Means ± SD with different superscripts is significantly different at 5% level of significance. NFE: Nitrogen-free extract. F1 is the control group without pigmented maize flour. F2 is the formulation with 25% pigmented maize flour with reference to mungbean flour concentration.

Nutrition label of the developed snack crackers

As shown in Table 4 is the amount per serving and calculated %REI/RNI are based on Philippine Dietary Reference Intakes (2018). To establish a nutritional label, the amount per serving was calculated based on the results of the proximate analysis. A 30-gram serving size was used which is the recommended portion size for snacks based on the European Snacks Association (2019). Based on the table, it can be seen that formulation 2 had a higher total protein and total carbohydrate content, making it more nutritious than formulation 1. This is attributed to the addition of pigmented maize flour (APN 408) which significantly affects the nutritional composition of the final product. Hence, it can be concluded that inclusion of raw materials high in protein will lead to better nutritional value of the product.

Table 4. Amount per serving and %REI/RNI calculation for 30 g snack product

	F1			F2		
	Amount Serving	per	%REI/RNI	Amount Serving	per	%REI/RNI
Energy (kCal)	135.159		8.447	128.153		8.010

Total Protein (g)	1.854	6.180	2.210	7.367
Total Carbohydrates (g)	21.471	-	22.806	-
Total Dietary Fiber (g)	0.632	4.514	0.559	3.993
Total Fat (g)	4.651	-	3.121	-

Note: The %REI/RNI values per serving (30g) is based on PDRI reference male children of 6 - 9 years old. F1 is the control group without pigmented maize flour. F2 is the formulation with 25% pigmented maize flour with reference to mungbean flour concentration.

As shown in Figure 3, a serving of the snack crackers with 7.5% pigmented maize flour addition contains 128 kCal which is lower than DOST FNRI's extruded product using a combination of rice and mungbean flour which contains 160 kCal (DOST - FNRI, 2022). This could be attributed to low protein content of the product due to the boiling process done. Boiling primarily affects the structure and solubility of proteins rather than significantly decreasing the actual protein content in the mixture (Yousefi & Abbasi, 2022). However, it can lead to the loss of some protein-bound nutrients into the cooking water, especially since the water is discarded after the process (Buratti et al., 2020). Since the protein content is low, it does not follow the standard protocols for nutritional claim of 'source of protein' since at least 12% of the food's energy content did not come from protein (Food and Drug Administration, 2022). Instead, since no sodium is added, a nutritional claim of 'no added sodium' is applicable, meaning the product contains no more than 0.12 g sodium (Food and Drug Administration, 2022). In addition, a claim indicating that no sugars have been added to the food is applicable as well.

NUTRITION FACTS		
1 serving per container		
Serving size	30g (1.76oz)	
Amount per serving		
	128 kcal	
	%DV*	%REI/RNI**
Total fat 7g	5%	
Saturated fat 0g		
Trans fat 0g		
Cholesterol 0mg		
Sodium 0mg		
Total Carbohydrates 25g	4%	
Dietary fiber 0.5g	2%	4%
Total Sugars 0g		
Includes 0g Added Sugars		
Protein 2g	2%	7%

*The %Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories is used for general nutrition advice.

** Percent REI/RNI values are based on FNRI reference male children of 6 - 9 years old.

Figure 3. Nutritional label of pigmented maize-based snack crackers

Conclusion

The study explored the use of pigmented maize (APN 408) in developing nutrient-dense snack crackers for children aged 3–5 years, aiming to contribute to food and nutrition security. Formulation 2 with 7.5% concentration of pigmented maize flour resulted in the highest overall acceptability among all the formulations with pigmented maize flour. Sensory evaluation indicated positive responses for appearance, taste, aroma, texture, though crispiness could be improved. Based on proximate analysis, this formulation showed a higher protein and carbohydrate content, making it a better alternative to existing snack options for improving dietary intake in young children.

To build upon these findings, the study further recommends to optimize the processing methods to achieve a product with better crunchiness and hardness. Additionally, it suggests exploring other raw materials to combine with pigmented maize to determine how well it integrates with other ingredients. Given the nutritional value of pigmented maize, especially iron and zinc, future researchers should include the assessment of these micronutrients, making it a good potential in addressing micronutrient deficiency through snack development. In relation, it is recommended to use other pigmented maize varieties, as APN 408 is not among those with the highest antioxidant activity. In addition, shelf-life analysis of the developed snack crackers is recommended for more accurate labelling of expiration date in the packaging. Lastly, microbial analysis is recommended to ensure that the samples are safe for consumption.

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References

- AOAC 2010. Official Methods of Analysis of Association of Official Analytical Chemists. 18th Edition, Washington, DC.
- Buratti S, Cappa C, Benedetti S, Giovanelli G. 2020. Influence of cooking conditions on nutritional properties and sensory characteristics interpreted by E-Senses: Case-Study on selected vegetables. *Foods*, 9(5), 607. doi:10.3390/foods9050607.
- Cheow C, Kyaw Z, Howell n, Dzulkifly M. 2004. Relationship between physicochemical properties of starches and expansion of fish cracker 'keropok'. *Journal of Food Quality*, 27: 1-12. doi:10.1111/j.1745-4557.2004.tb00633.x.
- Department of Science and Technology - Food and Nutrition Research Institute. 2018. Expanded National Nutrition Survey: 2019 Results - Nutritional Status 1499 Of Filipino Preschool Children. [http://enutrition.fnri.dost.gov.ph/site/uploads/2018-1500 2019%20](http://enutrition.fnri.dost.gov.ph/site/uploads/2018-1500%202019%20)

- European Snack Organization. 2019. Portion Size. <https://www.esasnacks.eu/PDF/PortionSize2019.pdf>
- Korkerd S, Wanlapa S, Puttanlek C, Uttapap D, Rungsardthong V. 2015. Expansion and functional properties of extruded snacks enriched with nutrition sources from food processing by-products. *Journal of Food Science and Technology/Journal of Food Science and Technology*, 53(1), 561–570. [doi:10.1007/s13197-015-2039-1](https://doi.org/10.1007/s13197-015-2039-1)
- Lu S. 2016. Rice: Chinese food uses. In Elsevier eBooks (pp. 110–115). [doi:10.1016/b978-0-12-394437-5.00127-3](https://doi.org/10.1016/b978-0-12-394437-5.00127-3)
- Oikonomou N, Krokida M. 2011. Literature data compilation of WAI and WSI of extrudate food products. *International Journal of Food Properties*, 14(1), 199–240. [doi:10.1080/10942910903160422](https://doi.org/10.1080/10942910903160422)
- Philippine Dietary Reference Intakes. 2015. Food and Nutrition Research Institute, Department of Science and Technology. Retrieved from <https://www.pclm-inc.org/uploads/2/0/4/0/2040875/pdri-2018.pdf>
- Serafico M, Goyena E, Desnacido J, Ducay A. (2023). Snacking Patterns of Filipino Children: Frequency and Contribution to Energy and Dietary Intakes. *Philippine Journal of Science*. <https://philjournalsci.dost.gov.ph/>
- Singha p, Singh S, Muthukumarappan K, Krishnan P. 2018. Physicochemical and nutritional properties of extrudates from food grade distiller's dried grains, garbanzo flour, and corn grits. *Food Science and Nutrition*, 6(7), 1914–1926. [doi:10.1002/fsn3.769](https://doi.org/10.1002/fsn3.769)
- Sotelo-Díaz L, Igual M, Martínez-Monzó J, García-Segovia P. 2023. Techno-Functional Properties of Corn Flour with Cowpea (*Vigna unguiculata*) Powders Obtained by Extrusion. *Foods*, 12(2), 298. [doi:10.3390/foods12020298](https://doi.org/10.3390/foods12020298)
- U.S. Food And Drug Administration. 2023. The lows and highs of percent daily value on the Nutrition Facts label. Retrieved from <https://www.fda.gov/food/nutrition-facts-label/lows-and-highs-percent-daily-value-nutrition-facts-label>
- Yousefi N, Abbasi S. 2022. Food proteins: Solubility & thermal stability improvement techniques. *Food Chemistry Advances*, 1, 100090. [doi:10.1016/j.focha.2022.100090](https://doi.org/10.1016/j.focha.2022.100090)

TENTATIVE AGENDA
The 2nd ASEAN University Symposium for Sustainable Food System
Faculty of Economics and Management, IPB University
Bogor, 5-6 May 2025

Date and Time (GMT+7)	Agenda	Venue
Day 1- 5 May 2025		
08.00-08.30	On Site Registration	Equilibrium Room, Department of Economics, Faculty of Economics and Management Building, Level 1.
08.30-08.35	Opening by MC	
08.35-08.40	Indonesian National Anthem	
08.40-08.50	Welcoming Remark Dr. Irfan Syauqi Beik Dean of Faculty of Economics and Management IPB University	
08.50-09.00	Opening Remark Prof. Arif Satria Rector of IPB University	
09.20– 10.30	Keynote Speech 1. Prof. Dr. Ir. Nunung Nuryartono, M.Si Deputy for Coordination of Social Welfare Improvement, Coordinating Ministry for Community Empowerment, Republic of Indonesia. 2. Datuk Amer Bukvić Director and Resident Representative Islamic Development Bank (IsDB) Regional Hub Indonesia <i>“The role of Islamic Development Bank in the Development of Sustainable Food System”</i>	
10.30-12.30	Invited Speakers Session 1 (Plenary Session) Prof. Bayu Krisnamurthi Professor at Faculty of Economics and Management, IPB University Topic: <i>Current Updates and Policies to Support Food System in Indonesia</i> Dr. Yose Rizal Damuri Director of CSIS	

Date and Time (GMT+7)	Agenda	Venue
	Topic: <i>Global Uncertainty and Food System in Indonesia</i>	
12.30-13.30	Break	
13.30-16.30	Parallel Session 1 and 2	Faculty of Economics and Management Level 1, IPB Darmaga Campus
19.00-21.00	Dean's Dinner	Local Restaurant, Bogor City
Day 2- 6 May 2025		
09.00-09.30	On Site Registration	Equilibrium Room, Department of Economics, Faculty of Economics and Management Building, Level 1.
09.30 -09.45	Opening by MC	
09.45-11.45	Invited Speakers Session 2 Prof Bustanul Arifin Professor in Agricultural Economics, UNILA Chair of Asian Society Agricultural Economist Topic: <i>Food System Transformation in Indonesia</i> Prof. Christopher Bennett Faculty of Land and Food Systems, University of British Columbia Topic: <i>Meeting the Challenge of Achieving Forestry Contributions to Food Security Sustainably</i>	
11.45-13.30	Break	
13.30-15.00	Parallel Session 3	Faculty of Economics and Management Level 1, IPB Darmaga Campus
15.00 -15.30	Keynote Speech Prof. Brian Yulianto Minister of Higher Education, Science, and Technology, Republic of Indonesia	Equilibrium Room, Department of Economics, Faculty of Economics and

Food Systems, Consumption, and Nutrition

Date and Time (GMT+7)	Agenda	Venue
15.30-16.00	Wrap Up and Closing Session Best Paper Announcement Chair of The 2nd ASEAN University Symposium for Sustainable Food System	Management Building, Level 1.