Research article

Enhancing Climate Resilience and Coffee Nursery Management in Bukidnon: Empowering Indigenous Coffee Farmers through IoT-Based Technology and Capacity Building

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Abstract The Philippine coffee industry faces decreasing yields and an increasing reliance on imports. Climate change exacerbates these difficulties, particularly for small-scale coffee farmers who lack the resources and infrastructure to adapt to changing weather, pests and diseases. Internet of Things (IoT) technologies present a promising solution for small-scale coffee farmers as a tool to monitor environmental conditions, manage and improve crop health, and optimize resource use. However, the effective adoption of IoT technology requires targeted capacity building to equip farmers with positive attitudes and essential knowledge and skills. A Pre-Assessment Survey (PAS) was conducted with 40 farmer participants across two coffee farming communities in the province of Bukidnon, Philippines. The PAS evaluated current knowledge, skills, and attitudes in each of the five key components: IoT familiarity, nursery management, plant nutrient management, pest and disease management, and openness to learning new horticultural handling techniques. The results revealed that most farmers were unfamiliar with IoT technologies and had limited or no experience in operating digital tools for agricultural purposes. While some expressed awareness of the potential benefits of technology in farming, this did not translate into actual usage or skills. Nursery management practices are often inconsistent, with many farmers lacking familiarity with proper spacing, shading, and seedling hardening techniques. Similarly, while the importance of plant nutrition has been acknowledged, practical understanding of microbial fertilizers and diagnostic methods, such as soil and leaf testing, remains limited. In terms of pest and disease management, farmers tended to rely on traditional methods, with minimal exposure to or use of technological tools for early detection of pests and diseases. Despite these gaps, farmers demonstrated a strong willingness to learn and were open to adopting new practices aimed at improving seedling quality and productivity. A comprehensive, culturally contextualized training program is recommended to build farmers' capacity, foster technology adoption, and support the transition toward climate-resilient, sustainable coffee production systems.

Keywords coffee production, IoT, PAS, farmer-scientist

INTRODUCTION

The Philippine coffee industry plays a vital role in the country's agricultural economy; however, it is plagued by declining productivity, heightened vulnerability to climate change, and increased dependence on imports (Department of Agriculture, 2017). Small-scale coffee farmers, particularly those from indigenous communities in the province of Bukidnon, Philippines, face unique challenges, including limited access to advanced agricultural technologies, poor infrastructure, and inadequate training on modern practices (Mia and Habaradas, 2021). These factors collectively reduce their resilience to environmental risks and economic pressures, threatening the sustainability of coffee production in this region.

Emerging technologies such as the Internet of Things (IoT) technologies offer a promising solution for addressing these challenges. IoT technologies enable real-time monitoring of environmental conditions, improve decision-making processes, and optimize resource utilization (Sharma and Shivadu, 2024). However, the effective integration of such technologies requires a foundational understanding among farmers, coupled with skill development and behavioral change (Javaid et al., 2022).

This study utilized a comprehensive Pre-Assessment Survey (PAS) to evaluate the existing knowledge, skills, and attitudes (KSA) in utilizing IoT Technologies for coffee nursery management of indigenous small-scale coffee farmers in the province of Bukidnon. By aligning local knowledge with scientific practices, this study addresses a significant gap in the academic discourse on sustainable agricultural development in Indigenous communities in Bukidnon Province.

OBJECTIVE

This study aimed to demonstrate how a Pre-assessment Survey can be used as a tool to design a tailored farmer–scientist training program (FSTP) that can help enhance the climate resilience and productivity of Indigenous coffee farmers in Bukidnon by equipping them with the knowledge, skills, and attitudes necessary to adopt IoT-based technologies and improved nursery management practices through a comprehensive gamified training program.

METHODOLOGY

Study Area and Participants

The study was conducted in two farming communities in Bukidnon Province: the Portulin Talaandig Tribal Association (PTTA) in the municipality of Pangantucan and the Milalittra Farmers Agriculture Cooperative (MILFACO) in the municipality of Talakag. Most of these farmers belong to the Talaandig tribe, one of the seven major tribes in the province of Bukidnon. These communities are characterized by their reliance on traditional farming practices and limited exposure to modern agricultural technology. A total of 40 coffee farmers participated in the study, with 20 farmers from each farming community. The farmers were selected based on their experience in traditional coffee farming, age, and the recommendation of the chieftain of the tribe.

Research Design

This study employed a mixed-methods approach, combining quantitative and qualitative data collection, to assess the baseline knowledge, skills, and attitudes (KSA) of farmers. The pre-assessment survey (PAS) used Bloom's Taxonomy of Educational Objectives to systematically evaluate the cognitive (knowledge), psychomotor (skills), and affective (attitudes) domains (Bloom, 1956). A pre-assessment form containing 30 items (Table 1), divided into five key components — IoT familiarity, nursery management, plant nutrient management, pest and disease management, and horticultural handling— was used to assess and establish baseline measures of knowledge, skills, and attitude (KSA) of the identified 40 indigenous farmers. The survey employed distinct response

formats for each KSA category: knowledge-related questions were answered with either "Familiar" or "Not Familiar," skills-related questions with "Yes" or "No," and attitude-related questions with "Agree" or "Disagree." To facilitate the analysis, the responses were classified as positive (Familiar, Yes, Agree) and negative (Not Familiar, No, Disagree). This approach allowed for a clear assessment of existing competencies and the identification of specific areas in which capacity-building interventions are needed.

Table 1 Pre-assessment survey questions on knowledge, skills, and attitudes (KSA) for coffee nursery management for the two small-scale farming communities in Bukidnon, Philippines

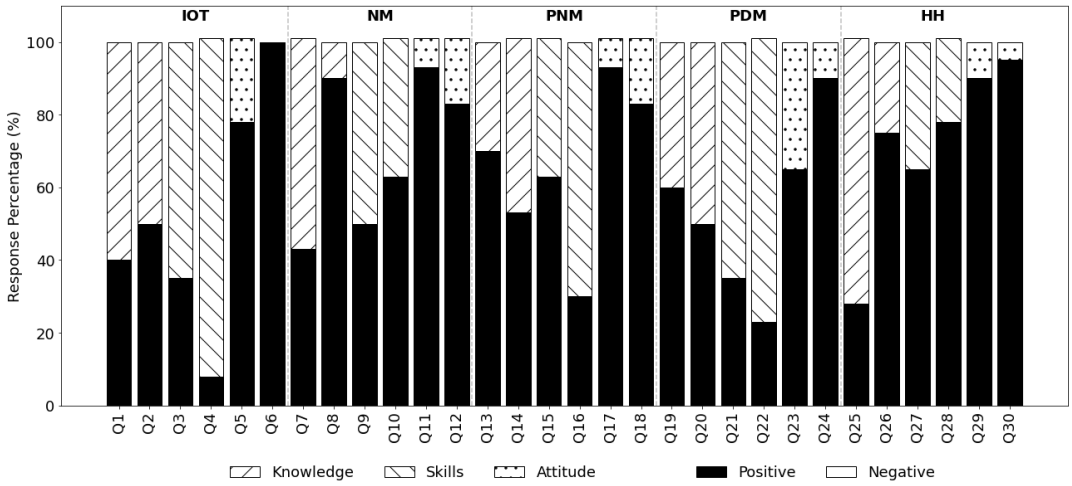
KSA	IoT familiarity	Nursery management	Plant nutrient management	Pest & disease management	Horticultural handling
Knowledge	1. How familiar are you with Internet of Things (IoT) devices used in agriculture?	7. How familiar are you with the practices of managing coffee seedling nurseries?	13. How well do you understand the importance of nutrient management for coffee seedlings?	19. How familiar are you with common pests and diseases affecting coffee seedlings?	25. Are you familiar with the hardening practices of coffee seedlings?
	2. Do you know how IoT devices can help monitor environmental factors such as temperature, humidity, and soil moisture?	8. Are you aware of how temperature, humidity, and light affect coffee seedlings in their early stages?	14. Are you familiar with the use of microbial fertilizers to improve nutrient levels in plants?	20. Do you know how to use technology and microbial fertilizers (e.g., Mykovam, Bio-N) to monitor and prevent pest or disease outbreaks?	26. Are you aware that hardening is a necessary preparation of coffee seedling before transplanting?
Skill	3. Have you ever used a mobile phone or SMS system to receive updates or information about your farm's activities and other crops?	9. Have you implemented practices such as proper spacing, watering schedules, or shading in your nursery?	15. Have you ever applied any nutrient recommendations for your coffee seedlings?	21. Have you used any traditional techniques, pest and disease prevention in your nursery?	27. Do you follow specific nursery practices to maintain the quality of coffee seedlings?
	4. Have you ever set up or operated digital devices (e.g., sensors) for agricultural purposes?	10. Have you been monitoring the environmental conditions in your nursery (e.g., temperature, humidity)?	16. Have you submitted any soil or leaf analysis to determine nutrient deficiencies?	22. Have you used any technology to monitor pest populations in your coffee nursery?	28. Have you used any interventions, solutions or techniques to improve coffee seedling production?
Attitude	5. How do you feel about using technology, such as IoT devices, to manage your farm's operations?	11. Do you feel that improving your seedling management practices will lead to better coffee production?	17. Do you think monitoring plant nutrient levels through technology can improve your seedling's growth?	23. Do you think that crop protection is needed on coffee nursery?	29. Do you believe that following proper nursery handling practices can improve the overall quality of coffee seedlings?
	6. Do you agree that adopting new technologies like IoT can improve the quality and speed of coffee seedling production?	12. Do you think that nursery should be accredited?	18. Do you believe that the use of microbial fertilizers (e.g., Mykovam, Bio-N) could improve production of coffee seedlings?	24. Do you agree that early detection of pests and disease is necessary?	30 How open are you to learning new techniques and practices to produce excellent quality coffee seedlings?

RESULTS AND DISCUSSION

Pre-assessment Survey (PAS) Results

The Pre-assessment Survey (PAS) revealed a significant gap in farmers' knowledge and skills while also showing a positive attitude towards sustainable agricultural practices and technologies, (Fig. 1). The results convey that 60% of the farmers are unfamiliar with (IoT) technologies. Despite 50% of the respondents being aware of IoT's potential in agriculture, 65% had never used mobile phones or SMS for agricultural activities, and only 7.5% had practical experience with devices such as sensors. This highlights the need for targeted interventions to improve technology adoption.

Similarly, while 90% of farmers understood the environmental factors affecting coffee seedlings, only 50% consistently applied best practices, such as proper spacing and shading, in their nursery management. In plant nutrient management, 70% of farmers acknowledged its importance, yet only 52.5% were familiar with microbial fertilizers, and 27.5% had never conducted soil or leaf analyses, demonstrating a disconnect between practical knowledge and implementation. Farmers also displayed familiarity with pests and diseases, with 60% recognizing common threats to coffee seedlings. However, only 15% regularly used technology and new practices to monitor pests and diseases in their crops. Moreover, 77.5% had never employed diagnostic tools, highlighting their reliance on traditional methods. In horticultural practices, 65% of the farmers applied interventions to improve the quality of coffee seedlings. In horticultural practices on coffee, 77.5% of the farmers knew that the hardening process was an important step in preparation before the transplantation of coffee seedlings. However, only 47.5% were very familiar with the process.



Notes: (IoT - IoT familiarity, NM - Nursery Management, PHM- Plant Nutrient, Management, PDM - Pest and Disease Management, HH - Horticulture Handling). Q1-Q30 corresponding to Questions

Fig. 1 Knowledge, skills, and attitudes of indigenous farmers gathered from PAS

The PAS shows a high attitude among farmers toward adopting new technologies, with 77.5% of them expressing strong willingness. The majority (92.5%) acknowledged that enhancing nursery management and monitoring plant health through technology could significantly boost productivity. Additionally, 65% recognized the importance of crop protection in seedling handling, and 95% expressed openness to learning new techniques and practices aimed at producing high-quality coffee seedlings.

These results underscore the need for enhanced training, access to resources, and promotion of smart agricultural technologies to bridge the gap between theoretical knowledge and practical application in the field. The gathered data indicate that while farmers possess foundational knowledge in key agricultural areas, practical application and technology adoption remain limited. Addressing these gaps through capacity-building programs, resource accessibility, and the demonstration of inventions is essential for promoting innovative and sustainable agricultural practices (Guevara and Tumague, 2023).

These findings illustrate a critical gap in the capacity of indigenous coffee farmers to adopt IoT technologies and sustainable agricultural practices. Similar studies, such as those by Deichmann et

al. (2016) and Aker (2017), highlight that access to technology alone is insufficient; knowledge and skill building are essential for effective utilization. The PAS provides baseline information to tailor a training program to develop the knowledge and skills of indigenous farmers to capacitate them to adopt IoT technologies and sustainable agricultural practices (Clark and Chopeta, 2004).

One of the effective models that empowers farmers to become local scientists and enables them to innovate and improve crop yield sustainability is Davide's Farmer-Scientist Program. The program's participatory approach fosters a deeper understanding of agronomic principles, which is crucial for addressing the unique challenges faced by indigenous farmers (Davide, 2001).

The findings of the PAS were used to design a tailored Farmer-Scientist Training Program (FSTP) based on Davide's model. The tailored FSTP seeks to bridge the gap between scientific knowledge and traditional agricultural practices by integrating a culturally sensitive, ritual-based approach. Tailored for indigenous coffee farmers, the program incorporates gamification elements to facilitate effective learning and ensure that training is accessible and engaging (Cayabyab et al., 2024). The gamification framework underpinning the FSTP is grounded in de Jesus' *Bahay-bahayan* Framework (Fig. 2), which emphasizes the use of culturally relevant interactive learning techniques to enhance knowledge retention and practical application (de Jesus et al., 2017).

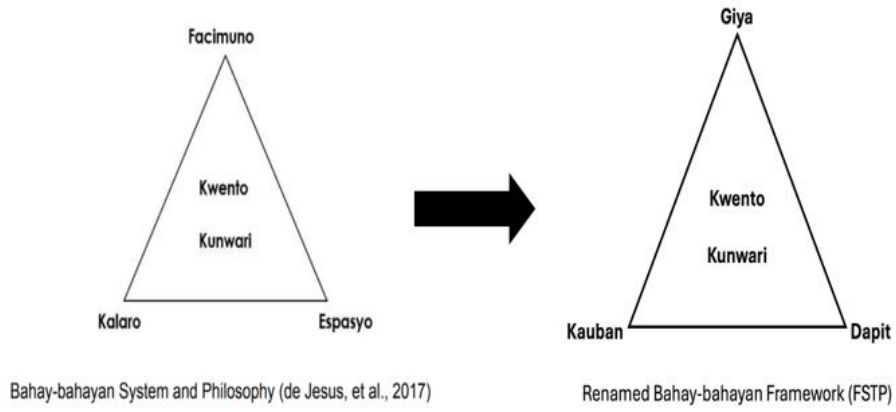


Fig. 2 Renamed *Bahay-bayahan* framework designed for FSTP

The results of the PAS, which revealed knowledge and skills gaps in IoT adoption for small-scale coffee farmers, were the focus of the tailored FSTP. It addresses a significant gap in rural agriculture, where technology is often underutilized because of a lack of understanding.

CONCLUSION

This study demonstrated the effectiveness of using a Pre-Assessment Survey (PAS) as a diagnostic tool to design a tailored Farmer-Scientist Training Program (FSTP) for indigenous small-scale coffee farmers in Bukidnon. The PAS successfully identified significant gaps in knowledge, skills, and practical applications related to IoT-based nursery management, despite a generally positive attitude toward adopting new technologies. By mapping the baseline competencies and learning needs of farmers across the cognitive, psychomotor, and affective domains, the survey informed the design of a culturally appropriate, gamified training program rooted in participatory learning.

The resulting FSTP, anchored in Davide's Farmer-Scientist model and the Bahay-bahayan framework, bridges traditional knowledge with scientific practices. It empowers farmers to become adaptive and innovative agents of sustainable agriculture, capable of enhancing productivity and resilience in the face of climate-related challenges. This approach not only supports technology adoption but also strengthens community-led capacity building, reinforcing the role of Indigenous farmers as stewards of knowledge and innovation.

Future research should focus on the long-term impacts of such programs on farmers' livelihoods, productivity, and resilience to climate risks. Additionally, exploring the scalability of this model to

other agricultural contexts can contribute to broader efforts to achieve sustainable and inclusive development.

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