UTAUT Model Insights on the Adoption of Smart Farming Technologies (SFTs) in Malaysia

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ABSTRACT

This study explores the adoption of Smart Farming Technologies (SFTs) through the lens of the Unified Theory of Acceptance and Use of Technology (UTAUT) model. In conjunction with the fact that agriculture is currently facing worldwide issues, SFTs present potential approaches to increase production and sustainability However, the rate at which they are being adopted, especially in developing countries such as Malaysia, is not meeting the anticipated level. This review compiles current literature on the adoption of SFTs utilizing the UTAUT framework by examining important factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions. The analysis demonstrates that these characteristics have a substantial impact on farmers' intentions to use SFTs, with their relative significance varying depending on different circumstances. Performance expectancy is a significant factor in predicting adoption intentions, whereas social influence has a vital impact on farmers' decisions, particularly in community-oriented agricultural environments. Facilitating conditions, including access to resources and technical support, are especially important for smallholder farmers. The study also reveals the complex relationship between behavioral intention and actual usage behavior, highlighting the importance for comprehensive initiatives to encourage the adoption of SFTs.

Keywords: Smart Farming Technologies (SFTs), Unified Theory of Acceptance and Use of Technology (UTAUT), Adoption, Sustainability, Behavioral Intention

INTRODUCTION

Food security is essential for sustainable development, requiring the transformation of global food systems to ensure the source of food for all while respecting to environmental guidelines. In order to accomplish this, it is essential to provide assistance and encourage cutting-edge technology that will facilitate the essential transformations in food production, distribution, and consumption approaches (Varzakas & Smaoui, 2024).

Smart farming is an agricultural management approach that uses technology to monitor and evaluate the needs of specific locations and crops. It is well-known for utilizing the potential of information and data technology with the goal of improving the productivity of complex agricultural systems. Technological integration will eventually facilitate the automation of farming activities, resulting in improved mechanization, efficiency, and production at every stage. This is crucial in meeting the worldwide need for food, especially considering the limited availability of agricultural land (Hashim et al., 2024).

Wee and Lim (2022) stated that the implementation of Smart Farming Technologies (SFTs) in Malaysia is still falling behind when compared to neighbouring countries. Malaysian farmers struggled to adopt smart farming because of expensive costs and technological difficulties such as limited transfer and usage. Regardless of the technologies' potential benefits for increased farm productivity and efficiency, the adoption of developed smart farming technologies by Malaysian farmers, especially those in rural areas, is still a challenge (Ahmad et al., 2024). Consequently, rural farmers could end up at an obstacle when it comes to adopting technologies that have the potential to significantly enhance their farming methods due to inequalities in technology access and support networks. Consequently, the imbalance between the regulation of technology and its actual use in rural regions hinders the progress of agricultural modernization and the quality of life in these communities. Multiple factors influence the willingness and implementation of these technologies by farmers, including both individual and environmental aspects. While Mat Lazim et al., (2020) supported that the adoption rate among Malaysian farmers is hindered by factors such as small-scale production, limited use of technology, a decrease in available arable lands, environmental deterioration due to climate change, rapid urbanization, and an ageing farmer community. Thus, gaining a comprehensive understanding of these influences is crucial for developing effective strategies to promote SFT adoption, particularly in the Malaysian context.

When discussing technology adoption, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is one of the most popular frameworks in the field; of technology acceptance models and offers a comprehensive framework for analysing these determinants. It has emerged as a valuable theoretical framework for examining the determinants of technology adoption across various domains, including agriculture (Michels et al., 2020). Hence, this paper aims to synthesize the existing literature on the application of the UTAUT model to the adoption of SFTs in the agricultural sector. By exploring the key constructs of the UTAUT model, such as performance expectancy, effort expectancy, social influence, and facilitating conditions, this review will provide insights into the factors that shape farmers' attitudes, intentions, and actual use of SFTs among farmers in the agriculture sector. The study is particularly significant because it bridges the gap between technological advances and their practical application in agriculture, a sector critical to global food security and economic stability. Understanding the drivers and barriers to SFTs. adoption will allow policymakers, agribusinesses, and researchers to develop more effective strategies for promoting sustainable and efficient farming practices, which lead to higher yields in agriculture and environmental sustainability.

LITERATURE REVIEW

Smart Farming Technologies (SFTs)

Agriculture has historically provided nations with economic stability and subsistence. The development of agricultural operations to meet the demands of growing populations has resulted in environmental degradation due to excessive pesticide use, deforestation, overexploitation of natural resources such as water, and ecosystem disruption, despite the fact that it has provided both food and employment. Through technological and research advancements, the agricultural sector has evolved to address these concerns while sustaining crop output. As a result, conventional labor-intensive farming techniques have given way to "smart farming" methods that use modern technologies to boost yields, preserve resources, increase efficiency, and promote long-term agricultural development (John & Arul Leena Rose, 2024). Utilising cutting-edge technologies and data-driven farm operations is what is known as "smart farming," which is also sometimes referred to as "smart agriculture." The goal of smart farming is to maximise and improve the sustainability of agricultural output. Meunier et al., (2024) report that due to a lack of faith in professional guidance, farmers' inappropriate actions and behaviors may significantly damage the environment in agricultural environments. The long-term sustainability of agricultural systems and the ecosystems around them are threatened by these harms, which also include increased climate impacts, soil degradation, biodiversity loss, water contamination, and excessive pesticide use thus the need to pay greater attention to sustainable agricultural practices. D'Silva et al., (2011) point out that sustainable agriculture combines social, economic, and ecological aspects to produce food sustainably over the long term while protecting the environment. This all-encompassing strategy seeks to create well-managed resources, steady employment, and continued farmer participation in agricultural development by establishing a balance between the preservation of the environment, economic stability, and community engagement. According to Banerjee and Sambhaji Dambale (2024), “Smart Farming Technologies” is a new product that has been developed with the intention of enhancing the production and sustainability of agricultural operations.

Based on the findings of Osrof et al., (2023), the concept of “Smart Farming Technologies” (SFTs) refers to a combination of farm management information systems, which include computers, smartphones, apps, web-based services and technologies that are commonly associated with precision agriculture, for instance for yield monitoring, remote sensing, and variable rate technologies. SFTs will additionally deal with digital or smart technologies such as cloud computing, automation, Artificial Intelligence (AI) and Internet of Things (IoT) applications.

Zhahir et al., (2024), highlighted the adoption of smart farming as an essential strategy that Malaysia’s agricultural sector can utilize to overcome obstacles like small-scale production, technological constraints, environmental degradation, and an ageing labor force. Therefore, in order to ensure successful and widespread adoption, it is essential to understand the factors influencing the adoption of new technologies, particularly Smart Farming Technologies (SFTs) in Malaysia.

Types of SFTs

According to Balafoutis et al., (2017), three (3) main categories comprise SFTs that address the Precision Agriculture (PA) cycle system: –

- Data acquisition technologies: This category includes all surveying, mapping, navigation, and sensing technologies.
- Data analysis and evaluation technologies: These technologies range from simple computer-based decision models to complex farm management and information systems incorporating various variables.
- Precision application technologies: This category encompasses all application technologies, focusing on variable-rate application and guidance technologies.

In the context of Malaysian agriculture, agricultural production has been rising rapidly since Malaysia gained its independence, reinforcing its historical contribution to the nation’s economic growth. The productivity and efficiency of the agricultural sector have risen much more rapidly in this post-independence era.

Idham et al., (2015) found that a drop in agricultural contributions in Malaysia was caused by a number of variables, including limited productivity, marketing, technical, institutional, and social concerns within the agricultural sector.

The agricultural sector in Malaysia is gradually adopting new technology, and recently with smart farming technology, mostly for important commodities like oil palm and paddy. These cutting-edge agricultural techniques improve the effectiveness of plantation management operations including pruning, fertilization, harvesting, and crop health evaluation by enabling real-time data collection and monitoring. By putting these technologies into practice, farmers can increase agricultural yields, save input costs, and improve resource efficiency. The development of smart farming techniques has the potential to raise production across a variety of crop kinds in Malaysia's agricultural environment, even if the focus is currently on major crops (Ahmad et al., 2024).

Critically, addressing all the challenges is paramount, as digitization not only facilitates connections with

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suppliers but also significantly accelerates farmers' decision-making processes. This acceleration applies to crucial aspects of farm management, including choices about inputs, technical costs, inventory control, and production quality oversight.

UTAUT MODEL

For the UTAUT Model, Venkatesh et al., (2003) devised a synthesized model that combines eight previously employed models in the Information Systems (IS) field, including the Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), TAM2, Motivational Model (MM), Model of PC Utilization (MPCU), Diffusion of Innovations (DOI), and Social Cognitive Theory (SCT). By merging conceptual and empirical similarities across these models, a unified framework was established. The UTAUT model consists of six main constructs, namely performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), behavioural intention (BI) to use the system, and usage behaviour (see Figure 1). The UTAUT model contains four essential determining components and four moderators. According to the model, the four determining components of BI and usage behaviour are PE, EE, SI, and FC. Gender, age, experience, and voluntariness of use are the moderators that affect the usage of technology (Venkatesh et al., 2003).

In order to predict the utilization of systems and to drive decisions on the acceptance and utilization of technology, the Unified Theory of Acceptance and Use of Technology (UTAUT) model was developed. Therefore, it has been extensively implemented and empirically established in a variety of fields.

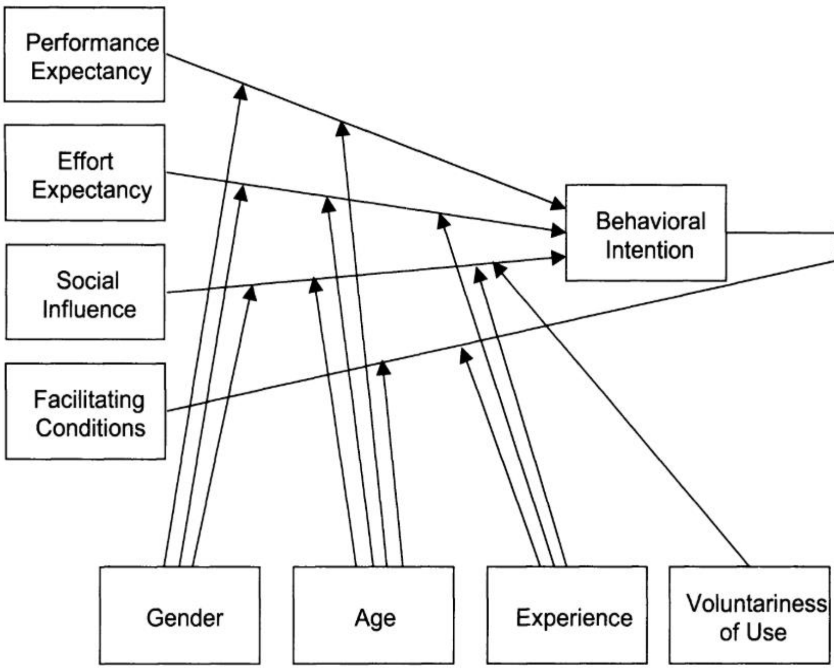

Figure 1. The unified theory of acceptance and use of technology (UTAUT) model (2003)

This includes fields like interactive whiteboards, near-field communication technology, mobile health, home telehealth services, and Enterprise Resource Planning (ERP) software acceptance. The UTAUT model provides a comprehensive framework that explains not only the acceptance of information technologies and information systems but also their actual use. By integrating different technology acceptance models, the UTAUT model significantly contributes to understanding technology acceptance and usage behaviours (Chao, 2019). Given its capabilities, this study can utilize the UTAUT model as a theoretical foundation to evaluate the influence of technology-related factors on the adoption of smart farming technologies (SFTs) in the agriculture sector.

PERFORMANCE EXPECTANCY

The concept of performance expectancy is an essential component of the Unified Theory of Acceptance and Use of Technology (UTAUT) paradigm. Performance expectancy is defined as the extent to which an individual believes that the use of a system will assist in the achievement of improvements in job performance (Venkatesh et al., 2003).

The theoretical underpinning of this variable originates from usefulness perceptions (Technology Acceptance Model), extrinsic motivation (Motivation Model), job fit (Model of PC Utilisation), relative advantage (Innovation Diffusion Theory), and result expectations (Social Cognition Theory). The perceived usefulness of the job, extrinsic motivation, and job fit are three elements that influence the performance expectations of an individual. As far as each model that was examined was concerned, the variables that were associated with performance expectations were the most accurate predictors of intention to utilise the technology that was being targeted (Chang, 2012).

In the context of smart farming technologies (SFTs), a great number of studies have been conducted to evaluate the impact that performance expectations have on the adoption of these technologies. Researchers have repeatedly discovered a substantial positive association between performance expectations and the desire to adopt or use SFTs. This relationship has been proven to be significant. In a study conducted by (Molina-Maturano et al., 2021), it was discovered that the most significant predictor of farmers' desire to adopt an app that provides agricultural information was their performance expectations. As an illustration, a study that investigated the intention of smallholder farmers in Guanajuato, Mexico to adopt an agricultural advice app found that technical infrastructure and knowledge acquisition are key predictors with performance expectancy particularly influencing adoption intentions. Performance expectancy was found to be a particularly influential factor in adoption intentions, particularly among younger farmers and those who were not connected to innovation hubs (Molina-Maturano et al., 2021).

One of the most important aspects of the UTAUT model is performance expectancy, which also plays a significant part in the implementation of smart farming technology. A better understanding of the benefits of SFTs among farmers and efforts to improve their views of those benefits can lead to increased adoption, which in turn improves agricultural output and sustainability.

EFFORT EXPECTANCY

According to Venkatesh et al., (2003), the term "effort expectancy" refers to the degree of easiness that is associated with the utilisation of a system. Farmers are obligated to assess the potential amount of work that will be required to use SFTs and determine whether or not these efforts are in line with the rewards that are recognised.

This article presents a detailed analysis of the specifics of effort expectancy in the specific scenario of farmers adopting SFT. This investigation takes into account a variety of factors, including the simplicity of use, the required skills, the amount of time invested, and the perceived advantages.

Kutter et al., (2011) highlighted the importance of simplicity as one of the fundamental components of successful innovation adoption. Innovations that are simply understood and easy to use (low complexity), able to show a clear advantage over present methods, compatible with current practices, and readily available for trial use have a higher probability of being successful. The complexity of Precision Farming

(PF) systems and the related learning costs have been recognised as barriers to adoption.

Demographic factors such as age, education, and experience with technology can influence effort expectancy. For instance, Alexander, (2005) found that adoption of genetically modified maize increased with age for younger farmers as they gain experience and increase their stock of human capital but declined with age for those farmers closer to retirement. Younger farmers or those with more education and exposure to technology may find it easier to integrate SFT into their farming practices, highlighting the need for targeted support for older or less tech-savvy farmers.

SOCIAL INFLUENCE

In many communities, farming practices are influenced by social norms and interactions, which can significantly motivate the adoption of new technologies. This social pressure can drive farmers to embrace SFTs, as they seek approval from their peers and community members. The pressure generated by social interactions and norms can motivate farmers to adopt SFTs (Wee & Lim, 2022).

Venkatesh et al., (2003) also mentioned the concept of social influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system. Social influence refers to the ability of respected persons to shape an individual's decisions, particularly in adopting new ideas or approaches. This influence is significant in determining whether an individual will utilize a particular product or technique.

In the context of smart farming, this indicates that if significant figures within a farming community accept and implement SFTs, then other farmers are more likely to follow suit and adopt them as well. The endorsement of these technologies has the effect of creating a ripple effect, in which the perceived benefits of adopting these technologies are enhanced by the social approbation that is associated with their use. Zaman et al., (2023) explained the spread of smart farming technologies is heavily dependent on social connections and networks. Farmers who belong to innovative groups or communities tend to be early adopters of these technologies and are more likely to advocate for their benefits to fellow agriculturists.

Social networks significantly influence agricultural technology adoption through mechanisms like information sharing, observational learning, risk reduction, and access to resources. These networks facilitate the spread of knowledge about new practices, provide support systems for farmers considering adoption, and can create social norms that encourage the uptake of new technologies as evidenced in the study (Rafael, 2011).

A study by Wee and Lim, (2022) also highlighted on examining the SFTs adoption by Sarawak rice farmers revealed social influence as the primary driver of adoption intent. The crucial role of peer, family, and community leader perspectives in farmers' decisions to adopt modern technologies is highlighted by this finding. Additionally, it emphasizes the possibility of integrating social networks to promote the digitalization of agriculture, hence strengthening digital inclusion and economic growth strategies by 2030.

FACILITATING CONDITIONS

When it comes to the adoption of technology, particularly in the context of SFTs, the conditions that facilitate adoption have a significant role in influencing the actions and perceptions of users, which ultimately leads to adoption behaviour. Venkatesh et al., (2003) discussed the term "facilitating conditions" is defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system.

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As highlighted by Aziz et al., (2024), the goal of enabling facilitating conditions is to provide users with support, education, and help in order to make better use of the technology. This is done without necessarily making the users aware of the benefits that the technology offers. There is a high probability that users will view a specific technology as having less utility if they believe that it is difficult to use and requires settings that are conducive to its use. The role of favourable conditions proves to be especially advantageous for smallholder farmers. This is because it ensures that these farmers regard agricultural operations that use technology as being more accessible and beneficial.

According to the findings of a study by Li et al., (2020), the crucial role that favourable conditions play in boosting the use of agriculture technologies among Chinese farmers is highlighted. It was discovered that the presence of facilitating conditions, which include access to financial support, requisite knowledge and resources, and advisory services from professionals, had a significant and beneficial impact on the intention of farmers to adopt technologies.

In additionYu, (2012) also revealed the impact of facilitating conditions on adoption behaviour is mediated by age. In particular, individuals with age of under 30 and those over 50 have a stronger impact on facilitating conditions which suggests that these age groups may need more resources and assistance for adopting technology than do individuals in the 30- to 50-year-old range.

Apart from that, the high cost of purchasing and maintaining smart farming technologies is one of the main barriers, which can put a heavy financial strain on farmers. Farmers find it challenging to invest in smart farming technologies due to an absence of government funding and limited access to financing sources. Creating the required infrastructure and switching to IR4.0 technologies can be extremely expensive. Certain businesses may be discouraged by the ongoing costs of the transformation process, which go beyond the initial investment (Mat Lazim et al., 2020). According to Koutridi & Christopoulou, (2023), this is particularly true for small-scale farmers, as they often are unable to afford the high expense of precision agriculture equipment. Farmers frequently believe that the initial and ongoing costs of implementing SFT are prohibitively expensive. A lot of individuals believe that for implementation to happen, the government has to step in and offer subsidies or lower interest rates.

BEHAVIORAL INTENTION AND USE BEHAVIOUR

The use of behavioural intention within the framework of the UTAUT is a powerful indicator of the actual adoption of technology. Behavioral intention or usage intention describes a person’s desire to engage in a specific action. This idea encourages behaviors that assist individuals embrace and use new technologies. In the context of technology adoption models, behavioral intention is considered an essential component for assessing customers’ real intentions as well as their actual behaviors with regard to technological advancements (Misra et al., 2022).

Osrof et al., (2023) highlight that behavioral intention is a significant predictor of use behavior, and the relationship is not always straightforward. Various factors, including perceived usefulness, ease of use, social influence, and cultural barriers, can influence whether farmers’ intentions to use SFTs result in actual implementation. The study also emphasizes that the adoption of SFTs is a complex process affected by numerous individual, organizational, technological, and external factors.

According to the findings by Wee and Lim, (2022), farmers were more likely to make decisions to implement smart farming technologies if they thought the tools could assist them perform better, if they were simple to use, if their social networks supported them, and if they had the tools and assistance they needed. This intention is affected by the opinions and practices of their peers and supported by the resources that are accessible to them.

A study done by Opdenbosch and Hansson, (2023) emphasizes the influence of psychological factors, including attitude and perceived behavioral control, on farmers' intentions to use technologies. Positive attitudes will enhance the probability of their adoption, with additional factors such as gender, education,and income also influencing the decision. The study suggests that farmers' decision-making is more thanjust profit maximization, highlighting the significance of attitudes, social norms, and self-efficacy.

CONCLUSION

In a nutshell, SFTs play an important element in strategizing and represent a transformative approach to modernizing agriculture, enhancing productivity, and promoting sustainability. The Unified Theory of Acceptance and Use of Technology (UTAUT) Model has provided a robust framework for understanding the adoption of these technologies among farmers, focusing on key determinants such as performance expectancy, effort expectancy, social influence, and facilitating conditions.

The synthesis of literature presented in this review underscores the importance of these factors in shaping farmers' attitudes, intentions, and actual use of SFTs. Performance expectancy, driven by perceived benefits in farm management and productivity, consistently emerges as a strong predictor of adoption. Effort expectancy, influenced by ease of use and technical support, plays a crucial role in mitigating barriers to adoption. Social influence highlights the significance of peer endorsement and community support in fostering technology uptake, while facilitating conditions, encompassing organizational and technical support, are pivotal in enabling effective technology integration.

Despite the potential benefits of SFTs, challenges such as high costs, technological complexities, and varying levels of infrastructure remain barriers to widespread adoption, as evidenced by empirical studies across different agricultural contexts. Addressing these challenges requires collaborative efforts from policymakers, technology developers, and agricultural stakeholders to enhance the accessibility, affordability, and usability of SFTs.

Looking forward, future research should continue to explore these determinants within specific regional and socio-economic contexts to tailor strategies that effectively promote SFT adoption. By advancing our understanding and addressing these factors, we can accelerate the transition towards smarter, more sustainable farming practices globally, thereby contributing to food security, environmental conservation, and economic development in agricultural communities.

The importance of youth involvement in agriculture cannot be overstated, particularly in light of the ageing farmer population and the need to maintain sustainable farming practices. Despite a large youth population of 13.9 million, only a small fraction about 15% are currently involved in agricultural sectors in Malaysia. Modernization of farming practices through the incorporation of advanced technologies could serve as a catalyst to attract younger individuals to the field. This strategy might assist in addressing the issues caused by the present demographic imbalance within the farming community as reported by Mat Lazim et al. (2020).

The demographic composition of rural areas, which typically consists of older people, further exacerbates the situation. As noted by Koutridi and Christopoulou (2023), this age structure can hinder the adoption of new agricultural technologies. The reduced motivation among younger people to pursue careers in agriculture contributes to a knowledge gap, potentially impacting the sector's ability to innovate and adapt to changing conditions.

In essence, bridging the generational divide in agriculture through technological advancement and increased youth participation is crucial for the future of farming in Malaysia and beyond.

In summary, the integration of SFTs holds promise for revolutionizing agriculture, and leveraging frameworks like UTAUT provides a pathway towards realizing this potential through informed decision-making and targeted interventions. This conclusion encapsulates the key insights and implications discussed throughout the article, providing a comprehensive summary of the adoption of smart farming technologies based on the UTAUT model application.

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