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Environmental Sustainability Performance and Readiness of Farmers to Adopt and Adapt Sustainable and Smart Farming Practices in Harumanis Mango Production

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Abstract

Malaysia's state of Perlis is popular for its Harumanis mango production, primarily produced over the years due to its impeccable flavour and sweetness. Regardless of their popularity and demand among consumers, the unstable yield of Harumanis mangoes constitutes significant challenges for farmers. The unstable production of Harumanis mango brings negative consequences on both livelihoods and market availability. To address this, sustainable smart agriculture farming is vital to ensure that the soil and Harumanis mango farming both receive the nutrients they require to be in peak health and production. The objectives of this research are to determine the environmental sustainability of the performance of Harumanis mango production in Perlis and to investigate the readiness of farmers, issues, and challenges in the implementation of sustainable smart farming. This study conducted a content analysis of in-depth interviews with a Harumanis mango farmer and a researcher who is an expert in Harumanis mango production. By examining the issues and probable challenges that farmers may encounter, the Theory of Planned Behavior (TPB) was developed, focusing on attitude, subjective norm, and perceived behavioral control. Our results reveal that the production of Harumanis mango is volatile, and the exact causes are inconclusive. Furthermore, the research highlights that the farmers are not adequately prepared to adopt and adapt sustainable and smart farming practices suggesting potential challenges in their future implementation. To ensure the long-term sustainability of Harumanis mango production these challenges need to be tackled cooperatively.

Keywords

Environmental sustainability performance, Smart farming, Harumanis production, Readiness, Challenges

1.0 Introduction

Harumanis mangoes are renowned for their remarkable flavor, perfume, and sweetness, particularly in Perlis, which is situated on Peninsular Malaysia's northwest coast. The production of Harumanis mangoes contributes significantly to the region's economy but due to their sensitivity to the environment and climate, they are in short supply despite great consumer demand. For them to begin blooming, a protracted stretch of dry weather is required (Talib et al., 2020). The livelihoods of farmers and consumers are severely threatened by inconsistent yields. Conventional farming practices may not address this challenge. The use of sustainable smart farming technology in producing Harumanis mangoes will offer a viable solution that will maximize resource usage, reduce environmental effects, and increase crop output. For adoption to be effective, it is essential to comprehend the present environmental sustainability of Harumanis mangoes production as well as the farmers' readiness to accept and modify new technology.

This study aims to close the existing research gap by investigating the application of sustainable smart farming technology in Perlis's Harumanis mangoes production. The research will determine factors influencing the yield variations, how environmentally sustainable are the present techniques in the production of Harumanis mangoes, and how eager are farmers to adopt sustainable smart farming methods. The study's objective is to determine the environmental sustainability performance (ESP) of Harumanis mango production in Perlis and to investigate the readiness of farmers, issues, and challenges in the implementation of sustainable smart farming.

This research employs qualitative methods to address the lack of knowledge on the environmental sustainability performance of Harumanis mango production in Perlis, farmer readiness to adopt sustainable smart farming, and challenges in implementation. This study seeks to gain valuable insights into the readiness of farmers, issues, challenges, and opportunities related to ensuring the long-term sustainability of Harumanis mango production in Perlis through in-depth interviews with an expert researcher and a farmer with first-hand experience. Having a better grasp of this will enable this study to support the development of sustainable smart farming techniques that are advantageous to farmers and the environment.

2.0 Literature Review

Mango is a popular fruit in South Asia, including Malaysia, with the 'Harumanis' variety being especially renowned in Perlis for its aroma, texture, and sweetness (Azizan et al., 2019). However, Harumanis mangoes face challenges such as susceptibility to fungi, fruit flies, and pests, and they produce less fruit compared to other varieties. Additionally, their cultivation is more costly (Musa et al., 2010). These issues threaten the long-term viability of Harumanis mango farming and market availability. Adopting sustainable smart agricultural methods could help address these problems and ensure the economic and environmental sustainability of Harumanis mango production.

ESP refers to the measurable effectiveness and impact of an organization's strategies and practices aimed at achieving environmental sustainability goals. It encompasses several key concepts including resource efficiency, waste reduction and environmental impact mitigation. To effectively address ESP, it is crucial first to define ESP as a measure of how organizations manage their environmental impact, including resource efficiency and waste reduction (Rizvi & Garg, 2022). Weather patterns like temperature and precipitation affect the productivity of Harumanis mango trees. These trees grow well in Perlis' climate, making the region ideal for their cultivation. To ensure optimal growth and high-quality fruit, it's important to monitor soil nutrients such as nitrogen, phosphorus, and potassium (Azizan et al., 2019). While traditional farming methods aim to produce quality Harumanis mangoes, sustainable smart farming techniques offer potential for further improvement. Evaluating environmental sustainability in Harumanis mango production involves understanding agricultural practices and sustainable performance to maintain quality and efficiency in mango farms.

The implementation of smart agriculture technologies has the potential to significantly enhance the sustainable production of Harumanis mangoes. The Wireless Sensor Networks (WSNs) are highly advantageous in precision agriculture for monitoring quality parameters such as soil moisture, nutrients, and weather (Rahu et al., 2023). This data will be transmitted via the Internet of Things (IoT) for data analysis, offering valuable insights into crop health and resource requirements (Ismail et al., 2021). This directly enables farmers to make more informed decisions based on the data, especially regarding irrigation,

fertilization, and pest management. Significant environmental advantages will be realized as a consequence, including reduced pesticide usage through early identification and targeted pest control, enhanced nutrient management that reduces waste and pollution, and optimized water use through precision irrigation.

Smart agriculture may have advantages; however, research indicates that farmers may encounter obstacles when using these smart farming technologies. Precision agriculture technologies require advanced knowledge of mechanical operations for data collection. They involve complex data management, interpretation, and decision-making for agronomic solutions, which can vary among farmers. These technologies still require a large initial investment, despite substantial cost reductions, and there are few financial incentives available. Incentives or subsidies have not generally been provided to make precision agriculture technologies more affordable. Therefore, the uncertainty of profitability is compounded by feasibility considerations and high investment costs (Tey & Brindal, 2012).

It is important to consider various factors that impact the adoption of technology, Consider factors such as the expertise of extension workers, the effective organization and management of extension programs, and the unique local conditions. In a study conducted by Truong (2008), several obstacles to implementing a successful technology strategy were identified. Some of the primary factors inhibiting technology adoption include limited understanding and appreciation of technology among farmers, low levels of education, inadequate training, insufficient knowledge among extension workers, lack of organization, geographical challenges, and limited resources and funding. Additionally, farmers need to have a certain level of education and a solid understanding of rice farming to be motivated to learn and adopt new technology (Abdullah & Samah, 2013).

Farmers' readiness to adopt sustainable and smart farming practices involves several critical factors including knowledge, skills, resources, and support systems. Readiness encompasses farmers' awareness of environmental benefits and operational requirements, their capability to implement new technologies, and the availability of financial and technical resources. Positive attitudes towards sustainability and strong external support, such as training and government policies, further enhance readiness (Sarvestani & Millar, 2024). Understanding these factors is essential for effectively applying the TPB in agricultural contexts, as readiness influences the likelihood of adopting and adapting to new practices (Shah et al., 2022; Han & Niles, 2023).

The long-term viability of the Harumanis mango-producing system is threatened by environmental issues. Sustainable smart farming technologies have the potential to ensure optimal resource management, minimize environmental impact, and enhance Harumanis mangoes production. It is essential to close the knowledge gap among farmers and make these technologies more affordable to improve farmers' readiness for smart farming. Effective extension services and targeted education programs can play a vital role in achieving the long-term sustainability of Harumanis mangoes production in Perlis.

2.1 Theoretical Framework

By examining the issues and probable challenges that farmers may encounter, the Theory of Planned Behavior (TPB) was established, emphasizing attitude, subjective norm, and perceived behavioral control as shown in Figure 1. The content analysis of in-depth interviews with Harumanis farmer indicated obstacles to their readiness for smart farming that are consistent with each TPB construct:

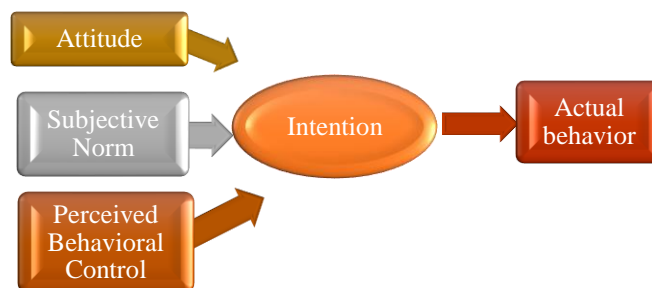


Figure 1: Theory of Planned Behavior (TPB)

3.0 Methods

3.1 Sampling Strategy

A purposive sampling strategy is employed in this study, entailing the deliberate selection of individuals or data sources to address specific research objectives (Ken-Giami et al., 2022). In this study, purposive sampling was used to select farmers based on specific criteria to ensure relevance and accuracy. The criteria included farmers actively involved in Harumanis mango production with at least 5 years of experience, those knowledgeable about or having experience with sustainable performance, and varying in farm size from 2 to 20 hectares. Additionally, farmers were chosen based on their geographical location in the Harumanis mango production area and their history of adopting agricultural innovations. These criteria ensure that the sample accurately represents the population and provides meaningful insights into readiness for adopting sustainable farming practices. To gain detailed insights, we selected a researcher with extensive knowledge of the Harumanis mango industry and a farmer with hands-on experience. This targeted approach helped us gather relevant information for our study. The program head chose these two participants, and all interviews were scheduled in advance. Both participants gave informed consent, and their confidentiality was protected. Audio recordings and transcripts are securely stored, accessible only to the research team. This study also has human ethics approval from the Human Research Ethics Committee USM (Code: USMJEPem/PP/23060524).

3.2 Data Collection

Semi-structured in-depth interviews with 2 respondents (a farmer and an expert in Harumanis) were conducted where tailored questions were asked according to each participant's expertise enabling us to get detailed information and allowing them to elaborate more on their experience and expertise. In qualitative research, it is common to use a small number of participants to gain deep, detailed insights into a particular phenomenon. The goal is not to generalize from a sample to a population but to develop a deep understanding of a particular context or phenomenon (Guest, Namey & Mitchell, 2013; Creswell & Poth, 2018). The purpose of the in-depth interview approach is to get a detailed picture of the participant's viewpoint on the study issue (Milena et al., 2008). This interview section has been conducted face-to-face and in a one-to-one session. The interview was conducted approximately for 17 minutes with the Harumanis mango research expertise and approximately 2 hours 12 minutes with the Harumanis mango farmer. The interviews were audio-recorded with the permission of both participants and transcribed verbatim before the commencement of the data analysis.

3.3 Data Analysis

The data will be analyzed using content analysis due to its ability to identify patterns, themes, and significant insights from open-ended interviews. This method is useful for exploring themes related to smart farming and environmental sustainability. Codes will be created based on themes about yield instability and the Theory of Planned Behavior (TPB), which includes attitudes, subjective norms, and perceived behavioral control. This approach will reveal how social, psychological, and environmental factors influence farmers' decisions. After coding, relevant codes will be grouped into main themes, which will be reviewed before interpreting the data.

3.4 Limitation

The findings of this single-case study offer valuable insights, but their generalizability to a wider population of Harumanis mango farmers may be limited. Future research could benefit from conducting additional interviews with agricultural experts and farmers to gain a more comprehensive understanding.

4.0 Results and Discussions

4.1 Environmental Sustainability Performance in Harumanis Mango Production.

i) MyGAP Certification

A comprehensive certification program for the agriculture, aquaculture, and livestock industries is called MyGAP. The Malaysian Standard Crop Commodities serve as the foundation for the implementation of MyGAP, while the crop sector module employs Good Agricultural Practices. The seven components of good agricultural practices such as storage records, plant type, pesticide use, worker health, harvesting technique, water irrigation, and fertilizer use must be adhered to by farms registered with MyGAP. These components are arranged to improve agricultural systems' sustainability. The Harumanis mango Farm adheres to MyGAP certification, following strict standard guidelines that cover 7 main good agricultural practices, including water irrigation, use of fertilizers, and pesticide usage. This directly demonstrates the sustainable practices implemented by the farm.

“We've got the MyGAP certificate and we make sure to follow all the requirements. We stick to MyGAP, which is recommended by the Department of Agriculture, and we always follow the SOP” (Own fieldwork, June 2024)

ii) Minimizing Chemical Use

The farmers mentioned that they use organic fertilizers whenever possible and also make use of minimal doses of chemical fertilizers to reduce their dependence on chemical inputs as a whole. The minimal usage of calcium carbide to make the Harumanis mango ripe faster also indicates the sustainable practices practiced by farmers. Similarly, the research expert mentioned using a plant hormone-based growth regulator instead of a chemical growth regulator. Additionally, they also use minimal doses of government-approved pesticides, prioritizing human health and aiming to reduce the negative impact on the environment (Damalas & Eleftherohorinos, 2011). The farmers specifically mentioned using a pesticide called Confidor, known for its lower dosage. This approach demonstrates their commitment to sustainability in the production of Harumanis mangoes, contrasting with the high-dose techniques commonly used in the cultivation of other mango varieties.

“We always make sure to use the best pesticide, Confidor, to maintain quality. It's the best because the dose is very low. But other producers use pesticides with a very high dose. Also, we make sure to use the right growth regulator based on plant hormones, and we don't use any chemicals” (Own fieldwork, June 2024)

iii) Pruning for tree health

The Harumanis mango farmer mentioned that they are also practicing regular trimming and pruning to maintain the shape and health of trees and to promote optimal growth. Eliminating dead or diseased branches helps halt infection spread and secures the tree's long-term survival. The practice of regular trimming and pruning in mango cultivation is crucial for maintaining tree health and ensuring optimal fruit production. Pruning helps in removing dead, diseased, or overgrown branches, which can reduce the risk of infections and pest infestations, thereby enhancing the overall health of the tree (Cantu et al., 2019).

"To keep the trees healthy and promote plant growth, we perform extensive pruning but never chop them down. We rejuvenate them to help the trees grow better." (Own fieldwork, June 2024)

iv) Waste reduction and resourcefulness

Off-grade fruits that do not meet the criteria to be labeled as premium fruit (which make up around 20% to 30% of overall fruit production) are not discarded. Instead, farmers try to find innovative ways to transform them into value-added products, such as mango chips, puree, juice, and so on. This approach helps reduce wastage and maximize resource utilization. Such strategies contribute to the broader goal of resource efficiency in agriculture, aligning with principles of circular economy (Ghosh & Singh, 2021).

"We will try to turn any misshapen or off-grade mangoes into chips, puree, juice, and even glutinous rice. These steps are part of our research and development efforts to minimize fruit waste." (Own fieldwork, June 2024)

v) Innovation of sustainability

The research expert highlighted that he is currently engaged in a study to develop the use of microbes to maximize nutrient absorption in solid material. This approach can reduce the reliance on chemical fertilizers, ensuring the long-term sustainability of the soil. The application of various microbial consortia has been demonstrated to enhance the bioavailability of essential nutrients, thereby improving soil fertility and reducing the need for chemical inputs (Bashan & Holguin, 2020).

"We are currently studying microbes and hope to formulate them to absorb nutrients beneficial for the soil. That is my wish." (Own fieldwork, June 2024)

4.2 Farmer Experiences with Yield Instability

According to the content analysis results, the theme of farmers' experiences with yield stability will cover three codes: fluctuation in production, limited impact of regulators, and sustainability not guaranteed.

i) Fluctuation in production

The Harumanis mango farmer and the research expert reported that the Harumanis mango yield tends to fluctuate from season to season. While some years produce more fruits than others, some years produce less fruit, and some years produce less than half of what was produced the year before. For instance, Yang et al. (2019) found that environmental conditions, such as temperature and rainfall, significantly impact the yield stability of fruit crops, leading to years of both high and low production.

"The production of Harumanis mangoes may decrease in the second season and possibly for some time in the third season. However, it is expected to increase again in the fourth season, depending on its carbohydrate reserves. At times, the production may be less than half of the previous year's output" (Own fieldwork, June 2024)

Some farmers even noticed a larger pattern of boom-and-bust cycles in addition to yearly changes. The farmer described the year 2017 as a period of high production of Harumanis mango, followed by a sharp decline until the year 2022 with a slight recovery in 2023. The exact factor causing this long-term trend is still uncertain and unknown among the farmers and field experts.

"In 2017, the Harumanis yield was at its peak. In 2018, the yield fluctuated until 2022. There was a slight increase in production in 2023 compared to 2022. The production was inconsistent, and we don't understand the reason for this inconsistency." (Own fieldwork, June 2024)

The observed fluctuation in Harumanis mango production aligns with findings by Singh and Singh (2021), who discuss how fruit yield can vary significantly from season to season due to climatic conditions and other environmental factors. Their research highlights that such variability often results in boom-and-bust cycles, where production can fluctuate dramatically year over year. This supports the farmer's observation of inconsistent mango yields and periodic declines.

ii) Limited impact of regulators

Success is not certain even when growth regulators are used, which are meant to encourage blooming and fruiting. Farmers pointed out that authorities could only create one successful growing season year. For instance, Wu et al. (2020) found that while growth regulators such as gibberellins can promote flowering and fruiting, their success varies significantly based on timing, dosage, and the specific crop variety.

"We tried to enhance the growth of the Harumanis fruit by using a growth regulator, but it seems like the production may have been disrupted due to the tree's genetic makeup. We attempted the same method on a different type of tree, and it was successful. However, the Harumanis fruit cannot be induced to grow. Regardless of our efforts, the Harumanis fruit will only be produced for one season." (Own fieldwork, June 2024)

iii) Sustainability is not guaranteed

Consistency in production is not always guaranteed even if Standard Operating Procedures (SOPs) are correctly followed and correspond with the seven MyGAP-recommended good agricultural practices. The Harumanis mango Farmer further stated that even with consistent best agricultural practices such as using a relatively low dosage of the best pesticide, like Confidor, and constant monitoring of soil health for the ideal level, proper pruning techniques must be used to ensure the long-term sustainability of tree health.

"The production is still the same yearly, regardless of following the SOP. Even though we have complied with the MyGAP standard, the Harumanis production is still affected." (Own fieldwork, June 2024)

4.3 Potential causes of yield instability

The content analysis conducted also identified several possible causes of yield instability. The codes classified under this theme are genetic predisposition, climatic conditions, problems in managing pests and diseases, and soil health are described below (Own fieldwork, June 2024).

i) Genetic predisposition

According to the Harumanis mango Farmer's speculation, trees may have differing amounts of inherent fertility from the moment of planting. He believes that the Harumanis tree's innate genetic traits could be involved. It could be helpful to conduct more studies on the genetic variants within the Harumanis mango cultivar.

"When it's a fruiting season, the tree doesn't produce any fruit. I've tried lots of methods, and I told the department that it might be because of genetic factors. The thing is, the tree has been barren from the beginning, so that could be one reason." (Own fieldwork, June 2024)

The farmer's speculation that genetic factors might influence the Harumanis mango tree's fertility aligns with research by Kumar et al. (2021), who highlight the significant role of genetic predisposition in fruit production. They suggest that inherent genetic traits can affect fruit-bearing capacity and response to cultivation practices.

ii) Climate Factors

The Harumanis mango farmer also emphasized that flowering can only occur if there is a significant temperature difference between the day and night. This statement by the farmer highlights that a favorable climate is essential for the best Harumanis mango production. Unpredictable weather patterns have the potential to disrupt this cycle.

"The plants need a big difference in temperature between day and night to grow their best. A wider temperature range helps them produce more by triggering the plant hormone for flowering." (Own fieldwork, June 2024)

The farmer firmly stated that after the pesticide is sprayed, the unpredictable rain consistently washes away the protective coating, leaving the trees susceptible to attacks by pests and diseases, such as the 'Kutu Trip' bug. Consequently, the farmer had to double the amount of pesticide applied. Unpredictable rainfall unequivocally hinders the effective application of pesticides, elevating the risk of crop loss and necessitating more frequent pesticide use, ultimately resulting in higher overall production costs.

"We always spray pesticide, but due to the uncertain weather, it ends up being washed off by the rain. This prevents the shoots from growing properly, making the Harumanis plant easily exposed to the pest named 'kutu trip'." (Own fieldwork, June 2024)

The Harumanis mango farmer's observation that significant temperature differences between day and night are crucial for optimal flowering aligns with findings from Wang et al. (2021), who emphasized the importance of temperature variability for flowering and fruit set in mangoes. Additionally, Nair et al. (2018) discusses how unpredictable weather, particularly rainfall, can undermine pest control efforts by washing away pesticides, leading to increased pest susceptibility and higher production costs. This literature supports the farmer's experience that fluctuating weather patterns and ineffective pesticide application due to rain can adversely affect mango production and increase costs.

iii) Pest and disease management challenges

The high expense of using pesticides has resulted in underuse; the farmer stated that they should spray pesticides at least twice a week, but they only do so once a month after the tree starts to sprout shoots because of high labor costs and hefty chemical purchases. This financial constraint may be the cause of the Harumanis' inconsistent fruit production in addition to raising the possibility that the plantation would be subjected to pests.

"We need to apply the pesticide every two weeks, but we only apply it once a month when the plants are growing shoots. This is because the daily cost for one worker is high, ranging from RM 70 to RM 100. We require at least four people, so the overall cost is high." (Own fieldwork, June 2024)

High pesticide costs often lead to underuse in agriculture. According to Sharma, Sharma and Pandey (2020), financial constraints make it difficult for farmers to use pesticides regularly, which can harm crop health and reduce yields. Feng et al. (2018) also found that economic limitations result in less frequent pesticide application, contributing to inconsistent fruit production and increased pest issues. This supports the observation that high costs for both pesticides and labor lead to reduced application frequency, impacting farm productivity.

4.4 The readiness of farmers, issues, and challenges in the implementation of sustainable smart farming.

i) Attitude (Reliance on Conventional Practices)

The Harumanis mango farmer mentioned that the farmers in this area are very content with their current methods because even the most basic sustainable practices need a lot of work, and some of the producers of Harumanis mango don't even follow these basic sustainable practices. He also expressed doubt about the producers' ability to follow sophisticated sustainable smart farming. They might not believe the benefits of smart agricultural technologies that are being touted (Own fieldwork, June 2024). This claim is supported by research conducted by Kaliba, which found that elderly farmers are often risk-averse and cautious (Kaliba et al., 2020).

Issues: These concerns point to a possible ignorance of the long-term gains in productivity, resource efficiency, and fruit quality that come from wise agricultural practices.

ii) Subjective Norms (limited awareness and lack of discussion)

The farmer emphasized the limited awareness about smart farming technology such as sensors, usage of drones, and so on among other farmers who are working on the farm. There may not be much societal pressure on farmers to embrace these approaches, as evidenced by their lack of discussion and limited knowledge.

“All of this smart farming technology sounds expensive and complex. Here, we do everything manually because our workers are all elderly and from the village. They aren't familiar with high-tech farming gadgets like sensors, unlike the younger generation.” (Own fieldwork, June 2024)

Issue: Adoption is hampered by a lack of knowledge and social pressure as farmers may feel alone and uninformed about the importance that other people attach to smart farming.

The limited awareness and lack of societal pressure regarding smart farming technologies are well-supported by research. Tey and Brindal (2012) identify that insufficient knowledge among farmers is a major barrier to adopting new technologies. Rogers (2003) highlights that when there is minimal discussion and social influence within the community, individuals are less motivated to embrace innovations.

iii) Perceived Behavioral Control

Limited knowledge: The farmer mentioned that they have very limited knowledge regarding smart farming technologies as the majority of workers who work on the farm are old, uneducated, and live in rural areas.

Government support, funding, and priorities: The government's uneven support for necessities like fertilizer and pesticides, for which farmers sometimes have to spend their spare cash, causes farmers to question the adoption of smart agricultural practices, as these initiatives need significantly more capital. Farmers also stress that government subsidies for Harumanis mangoes have not been given for a very long

period. The more difficult farmers find it to access the subsidy, the lower the probability that they will adopt smart farming practices (Yatribi, 2020). The farmer said that the discrepancy was caused by ongoing changes in government and policy. The farmer also lamented the government's apparent lack of support, citing their concentration on export fruit production rather than Harumanis mangoes as evidence of their neglect.

"The government isn't offering any help right now. The last time they helped us was in 2018 when they gave us fertilizers, but we still had to pay some of the costs ourselves. This is because the government keeps changing and the policies are all over the place. They're more into exporting fruits like papayas and starfruits now." (Own fieldwork, June 2024)

Lack of generational transfer: The farmer mentioned that most of the laborers in the field are elderly and from rural areas. He also stated that the younger generation is not interested in taking over the Harumanis mango plantation, which is hindering the adoption of technology. This is because, unlike the older generation who show little interest, the younger generation will find it much easier to implement smart farming due to their greater exposure to technology.

"Nowadays, young people prefer working in cities like KL and others. They're not keen on taking over these Harumanis plantations. All the workers here are older folks from the village." (Own fieldwork, June 2024)

The lack of generational transfer in farming, where older laborers dominate and younger individuals show little interest in continuing traditional practices, is a recognized barrier to technology adoption. According to Zhang et al. (2019), the reluctance of younger generations to take up agricultural roles significantly hampers the adoption of modern farming technologies. This generational gap in interest and technological exposure impedes the integration of advanced farming methods like smart farming.

Efficacy concern: While the field research expert is working on a study about using sensors to analyze the nutrient content and structure of flowering and non-flowering trees, the farmer exhibits low perceived behavioral control. This is due to their experience of trying numerous ways to improve the yield without success leading to the belief that nothing they do will work.

"We've tried everything possible to make the tree produce fruits, but sometimes it only yields 4 to 5 fruits. I'm unsure if the new smart farming method will work because we've already tried everything." (Own fieldwork, June 2024)

Issues: Due to these obstacles, farmers may believe that their behavior is less controllable since they are uncertain about the technology's efficacy, have limited resources, and lack the information and resources necessary to properly apply it.

The concern about the efficacy of new technologies, such as sensors for analyzing nutrient content in agriculture, is often influenced by past experiences and perceived lack of control. Research by Bandura (1997) highlights that past failures can undermine confidence in new interventions, leading to a lower perceived effectiveness of new technologies. These factors contribute to the reluctance to adopt new farming practices, as farmers may doubt their efficacy and feel constrained by limited resources and information.

5.0 Conclusion

This study explored the sustainability performance in Harumanis mango production, focusing on farmers' readiness to adopt sustainable smart farming practices. It identified challenges such as inconsistent weather, pest control difficulties, and genetic factors affecting yield variability. The theory of planned behavior highlighted how attitudes, societal norms, and perceived control influence farmers' adoption of smart farming technologies. While purposive sampling provided valuable insights, it may have introduced selection bias. Future research should use a larger, more diverse sample to get a more accurate view. Key challenges include reliance on traditional methods, lack of societal pressure, age-related labor issues, and concerns about government support. To address these, it's crucial to enhance farmer awareness through public relations, training, and provide financial support. For example, the U.S. has invested significantly in farm productivity and resource optimization, leading to innovative solutions in agriculture (Farooq et al., 2019). It is imperative to expand their information channels, boost trust in sustainable smart agricultural technology regulations, and implement actionable advice in the field (Xie & Huang, 2021). To enhance the use of sustainable smart farming technology, it's essential to promote collaboration and information sharing among farmers, researchers, and industry professionals. For example, the partnership between Western Mindanao State University and the University of Southeastern Philippines aims to develop a smart farming solution to monitor crop heat stress, which will help farmers improve yields with minimal input (Farooq et al., 2019). Finally, closing the knowledge gap and enhancing the long-term viability of smart farming techniques may be achieved by encouraging the younger generation to be active in the production of Harumanis mango and to utilize their technological experience (Tey & Brindal, 2012). To boost resource efficiency and ensure the long-term sustainability of Malaysia's Harumanis mango industry, farmers will be encouraged to adopt sustainable smart farming technologies through a solution that addresses both social and technical aspects.

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Tarikh : 20 Januari 2023

Prof. Madya Dr. Nur Hisham Ibrahim
Rektor
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Tuan,

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Sekian, terima kasih.

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Saya yang menjalankan amanah,

SITI BASRIYAH SHAIK BAHARUDIN
Timbalan Ketua Pustakawan

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Setuju.

27.1.2023

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