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Beyond Adoption: Drivers, Challenges and Farmer-Led Recommendations for Sustained "Internet of Things" (IoT) Use in Malaysian Smallholder Farming

*Nur Ain Yaacob[1,2], Shaufique Fahmi Sidique[3], Nik Ahmad Sufian Burhan[4], Ahmad Hanis Izani Abdul Hadi[5]
[1]Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
[2]Faculty of Administrative Science and Policy Studies, Universiti Teknologi MARA (UiTM), Persiaran Seremban Tiga 1, Seremban Negeri Sembilan, Malaysia
[3]School of Business and Economics, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
[4]Department of Social and Development Science, Faculty of Human Ecology, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
[5]Department of Agribusiness and Bioresource Economics, Faculty of Agriculture, Universiti Putra Malaysia, UPM Serdang, Selangor, Malaysia
Email: *ainyaacob24@gmail.com, shaufique@upm.edu.my, nikahmadsufian@upm.edu.my, hanis.izani@upm.edu.my
Corresponding Author: Nur Ain Yaacob

Abstract: Smart farming technologies are essential for enhancing food security and the welfare of the farmers. The Internet of Things (IoT) facilitates real-time monitoring and administration of agricultural activities. In Malaysia, IoT is vigorously endorsed through the National Agrofood Policy 2.0 and Agriculture 4.0, yet its implementation and sustained utilization are inconsistent. Previous research has mostly emphasized quantitative determinants of adoption, leaving farmers' lived experiences largely unexplored. This study examines the factors, obstacles, and farmers' generated suggestions for the adoption of IoT among farmers in Selangor and Negeri Sembilan. In these two central region states, smart farming efforts are vigorously encouraged. A semi-structured interview was performed with 10 farmers who had utilized IoT for over one year, and the data were thematically analyzed to discern factors affecting acceptance, obstacles faced, and farmers' suggestions. The results indicated that adoption is influenced by perceived utility, user friendliness, institutional and external assistance, elevated expenses, technological apprehension, and operational challenges. To strengthen the adoption, they recommended strengthening system usability, augmenting technical support and accountability, securing ongoing government backing, broadening training options, offering financial aid, and presenting solutions that demonstrate the real value.

Keywords: *Adoption, Challenges, Internet of Things, Recommendation, Thematic Analysis*

1. Introduction

The smallholder farmers are responsible for up to 80 percent of the food supply in Asia and Sub-Saharan Africa (Food and Agriculture Organization, 2021). It portrays a substantial contribution to agricultural production that occurs on a global scale. Smallholder farmers in Malaysia supported the rural agricultural economy by cultivating key commodities such as rice, fruits, vegetables, and palm oil. They are all regarded as the backbone of the rural agriculture industry through supplying a vast production of fruits and vegetables, which enables the country to reduce the need for imports, guarantee the availability of fresh food, and support the rural livelihoods through agricultural employment. The agrifood sector constitutes around 7.4 percent of Malaysia's GDP, with the smallholders serving as significant contributors and supporting nearly 10% of the national workforce. Despite their significant role, they face several challenges and obstacles, including limited land, insufficient market access, inconsistent policy support, and increasing vulnerability to climate change.

The use of technology has been more essential to curb these problems. The use of technology, particularly digital and the Internet of Things (IoT), can provide farmers with the opportunity to make informed decisions, industrialize and automate operations, use scarce resources, and enhance productivity in agricultural enterprises (Kumar et al., 2024). Technology is a significant resource to achieve the sustainability and competitiveness of the Malaysian agriculture sector, to eliminate inefficiencies, and enhance resilience. Moreover, there is a high use of chemical fertilizers and pesticides in Malaysia, which must be considered, as they have a harmful impact on the environment and the health of farmers (Adnan et al., 2020). As a matter of fact, even overutilization can lower the productivity and the fertility of the soil. Consequently, there is an urgent need to use technology to determine the nutrients in the soil, ensuring that fertilizers and other nutrients are

applied according to the specific needs of plants. This approach will help in minimizing the use of inefficient inputs and agricultural costs.

The implementation and application of IoT technology among smallholder farmers in Malaysia is an important step towards the attainment of the Twelfth Malaysian Plan (12MP) of promoting smart farming in the agro-food sector, in line with the Industrial Revolution 4.0 (4IR). This program aims at modernizing and ensuring efficiency in small-scale agricultural methods. This closely aligns with the National Agrofood Policy of Malaysia (NAP2.0) that sees modernization and smart agriculture as reasons that must be included in the agrifood transformation to make it a resilient and high-technology industry (Ministry of Agriculture and Food Industry, 2021). This is echoed by En and Hui (2023), who stated that the deployment of smart agriculture systems, especially IoT, offers multiple benefits across crop and plantation operations, including input optimization, yield enhancement, and real-time monitoring. Further, the entire agro-food system is transformed to be more efficient operations, improved economic returns, strong environmental outcomes, and better working conditions in the field (Azlan et al., 2023).

In Malaysia, the application of smart farming in the agricultural industry is still in its initial development phase and has not been thoroughly applied (Wei et al, 2020). For instance, the most common uses of IoT in Malaysia's agriculture industry are IoT-based fertigation and IoT-based hydroponic systems, which enable farmers to monitor and control their farm operations through an application installed on their smartphone or computer. Additionally, the E-Satellite Farm program, which was introduced by Malaysia Development Corporation Berhad (MDEC), also helps modern and data-driven farming practices by combining IoT technologies, information and communication technology (ICT) applications, and drone solutions through a matching grant scheme (MDEC, 2022). The programs use smart systems for fertigation and farming, radio frequency identification (RFID), and drones. These IoT-based smart systems enable farmers to monitor and evaluate crop performance by collecting real-time data, such as fertilizer status in tanks, fertilizer mixture levels and concentration, irrigation settings, and timely pesticide spraying. The Ministry of Agriculture and Food Industry (MAFI) allocated RM10 million in the Malaysia Budget 2021 to the Farmers' Organization Authority (LPP) for the execution of this program. This project resulted in a 20% increase in production and a 30% decrease in operating costs among the chili producers. The programs facilitate farmers by providing information through digital laboratories and intensive training for the newbie. Meanwhile, in the paddy sector, the SMARTSBB/SMART Paddy Field in Sekinchan, Selangor, is also another project aimed at incorporating the use of IoT throughout extensive paddy fields. This program is being expanded to thousands of hectares, engaging several thousand farmers, and successfully increasing production exceeding 50% (Malay Mail, 2023). In vegetable farming, the researchers were actively using IoT-powered irrigation, fertigation, and environment-controlled systems to increase the supply of vegetables, especially the temperate crops that grow better in cooler climates. For instance, a recent study on Malaysian greenhouse vegetable systems illustrates how sensors and automation enhance the optimization of water and nutrient utilization (Ahmad, Nik Omar, & Engku Ariff, 2024).

Nevertheless, while these programs demonstrate the efficacy of smart agriculture, their efficacy has largely been limited to only well-resourced or commercial-scale farms. On the other hand, the smallholders who are the backbone of Malaysia's agro-food sector have not yet reaped these advantages to a similar extent. Ahmad et al. (2024) reported that the smallholders frequently encounter enduring obstacles, including high implementation costs, insufficient technical support, and unstable infrastructure, which hinder their capacity to adopt and maintain the use of IoT technologies. Therefore, it is important to focus on smallholder farmers to attain an inclusive agricultural change. They are the most significant players in the food security of Malaysia, yet they remain outsiders in the use of the technology. It is important not only to understand their problems and lived experience to increase initial acceptance of the IoT but also to ensure continuity and sustained use, which will eventually determine the sustainability of Malaysian digital agricultural transformation.

Therefore, this research seeks to explore the key aspects that drive smallholder farmers in two central region states in Malaysia, namely Selangor and Negeri Sembilan, which are central to Malaysia's agro-food production and have been early adopters of smart farming initiatives to keep on using IoT. It also discusses the challenges that hinder implementation and highlights the concepts farmers have proposed to enhance long-term adoption results. The current research goes further than previous studies that mainly focused on the initial adoption

intention for smart farming technologies by farmers by focusing on continuity and sustainability of IoT adoption, which have not been adequately explored in the Malaysian agricultural setting. It uses the qualitative method based on the real experiences of the farmers who have been analyzed, identified the perceived barriers, and made suggestions on how to continue using IoT.

2. Conceptual Underpinning

The implementation and further utilization of smart technology in farming, like IoT, are affected not only by the initial acceptance but also by the constant evaluation of performance, benefits, and usability by the farmer. This paper highlights the relevance of learning the behavioral commitment towards the further use of IoT in agriculture beyond the initial use of technology adoption beyond the initial diffusion phase, as much as the diffusion-based school of thought seems to dominate research on technology adoption. To direct this investigation, the inquiry is conceptually informed by the Unified Theory of Acceptance and Use of Technology (UTAUT) components suggested by Venkatesh et al. (2003) and the Expectation-Confirmation Theory (ECT) proposed by Bhattacherjee (2001). The UTAUT theory assumes that the behavior of using technology is determined by performance expectancy, effort expectancy, social influence, and facilitating conditions. Though the theory is first intended to be applied to organizations, these constructs are becoming more and more applicable to the agriculture sector, where the decision of farmers is conditioned by the expected yield of the activity, the ease of operation of instruments, experience, and the support systems of the institutions (Cimino et al., 2024; Ronaghi & Forouharfar, 2020; Michels et al., 2020). This research uses UTAUT to explain the psychological and social factors that motivate farmers to adopt and integrate IoT technologies in their daily farm management.

Nonetheless, the availability of driving forces does not ensure a long-term interaction. In order to overcome this drawback, this research incorporates the Expectation Confirmation Theory, which states that the continuing intention depends on whether the user is satisfied with the product, and this satisfaction depends on whether their initial expectations were fulfilled or not met after the actual use of the product (Bhattacherjee, 2001). As IoT technologies provide good performance results, financial benefits, and work comfort, farmers are sure of their initial expectations and are more willing to maintain the system. On the other hand, dissatisfaction and diminished continuance occur when customer expectations are not met due to reasons of failure, a lack of after-sales service, and vague financial gain (Al-Emran et al., 2018). This is especially crucial among smallholder farmers whose technological decisions are largely affected by perceived risk, learning requirements, and financial constraints.

Moreover, the choice made by farmers is usually affected by the national digitalization agenda, market forms, institutional interventions, and training and infrastructure accessibility (Klerkx et al., 2019). Confidence and trust in the IoT system gradually improve as farmers are assisted by policy incentives, accountability of the vendor, and the availability of digital knowledge networks. Taken together, these theoretical perspectives give a unified perspective on evaluating the interplay between individual perceptions, social cues, institutional structures, and technological performance in influencing the further usage of IoT. The continuance intentions do not merely represent the continuation of initial adoption but rather a process influenced by confirmation of expectations, trust development, and perceived value.

Therefore, in this study, UTAUT explains the initial drivers that encourage farmers to adopt and experiment with IoT technologies, including perceived usefulness (performance expectancy), ease of use (effort expectancy), social influence, and facilitating conditions. However, adoption alone does not guarantee long-term use. Therefore, Expectation Confirmation Theory (ECT) is integrated to explain how post-adoption evaluation shapes continuance behavior. When farmers experience actual benefits such as improved productivity, reduced labor, and better monitoring capabilities, their expectations are confirmed, which leads to satisfaction and reinforces their intention to continue using IoT. Conversely, when system failures, high costs, or weak technical support contradict initial expectations, dissatisfaction emerges and discourages continued usage. Thus, continuance of IoT among smallholder farmers is conceptualized as the interaction between adoption drivers (UTAUT) and post-adoption evaluation (ECT).

3. Methodology

This study uses a qualitative approach. The data required to meet the objectives of the study were obtained and collected through interviews with fruit and vegetable farmers who have used IoT for more than one year. An in-depth interview of about 1-2 hours with farmers was conducted after receiving a list of potential farmers as respondents suggested by the Selangor State Department of Agriculture, while those in Negeri Sembilan were identified through random and convenience sampling among local smallholder farmers. Selangor and Negeri Sembilan were selected as study areas because both states are in the central region where smart farming initiatives are actively promoted, and they provide a relevant and practical context to this study, while their proximity ensures accessibility and feasibility for data collection. A total of 10 farmers were involved as respondents for this study. A purposive sampling strategy was employed to select participants who had direct experience using IoT technologies in their farming activities. Farmers who had utilized IoT systems for at least one year were specifically targeted, as they were considered information-rich cases capable of providing meaningful insights into both adoption and continued usage experiences. This criterion ensured that respondents had sufficient exposure to the technology to reflect on its benefits, limitations, and sustainability in daily farming operations. Qualitative studies commonly rely on purposive sampling to capture in-depth perspectives from participants with relevant knowledge and experience (Palinkas et al., 2015).

The interviews were conducted either on the participants' farms or at locations convenient for them. Every session was audio recorded and later transcribed to enable data analysis. Demographic information of the respondents was collected after the interviews. The preliminary portion of the interview sought to document participants' experience as fruit and vegetable cultivators and their views on the utilization of IoT in their agricultural practices. The next section discusses the internal and external factors that impact their readiness to adopt, the barriers to the use of IoT, and the recommendations needed to enhance long-term adoption outcomes. Data collection continued until thematic saturation was achieved. Saturation was determined when additional interviews no longer produced new themes or meaningful insights related to IoT adoption and continuity. After approximately the eighth interview, similar patterns and experiences began to be repeated across respondents. Two additional interviews were conducted to confirm the stability of the identified themes, resulting in a total of ten participants (Bryman, 2016). Although the number of participants in this study was relatively small (n = 10), such sample sizes are common in qualitative research that aims to obtain rich, in-depth insights from participants with relevant experience. The emphasis of qualitative research is not statistical generalization but analytical depth and contextual understanding (Miles & Huberman, 1994). In this study, the interviews generated detailed narratives regarding farmers' experiences with IoT usage, and thematic saturation was reached when additional interviews no longer produced new insights. Therefore, the sample size was considered sufficient to capture the key themes relevant to the research objectives while ensuring depth of analysis.

The interviews were analyzed using thematic analysis, which entailed the extraction of common themes in the data collected. The analytical questions guide the thematic analysis. The identified themes, codes, and patterns accurately displayed the content of the entire data set of the interview. It was conducted following several systematic stages. First, all interview recordings were transcribed verbatim and reviewed multiple times to ensure familiarity with the data. Second, initial open coding was conducted to identify meaningful statements related to farmers' experiences with IoT adoption and continuance. Third, similar codes were grouped into broader categories to develop preliminary themes. These themes were then reviewed, refined, and compared across interviews to ensure consistency and relevance. Finally, the themes were interpreted at a latent level to identify underlying patterns that explain drivers, challenges, and recommendations regarding IoT use among smallholder farmers (Levitt et al., 2017; Corbin & Strauss, 2008).

To enhance the trustworthiness of the analysis, several strategies were employed. The coding process involved repeated review and refinement of the transcripts to ensure consistency in theme identification. Codes and emerging themes were continuously compared across interviews to confirm their relevance and accuracy. In addition, representative quotations from respondents were included to support the interpretation of themes and maintain transparency between the data and the findings. In addition, ethical considerations were carefully observed throughout the research process. Participation in the study was entirely voluntary, and all respondents were informed about the purpose of the research before the interviews were conducted. Verbal

consent was obtained from each participant before recording the interview sessions. To protect confidentiality, respondents' identities were anonymized and are represented using respondent numbers in the findings section. All collected data were used strictly for academic purposes.

4. Results

Overview of IoT Practice Among Smallholder Farmers

The findings of the interview showed that every respondent was an active user of smart farming technologies using IoT, primarily smart fertigation and hydroponic systems. Agro-technology companies and government programs like the Program Pembangunan Pertanian Jabatan Pertanian Negeri Selangor and Negeri Sembilan have been introduced as the most prevalent sources of information about IoT for most farmers. Throughout the interview, the respondents became aware of various advantages of the application of IoT in farming as per their experience and intuition. These advantages include less use of labor, effective fertigation, and real-time monitoring of pH, EC, temperature, and humidity. In general, IoT was seen to make the operations of the farm more efficient, accurate, and trustworthy.

Drivers of IoT Adoption among Smallholder Farmers

The following themes have been identified in the adoption of IoT smart farming based on interviews and analysis: (1) perceived usefulness, (2) ease of use, (3) institutional and external support, (4) personal innovativeness, (5) social influence, and (6) awareness. In the first theme, perceived usefulness is portrayed by how the system helps increase efficiency and accuracy in managing the farming jobs. The farmers observed that with the help of IoT-based fertigation systems, fertilizer and water can be supplied in appropriate amounts and evenly distributed across the crops. Moreover, the implementation of automated monitoring systems enables farmers to sustain appropriate pH, EC, temperature, and humidity levels, resulting in healthier and more consistent yields. Farmers also recognized that IoT technologies reduce manual labor, save time, and minimize physical exposure to chemicals, especially during the application of fertilizer and nutrients. In summary, IoT is regarded as an efficient instrument that simplifies work processes and enhances productivity in daily farm operations.

With IoT, fertilizer mixing and water control are faster and more accurate. It saves us time, reduces labor, cuts costs, and helps produce better-quality crops with almost zero defects (Respondents 1 and 4).
IoT can give direct feedback about farm conditions such as soil moisture, salinity, and environmental temperature. It helps me make faster decisions without having to manually check every day (Respondent 3).
My vegetable production increased about 30% after using IoT (Respondent 5).

The second theme is ease of use. During the interview, farmers constantly highlighted that IoT-based smart farming devices are user-friendly and facilitate daily farm operations. Numerous respondents indicated that they could effortlessly track the crops' growth, pH, EC meter, temperature, and humidity using their smartphones, which enables them to make quick and informed decisions.
I can easily check and monitor my plant growth, such as EC, pH, and temperature, just using my phone (Respondents 1, 4, and 7).
The application interface is simple, and I can easily understand and use it without any problem (Respondent 5).
Because of my disability, IoT really helps me. I can monitor the plants just using my smartphone, without moving around too much or doing heavy work (Respondent 2).

Next is the institutional and external support. It has become a significant issue affecting farmers' motivation to adopt and continue the use of IoT. Several respondents recognized that government agencies and programs, including the Department of Agriculture and MDEC, significantly contributed by offering financial aid, subsidies, or IoT equipment to the farmers. Instead, farmers emphasized that they should have more precise guidelines for implementation and regular technical assistance. This implies that institutional assistance reduces financial barriers, but constant technical support, supervision, and follow-ups are also critical to get farmers to be able to use the IoT systems as effectively and sustainably as possible.
I managed to get an incentive from Jabatan Pertanian Selangor to get IoT units worth RM25,000 each, and the IoT is from RedTone Company (Respondent 3).

One of the motivating factors is that the IoT system was given for free by the Department of Agriculture (Respondent 4).
We support it, but the way it's implemented should be clearer… Don't just give the equipment and then expect us to figure it out (Respondent 6).
In addition to this, there is personal innovativeness that encourages farmers to employ IoT in their farms. It centers on the willingness of the farmers to implement and test IoT smart farming. Many of the respondents report that they are highly curious and open to learning new approaches to farming and investigating digital solutions in farming.
I enjoy trying new things, seeing it as a chance to gain knowledge, networking, and skills to share with others (Respondent 1).
I was excited when given the chance to try this new technology (Respondent 3).
We could not overlook agricultural innovation... we just needed to test it, as IoT was trending at that moment (Respondent 6).

In addition, social influence affects the uptake of IoT by the farmers. The views and experiences shared by farmers' social networks, their peers, friends, and fellow farmers made a great difference in their willingness to adopt new technologies. There is also a high level of peer influence and demonstration in motivating adoption. Seeing other farmers succeed builds trust and reduces uncertainty about new technologies.
I was very interested in using IoT after seeing the impressive yields and quality of produce from my friend's farm (Respondent 10).
Some friends said, 'try using it, it's good'… others said, 'don't use it, I had problems with it (Respondent 6).

Lastly, there is the awareness. Awareness of IoT is influenced by direct experience, government policy, training initiatives, and social media exposure. The interview revealed that farmers are more inclined to adopt IoT when they possess prior knowledge and understand the potential benefits that they might gain from the technology. According to Akpojotor (2016), awareness encompasses comprehension or observation of a circumstance, facts, awareness, identification, realization, grasp, and acknowledgment. This shows the role of information dissemination and policy signals in shaping farmers' readiness for IoT.
I came to know about IoT from reading the newspaper, government policy, and social media (Respondent 4).
I got to know more about IoT because I often join programs and projects with MARDI, UPM, and other government agencies. Through these events and presentations, I was exposed to the latest technology (Respondent 5).
If the government hadn't highlighted IoT, maybe I wouldn't know much about it. The policy really made me start paying attention (Respondent 8).
I got exposed to IoT when I attended a course organized by the agriculture office. Before that, I had no idea this kind of technology even existed (Respondent 9).

Challenges of IoT Adoption among Smallholder Farmers
Interviews with smallholder farmers revealed that the issues they faced can be grouped into five main areas, which are (1) knowledge and learning, (2) inadequate technical support, (3) high cost, (4) technology anxiety, and (5) operational difficulties.
First, there are knowledge and learning issues. Farmers reported that they only have minimal exposure to digital technologies, which hinders their capacity to understand and effectively use IoT devices and applications during the first implementation stages. The lack of structured training and clear instructional materials further compounded this challenge, forcing farmers to rely on self-learning or external support from vendors. This limited technical knowledge not only hindered their confidence but also increased dependence on suppliers whenever system issues occurred.
I was unfamiliar with IoT at first. I had to learn step by step on my own until I got used to it (Respondent 1).
I take the chance to learn from the manufacturer whenever there is a problem that occurs. So that I can solve it myself after the warranty ends (Respondents 2 and 4).
Every time something goes wrong, I will call the supplier. I don't have enough knowledge to solve it myself. We rely too much on the vendor; if they don't answer, we are stuck (Respondents 7 and 8).

Besides that, the farmers also indicated that the technical support issues are another obstacle to the adoption of IoT. This is when they always experience frequent delays and inadequate responsiveness from the supplier

or service provider during system failures. The lack of timely and reliable after-sales support not only hindered their agricultural operations but also resulted in financial losses, especially when crops suffered due to the prolonged downtime. This situation diminished farmers' confidence in the long-term sustainability of IoT technologies, as many felt abandoned once the system was installed.

The supplier's responses were very slow, and I had to face losses while waiting for repairs (Respondent 3).

Backup service is very poor, and complaint calls are not resolved promptly, which incurs financial losses to me (Respondent 10).

If there were a technician nearby, it would be easier. Currently, they come from far away, so it takes too long. There should be someone in the district who can handle IoT issues quickly (Respondent 7).

Additionally, the results also emphasize that high cost represents a major challenge to IoT adoption among farmers. Many participants indicate that even though the technology offers great potential for long-term benefits, the initial investment, maintenance fees, and infrastructure equipment are financially burdensome. For a small-scale farmer who operated with a small cash flow, IoT was perceived as a risky and slow-return investment by them. Even when government grants or departmental assistance are available, farmers still face expenses related to system upkeep, repairs, and subscription renewals once the support period ends.

I am worried about the maintenance cost of using IoT once the warranty ends. We also need extra money to be spent on training and face difficulties in getting financing (Respondent 1).

Even though the IoT systems are free, given by the department, the cost of basic infrastructure remains high. For example, it costs about RM30,000 for the IoT system plus RM5,000–6,000 for the basic infrastructure, such as pump houses and pipes. Profitability takes a long time, about five years before you really see the return (Respondent 3).

The subscription is still covered under the grant for these three years, and after that, I need to pay about RM400 per year (Respondents 4 and 6).

Another challenge identified from the interview is the technology anxiety, which refers to nervousness, uncertainty, and fear farmers experience when using unfamiliar digital tools such as IoT systems. Certain farmers express a lack of confidence during the first stage of using IoT on their farms. This is when they feel worried that incorrect settings or system errors could harm their crops. This anxiety was especially affecting farmers who had been using the conventional farming approach for many years. Even though some of them were able to overcome their fear after self-education, training, and peer-to-peer support, the mental resistance at the outset underscores how mental barriers may hinder the seamless integration of IoT.

At the initial stage of using IoT, I had to acquire knowledge independently with the help of the manual. Initially, I felt nervous because I had little idea about it, and I had to take time to learn. I also enrolled in courses and inquired with friends who already had IoT (Respondent 2).

At the beginning, I was worried about using IoT because I was afraid of making mistakes with the application. If I pressed the wrong setting, it could cause damage to the crops and lead to losses (Respondents 3 and 6).

I really felt very afraid. Because we've been manual for more than 14 years (Respondent 5).

Lastly, the findings also reveal persistent technical and operational issues that hinder farmers' confidence in the reliability of IoT systems. Although automation is meant to streamline farm management, farmers reported that they experience the problem of technical failures in their devices, including blocked pipes, biased distribution of nutrients, sensor breakages, and unreliable internet access. Not only do these issues interfere with normal operations, but they also influence the crop growth and quality of yield. Consequently, there are still numerous farmers who observe their farms manually despite the presence of IoT systems.

Even though I can control my farm using a smartphone, I still need to go to the farm and check whether there is any blockage because sometimes the cocopeat floats and blocks the channels, causing plants to turn yellow and not grow evenly because nutrients aren't delivered properly (Respondent 2).

The IoT interface is outdated, not user-friendly, and often fails to function. Sometimes the system only pumps fertilizer solution A but not B, or vice versa, leaving the crops without sufficient nutrients and causing damage (Respondent 3).

Sometimes water-soluble fertilizer doesn't dissolve fully, creating crystals that block the drippers and increase pressure until the pipe bursts (Respondent 6).

Sometimes it depends on the internet… if the internet has problems, it's difficult for us to control and monitor (Respondents 8 and 4).

Insights and Suggestions from Farmers for Better IoT Utilization

The farmers not only display the impediments to using the IoT but also offer various recommendations and suggestions to make its implementation a better process with long-term sustainability. All these recommendations reflect first-hand experience in dealing with daily operational challenges and show that there is a real desire to adopt digital technology, as long as sufficient supportive systems are available. The recommendations emphasized (1) improving system usability and reliability, (2) improving technical support and accountability, (3) sustaining government support and policy improvements, (4) increasing exposure and training opportunities, and (5) making it economically viable and sustaining financial support.

To begin with, the farmers emphasized the need to make the IoT more usable and reliable to promote its broader implementation. Most of them said that the existing systems are overly complicated, volatile, and liable to crashes, which restrains their usefulness in the daily running of their farms. They require IoT systems that are easier to use, deliver precise, detailed data, and are stable without repeated technical failures. They also emphasized the need to possess an elaborate manual in the local language and for active maintenance capabilities, like clog detection sensors and scheduled maintenance, to avoid repetitive operational inconveniences.

The system interface needs to be more user-friendly and up to date. It should be improved to provide more comprehensive and accurate data, not just basic controls (Respondent 3).

Should provide manuals and tutorials on IoT in Malay and include more detailed guidelines to facilitate comprehension (Respondent 2).

Establish a working maintenance process to inspect and clean systems to avoid problems of clogging, such as those that come with floating cocopeat. Maintaining a system proactively is able to guarantee smooth running of the system (Respondent 6).

Secondly, farmers always insisted on the necessity of improving the technical assistance and responsibility of the service provider. They suggested that every district would assign a special officer or technician to provide immediate on-site assistance in the event of system failures. Others recommended that close monitoring and active participation by the providers should be done to help farmers after installation to ensure the technology meets its intended performance.

The service provider must be accountable for any complaints or reports made and ensure prompt responses (Respondent 3).

Each district should have a special officer who oversees the IoT system and takes immediate action in case of any failure or interruption. It is not merely about system installation. Once it is installed, we require constant support so that the system will not be working properly and the workers will not be guided properly (Respondent 5).

They should send technical officers to the farm… to teach us… because every IoT system is different, with different sensors (Respondent 6).

Furthermore, farmers also emphasize the significance of continuous government support and improved policy frameworks in promoting sustainable use of IoT in the agriculture sector. Though most farmers appreciated the existing initiatives, subsidies, and training programs as good moves, they pointed out that there was a need to have consistency of policy in the long term and equal support to all classes of farmers. The change in policy direction was witnessed too often and was considered a hindrance to the confidence of farmers in their investment in IoT systems. Some respondents were also worried that government aid targets bigger farms, and thus, smallholders have little access to technological resources and financial support.

Perhaps the government might continue to fund us to use this type of technology. It actually assists farmers like us and, therefore, should not be halved (Respondent 4).

The policies must not be revised regularly; every few years, farmers require stability to invest in IoT (Respondent 6).

Support should reach all farmers, not just those in certain projects or areas. Sometimes big farmers get more help… we want policies that also focus on small-scale farmers (Respondent 10).

More than that, more formal training and exposure are also proposed by farmers who need to know more about it, as it is crucial for farmers to help them make more of IoT. Despite the clear benefits of technology, a lack of digital fluency and more experience continues to be a hindrance to uptake, particularly in older farmers or

those with less formal education. They proposed that regular and practical courses that are accessible and free of charge should be offered by government agencies, training centers, and project managers. Moreover, respondents suggested that there should be the establishment of farmer-farmer support networks and knowledge-sharing systems, like the Internet forums, field visits, or experience exchange programs, to reinforce group learning and eliminate technology anxiety.

IoT classes should be increased; however, in pay-related cases, small farmers may not be able to attend (Respondents 4 and 6).

That would be nice to have a community or online group of farmers using IoT only. We get to discuss our issues and their solutions... sometimes a fellow farmer already had the same issue and knows what to do (Respondent 2).

Maybe the department can organize farm visits or exchange programs. When we see how other farmers use the technology, we can learn faster and get new ideas to improve our own system (Respondent 7).

Finally, farmers underscored that the sustained success of IoT adoption depends on its economic sustainability, encompassing both the technology cost and its capacity to generate meaningful returns for farmers. Most participants also reported that they are not able to use IoT without sufficient financial assistance, especially among small-scale operators who have little to no capital at hand. They proposed other forms of subsidies, such as monthly payments and government-subsidized grants, to reduce the high initial investment. Farmers, however, also emphasized that monetary assistance will not suffice. IoT should provide tangible value of enhanced returns, fewer losses, or increased market revenue. In the absence of direct financial rewards, technology implementation will be perceived as an unnecessary cost and not an investment to consider.

The government should introduce cheaper purchase options or allow instalment payments or subsidies to encourage the use of IoT (Respondent 8).

With a subsidy, at least we can try. Otherwise, the technology is just applicable to large farmers. With the government still providing grants, they will have more farmers willing to embrace the use of IoT (Respondent 9).

Now we're using IoT technology… but fruit prices are still the same… so the ROI isn't worth it. If the cost of using IoT is higher than what we earn, then it becomes a burden, not a help (Respondent 6).

Discussion

This paper clarifies the long-term use of IoT technology by Malaysian smallholder farmers by examining the determinants, challenges, and recommendations of the farmers, which affect continued use. It is important to distinguish between the factors influencing the initial adoption of IoT technologies and those shaping their continued use. Initial adoption typically occurs when farmers perceive potential benefits, such as improved productivity, automation, or efficiency in farm management. These motivations often relate to expectations about the technology's usefulness and the influence of peers, government programs, or technology providers. However, the findings of this study suggest that the decision to continue using IoT is influenced by a different set of considerations that emerge after farmers gain practical experience with the system. Continuance behavior is shaped largely by farmers' post-adoption evaluation of the technology. Once the system is implemented, farmers assess whether the expected benefits are realized in practice. When IoT technologies demonstrate tangible improvements in farm operations, such as reduced labor requirements and more efficient monitoring of environmental conditions, farmers are more inclined to maintain their usage.

Conversely, operational challenges, unreliable technical support, and financial burdens may undermine farmers' willingness to depend on the technology in the long term. The findings indicate that IoT persistence is influenced by perceived usefulness, convenience of use, and supportive systems but hindered by financial constraints, inadequate knowledge, unreliable technical support, technology-related anxiety, and operational difficulties. These findings align with the theoretical perspectives of UTAUT and Expectation Confirmation Theory (ECT), suggesting that continuance of IoT usage is influenced not only by initial adoption drivers but also by farmers' post-adoption evaluation of technology.

Furthermore, the perceived compatibility of IoT with existing farming routines plays a critical role in sustained usage. Smallholder farmers tend to adopt technologies that integrate seamlessly into their daily operations without requiring complex technical skills or significant changes to established practices. Additionally, social influence emerges as a significant factor, as farmers frequently relied on peer recommendations,

demonstrations and informal networks before committing to sustained usage. This is indicative of the UTAUT propositions that farmers trust a technology more when it is socially approved by means of trusting relationships (Yeo and Keske, 2024). Moreover, institutional support in the form of incentives, subsidies, and training increased adoption and sustained participation (Ansari et al., 2024). Nonetheless, the results point out that enabling circumstances should extend beyond the initial setup. Farmers need guidance on a constant basis, clear implementation procedures, and responsive technical support to make sure that IoT can be viable and useful in the long term.

Despite the perceived benefits of IoT technologies, farmers encountered several barriers that limit their willingness to rely on the systems in the long term, such as a lack of knowledge and learning capacity, insufficient technical assistance, the expensive nature, anxiety toward technology, and challenges in using the technology. These challenges highlight the fragile nature of technology continuance in smallholder farming systems, where operational disruptions can directly affect crop productivity and financial stability. Unlike conventional technologies that allow manual intervention, failures in automated IoT systems may expose farmers to higher perceived risks, which explains their hesitation to rely fully on digital farming solutions. Reliance on suppliers was also a significant issue, as support after sales was either delayed or unreliable, which resulted in possible losses of crops. Large investment and maintenance costs, such as subscription payments at the end of the grant period, also reduced farmers' confidence in their long-term affordability. In the meantime, technology anxiety further restricted the use of IoT, particularly among farmers switching to non-mechanized systems, and technical problems such as system clogging, sensor failures, and unreliable internet shut down operations daily. These issues show that adoption does not necessarily lead to continuance, particularly in situations where system failures pose direct risks to production.

From the perspective of Expectation Confirmation Theory (ECT), continuance behavior depends on whether farmers' expectations are confirmed through actual outcomes such as improved yields, easier farm management, and reduced labor. When IoT performance meets these expectations, satisfaction increases, and continuance becomes more likely. In contrast, repeated malfunctions, weak support systems, and unclear return on investment create dissatisfaction and reduce farmers' willingness to depend fully on the technology (Jaroenwanit et al., 2022). However, this study shows that satisfaction is influenced not only by system performance but also by vendor accountability and the consistency of institutional support. Based on farmers' recommendations, there is a need for more reliable and user-friendly systems, improved technical support and accountability, stable government support, wider training and exposure opportunities, and financial mechanisms that reduce the financial burden on smallholders.

Taken together, the findings indicate that continuance of IoT usage among smallholder farmers is shaped by the interaction between the motivational drivers identified in the Unified Theory of Acceptance and Use of Technology (UTAUT) and the post-adoption evaluation mechanisms proposed in ECT. While UTAUT explains the factors that motivate farmers to initially adopt IoT technologies, ECT explains how farmers evaluate the technology after practical use and decide whether to continue using it. When farmers observe tangible improvements in crop management and productivity, their expectations are confirmed, generating satisfaction and reinforcing continuance intention. Conversely, system failures, high maintenance costs, and weak technical support undermine expectation confirmation, leading to dissatisfaction and reduced reliance on IoT systems. This suggests that continuance behavior among farmers is not merely a continuation of adoption but rather a post-adoption evaluation process shaped by perceived value and system reliability.

This study contributes to the literature by shifting from a traditional adoption lens toward a continuance perspective grounded in farmers' lived experiences. The results validate the important UTAUT constructs in the agribusiness environment and complement ECT by demonstrating that expectation confirmation among the smallholders is strongly contingent on the reliability of the service, responsiveness of the vendors, and economic sustainability. Sustainability in IoT adoption in the Malaysian context is not only based on equipment provision but also long-term provision, consistent implementation strategies, and accessibility for small-scale farmers, since policy-led programs often spearhead technology introduction. Overall, the findings suggest that the sustainability of digital agriculture initiatives depends not only on the availability of advanced technologies but also on the alignment between technological performance, institutional support, and farmers' everyday operational realities.

5. Conclusion and Recommendations

The overall results showed that smallholder farmers have a reason to use the IoT due to its apparent help in the farmers' farm management more efficiently, ease of use, institutional reinforcement, innovativeness of individuals, social influence, and the rising awareness created by governmental efforts and educational programs. However, based on the experience of farmers with the use of the IoT, there are numerous barriers that have to be addressed to ensure that they keep using the IoT. The barriers included a lack of digital literacy, unreliable technical support, the prohibitive cost of original investment, technology fear, and constant operation challenges that render the system unreliable. Farmers, through their experience, provided viable ideas to enhance the long-term effectiveness of IoT projects. These involve making IoT systems easier to use and more reliable, providing accountable and responsive after-sales services, enhancing government support and the continuity of policies, creating more practical training opportunities, and increasing finance so that IoT can be affordable to the smallholders. Combined, these observations highlight that effective IoT implementation must go beyond hardware installation. It relies on the unremitting capacity building, reliable support networks, and empowering policies that appreciate the limitations of small-scale farmers. The research is relevant to the existing literature on digital agriculture because it does not focus on the first adoption but rather on the realities of continuance and sustainability, which have not been well studied in Malaysia.

The findings of this study offer several practical implications for policymakers, agricultural agencies, and technology providers aiming to promote the sustainable use of IoT in smallholder farming. First, policymakers should design long-term support mechanisms rather than short-term technology distribution programs. While many farmers initially adopt IoT through government grants or subsidies, the sustainability of these technologies depends on continuous technical assistance, maintenance support, and stable policy commitments. Establishing district-level technical support units or digital agriculture service centers could help farmers obtain timely assistance when technical failures occur. Second, training and capacity-building programs should be strengthened to improve farmers' digital literacy and confidence in using IoT technologies. Rather than relying solely on one-off training sessions, agricultural agencies could implement continuous learning programs such as hands-on workshops and peer learning networks that allow farmers to exchange knowledge and practical experiences in using smart farming technologies. Third, technology providers should prioritize user-centered design when developing IoT systems for smallholder farmers. The study indicates that complicated interfaces and system failures discourage long-term use. Therefore, IoT solutions should be designed with simpler interfaces, clear manuals in the local language, and automated maintenance features like clog detection or system alerts to assist farmers in managing technical issues.

Finally, financial accessibility remains a critical factor affecting long-term adoption. Policymakers could consider introducing flexible financing mechanisms such as subsidized leasing schemes, instalment payment options, or shared digital infrastructure programs to reduce the financial burden on small-scale farmers. Ensuring that IoT technologies demonstrate clear economic value, such as increased productivity or reduced operational costs, will also be essential in encouraging farmers to sustain their use of digital farming systems. The results provide practical guidance to policymakers, providers of technology, and agricultural agencies that aim to accelerate the uptake of smart farming by smallholders. The economic effects of IoT in the long run, policy loopholes, cross-state analysis, or longitudinal research could offer additional insights into the continuance behavior of farmers in the long term and could serve as future studies. Strengthening these areas will be essential to ensuring that IoT becomes an accessible, reliable, and valuable tool that truly supports Malaysia's agricultural transformation and smallholder resilience.

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