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RESEARCH ARTICLE

# Smart Farming: Integrating IoT and UAV Technologies for Precision Agriculture through the Lens of Technology Acceptance and the UTAUT2 Model

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**ABSTRACT**

This article employs the UTAUT2 (Unified Theory of Acceptance and Use of Technology 2) model and the lens of technology acceptance for examining the transformative potential of integrating Internet of Things (IoT) and Unmanned Aerial Vehicle (UAV) technologies in precision agriculture. It covers developments in smart agricultural systems, how these technologies might be used to improve crop management, and the issues that arise when putting them into practice. Using the UTAUT2 paradigm, special attention is placed on comprehending the factors driving the acceptance of IoT and UAV technologies in precision agriculture. It is emphasised how important these technologies cotributed to the Malaysian plantation sector, where their implementation can result in appreciable increases in productivity, sustainability, and efficiency. Using a qualitative methodology, this study synthesises findings from pertinent publications and journals published between 2019 to the present. Using the UTAUT2 model as a framework, the analysis focusses on the effects of IoT and UAV technologies on precision agriculture, finding important factors influencing their acceptance and integration into farming methods. The findings for this article are categorized based on the constructs of the UTAUT2 model; performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value and habit. IoT and UAV technologies have a wide range of real-world uses in precision agriculture. IoT devices have the ability to automatically control irrigation systems, detect weather patterns, and monitor the health of the soil. UAVs can be used for a variety of activities, including yield estimation, pest detection, and crop reconnaissance. Precision farming techniques are made possible by these technologies, which increase productivity and efficiency. The distinctive feature of this study resides in its complete evaluation of the latest breakthroughs and research findings on the integration of IoT and UAV technologies in precision agriculture, while applying the UTAUT2 model to understand technological acceptance. This paper contributes to the growing body of knowledge in smart farming by synthesising recent studies and applying the UTAUT2 framework to provide updated insights into the advantages, obstacles, and factors influencing the acceptance of these technologies.

## INTRODUCTION

The development of precision agriculture signifies a dramatic shift in farming operations, moving away from traditional methods toward more efficient and data-driven alternatives. Unmanned aerial vehicles (UAVs) and the Internet of Things (IoT) are leading this change and have become indispensable tools for agronomists and farmers alike. Stakeholders may optimise resource management, minimise environmental impact, and boost crop yields by using these tools to make educated decisions. In particular, the UTAUT2 (Unified Theory of Acceptance and Use of Technology

2) model and the lens of technology acceptance are used to examine the integration of IoT and UAV technologies in precision agriculture, along with their implications and the variables that propel their uptake.

Precision agriculture, or "smart farming," which combines IoT and UAV technology, has the potential to completely transform the agriculture industry. Farmers can perform targeted interventions and optimise inputs by using real-time data from IoT devices on pest infestations, nutrient levels, and soil moisture (Wolfert et al., 2017). However, according to Candiago et al. (2015), unmanned aerial vehicles (UAVs) can offer high-resolution aerial photography for crop monitoring, yield calculation, and precision spraying. Farmers can increase the precision and efficiency of their operations by combining these technologies.

Nonetheless, the technological acumen of IoT and UAV technologies is not the only factor that determines their effective integration in precision agriculture. The opinions and viewpoints of farmers and other stakeholders also have an impact on it. According to Venkatesh et al. (2012), the UTAUT2 model offers a thorough framework for comprehending the variables influencing technology acceptance and use in a consumer setting. By using this model in the context of smart farming, we can learn important lessons about the factors that encourage and hinder the acceptance of IoT and UAVs, which will help us develop strategies for advancing their wider usage.

The purpose of this paper is to investigate the application of IoT and UAV technologies to precision agriculture, with an emphasis on the plantation sector in Malaysia. Through the prism of the UTAUT2 model, it looks at the possible advantages of these technologies, the difficulties in putting them into practice, and the variables affecting their uptake. This study adds to the increasing body of knowledge on smart farming by synthesising recent research findings and applying this theoretical framework. It also offers practical insights for stakeholders looking to harness the power of these transformational technologies.

## 1. Literature Review

A paradigm change in farming operations is represented by precision agriculture, which abandons traditional techniques in favour of effective, data-driven strategies. Unmanned aerial vehicles (UAVs) and the Internet of Things (IoT), which provide farmers and agronomists with practical information, are key components of this revolution. Stakeholders can maximise crop yields, reduce environmental impact, and optimise resource allocation by utilising these technologies.

Real-time data plays a crucial role in precision farming, according to recent studies. IoT sensors integrated into the agricultural ecosystem collect data on temperature, humidity, soil moisture, and other pertinent elements continuously. UAVs with sensors and cameras provide extremely high spatial resolution photographs of crops, which supplement traditional ground-based data collection methods. Timely actions, such modifying irrigation schedules or identifying anomalies, are made possible by this real-time monitoring (Smith et al., 2019; Johnson & Lee, 2020; Zhang et al., 2020; Alreshidi, 2021).

IoT-enabled sensors monitor growth patterns, disease susceptibility, and nutrient levels, among other crop health indicators. Soil moisture sensors, for example, aid in irrigation optimisation by avoiding over- or under-watering (Aqeel-Ur-Rehman et al., 2020). Multispectral sensors on UAVs allow for the detailed collection of images, which in turn helps in the early detection of stress factors including diseases, pests, and nutritional shortages. Based on accurate spatial information, farmers can then customise treatments (Mogili & Deepak, 2019; Zhang et al., 2021).

Sustainable agriculture requires a fundamental understanding of soil conditions. IoT devices measure the pH, nutrient content, and compaction of the soil to help with crop rotation, fertilisation, and soil amendment decisions. UAVs help by enabling site-specific management techniques by mapping the heterogeneity of soil across fields. Farmers can maximise output while reducing their negative environmental effects by attending to the health of their soil (Chen et al., 2020; Gao et al., 2021).

Crop outputs are substantially impacted by climate variability. IoT weather stations gather information about solar radiation, wind speed, temperature, and humidity. Predictive analytics is made possible by combining this data with models tailored to individual crops (Yuan et al., 2020). By detecting frost-prone locations, monitoring microclimates inside fields, or evaluating wind damage following storms, UAVs broaden the coverage. Resilience is increased via adaptation techniques founded on these realisations (Xue & Su, 2021).

Although it requires an initial investment, using IoT and UAV technology offers long-term benefits. Cost efficiency is influenced by improved yield forecasts, efficient resource allocation, and less input waste. Because UAVs can cover huge regions quickly, they save labour expenses compared to manual scouting. Acceptance of these technologies is driven by their economic viability (Shamshiri et al., 2019; Mir et al., 2021).

Technology acceptance is influenced by social and cultural variables in addition to technical ones. Campaigns to raise awareness and provide training and education for stakeholders are essential. Furthermore, successful implementation is ensured by an awareness of community dynamics and local practices. When integrating IoT and UAV technologies, the Malaysian plantation industry must take these variables into account due to its particular setting (Mazur et al., 2020; Ismail et al., 2021). The originality of this work comes from its thorough synthesis of current studies on the application of IoT and UAV technologies to precision agriculture. We add to the growing body of knowledge in smart farming by using the UTAUT2 model to analyse the most recent developments, difficulties, and acceptance factors. Our knowledge enables researchers, practitioners, and legislators to successfully traverse the rapidly changing field of precision agriculture (Wolfert et al., 2019; Li et al., 2020; Zhang et al., 2021).

## 2. IoT and UAV Technologies in Smart Farming

Precision agriculture has completely changed the way farmers gather, process, and apply data thanks to IoT and UAV technologies. An in-depth knowledge of the farm's microenvironment is possible thanks to Internet of Things (IoT) sensors spread throughout fields that collect data on temperature, fertiliser content, soil moisture levels, and other environmental factors. High-resolution aerial imagery of crops is captured by UAVs fitted with cameras and sensors, which is an addition to ground-based data collection methods. Timely interventions, such modifying irrigation schedules, identifying regions that need targeted treatments, or spotting anomalies, are made possible by this real-time monitoring (Li et al., 2021; Zhang et al., 2021).

Given that they can collect data in real time, Internet of Things (IoT) sensors are essential to precision agriculture. These sensors are positioned strategically to monitor different environmental conditions across the agricultural field. For instance, soil moisture sensors offer real-time information on the amount of water in the soil, which is crucial for irrigation technique optimisation. Temperature sensors facilitate better planning of planting and harvesting schedules by providing information about the field's thermal conditions. According to Balamurugan et al. (2019), nutrient sensors identify the concentrations of vital minerals and components in the soil, assisting farmers in applying the right kind and quantity of fertilisers. Multispectral sensors on unmanned aerial vehicles (UAVs) provide comprehensive images that can be used to detect stress causes early on, such as disease, pests, or nutritional deficits (Mogili & Deepak, 2019).

Data is transferred to a centralised system for analysis and processing from IoT devices and UAV pictures. This study aids farmers in making prompt, well-informed decisions. Real-time data on soil moisture, for example, can be used to program automatic irrigation systems to water crops only when needed, saving water. Similarly, accurate fertilisation regimens that ensure crops receive the proper amount of nutrients at the right time may be determined using data on soil nutrient levels. This maximises crop yield and development while reducing waste. Targeted interventions are possible with UAV-based crop monitoring, which minimises input misuse and maximises resource allocation (Kumar et al., 2020; Zhang et al., 2021).

The optimisation of resource utilisation is a notable benefit of IoT and UAV technologies in the context of smart farming. Through the provision of accurate field condition data, these devices aid in minimising excessive water and fertiliser consumption. Research has indicated that the use of IoT in irrigation can result in notable water savings without lowering agricultural yields. For example, Shamshiri et al. (2018) found that when compared to conventional techniques, irrigation systems based on the Internet of Things might save up to 30% of the water used. Because UAVs can cover huge regions fast, they also save money by lowering labour costs that come with human reconnaissance (Shamshiri et al., 2019).

Enhanced agricultural yields have been associated with the combination of UAV and IoT technology. These technologies make sure that crops develop in ideal conditions by constantly monitoring and controlling the farm's environmental parameters. Plants grow healthier and produce more as a result of this. Farms using IoT technology have reported 15-20% increases in crop yields, according to Li et al. (2021). Better crop health and higher agricultural productivity are facilitated by the capacity to identify and treat problems early on, such as nutrient deficiencies or insect infestations, utilising both IoT sensors and UAV imaging (Mogili & Deepak, 2019; Zhang et al., 2021).

Numerous case studies demonstrate how IoT and UAV technology can be used to achieve real benefits in smart farming. For example, a study carried out in vineyards shown that IoT sensors could track soil moisture levels and provide information to the irrigation schedule, which led to a 10% increase in grape output and a 25% reduction in water usage (Zhao et al., 2020). Another illustration is the application of IoT and UAVs in greenhouse farming, where sensors keep an eye on CO2 levels, temperature, and humidity to create the ideal growth environment for plants and greatly increase agricultural yield (Xue et al., 2021).

Although there are many advantages to IoT and UAV technologies, there remain obstacles to their general acceptance. Barriers that small-scale farmers may face include high startup costs, problems with data administration, and the requirement for technological know-how. But as these technologies progress and get cheaper, they become more widely available. In addition to taking into account the elements impacting technological acceptance through the UTAUT2 model, future research should concentrate on creating training programs and inexpensive solutions to assist farmers in efficiently using these technologies (Rao et al., 2021).

## 3. UAV Technologies in Smart Farming

Unmanned Aerial Vehicles (UAVs), commonly known as drones, offer a bird's-eye view of farmland, capturing high-resolution images that are essential for crop monitoring and management. These images can reveal patterns that are not visible at ground level, such as variations in plant health, water distribution, and pest infestations (Mekonnen et al., 2021). UAVs have been shown to increase the efficiency of field operations and reduce labor costs, making them integral to the smart farming paradigm (Gago et al., 2015).

### 3.1 Enhanced Crop Monitoring

UAVs are equipped with advanced imaging technology, including multispectral and hyperspectral cameras, which allow for the detailed assessment of crop health and field conditions (Mekonnen et al., 2021). The high-resolution images captured by UAVs reveal patterns and variations that are often not visible from the ground. These patterns can include variations in plant health, water distribution, and pest infestations (Mekonnen et al., 2021; Tseng et al., 2018). For example, UAVs can detect subtle changes in crop color and texture, which may indicate nutrient deficiencies or disease, allowing for timely and targeted interventions (Huang et al., 2020). This capability enhances the decision-making process for farmers, enabling them to adopt precision agriculture practices that lead to improved crop management.

### 3.2 Improved Efficiency and Reduced Labor Costs

The integration of UAVs into agricultural operations has been shown to significantly enhance field efficiency. UAVs streamline various field operations by providing real-time data that aids in the precise planning and execution of tasks such as irrigation, fertilization, and pest control (Gago et al., 2015). This capability reduces the need for manual inspections and field surveys, which traditionally require extensive labor and time. Studies have demonstrated that UAVs can cover large areas in a fraction of the time compared to ground-based methods, thus reducing labor costs and increasing operational efficiency (Dandois & Ellis, 2020; Zhang et al., 2019). This efficiency not only saves time and resources but also allows farmers to allocate their labor more effectively, contributing to overall productivity.

### 3.3 Precision Agriculture and Decision Support

In addition to improving efficiency, UAVs contribute to precision agriculture by enabling site-specific management practices. The data collected by UAVs can be analyzed to create detailed maps of field variability, including soil health and crop conditions. This information supports the precise application of resources, such as water, fertilizers, and pesticides, which can lead to improved crop yields and reduced environmental impact (Wang et al., 2019). Furthermore, UAV technology supports the development of decision support systems that integrate UAV data with other agricultural information, providing farmers with actionable insights for better management decisions (Liu et al., 2021). By leveraging the UTAUT2 model, stakeholders can better understand the factors influencing the acceptance of UAV technologies, ensuring that these tools are utilized effectively in smart farming practices.

In summary, UAV technologies offer significant advantages in smart farming by providing detailed and actionable insights into crop health and field conditions. Their ability to enhance efficiency, reduce labor costs, and support precision agriculture makes them a valuable tool for modern farming practices. By integrating UAVs with IoT technologies, farmers can create a more holistic approach to precision agriculture, ultimately leading to sustainable and productive farming systems.

## 4. Challenges and Opportunities

IoT and UAV technology integration in smart farming has a lot of potential, but there are a few issues that need to be resolved before it can be widely used. Farmers have several obstacles when evaluating these technologies, including high initial costs, a lack of technical experience, and worries about data protection (Wolfert et al., 2017). Critical problems that must be addressed include the absence of standardised procedures for the use of UAVs in agriculture and the requirement to comprehend farmer attitudes towards these technologies better.

Still, new avenues for smart farming are being opened up by sustained technological breakthroughs and encouraging policy initiatives (Kamilaris et al., 2019). Farmers' decisions to use IoT and UAV technologies can be better understood by applying technology acceptance models, such as the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) (Venkatesh et al., 2012). Researchers can create focused strategies to increase the acceptance and usage of these technologies among farmers by identifying the key determinants of technology acceptance, such as performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit. Precision agriculture is becoming more and more dependent on the integration of IoT and UAV technologies in order to improve practices and ensure sustainability as the world's food need rises. In order to address these issues and take advantage of the opportunities these emerging technologies present, my research on this topic—which combines the technological advancements in smart farming with the socio-psychological factors that influence technology acceptance—can make a significant contribution.

### 4.1 High Initial Costs

The high initial cost of IoT and UAV technologies in smart farming is one of the main obstacles to their acceptance. For small to medium-sized farms in particular, the cost of acquiring and putting these technologies into place might be high (Wolfert et al., 2017). The equipment itself, together with any related software, maintenance, and training, are all included in the costs. Many farmers may find this financial burden to be unmanageable, which restricts their capacity to invest in precision agriculture technologies (Shamshiri et al., 2019). It is imperative that these cost issues are resolved in order to improve technological acceptance and promote wider acceptance.

### 4.2 Lack of Technical Expertise

The lack of technical know-how needed to operate and maintain IoT and UAV systems is another major obstacle. A considerable degree of technical expertise and training is required due to the intricacy of these technologies (Kamilaris et al., 2019). It may take a great deal of training and assistance for farmers and other agricultural experts to handle and analyse the data produced by these systems. Acceptance may be hampered by this requirement for technical competence, especially in areas where such knowledge is hard to come by (Gao et al., 2021). Strategies to improve farmers' abilities and confidence in using these technologies can be identified by taking into account the function of facilitating conditions, as described in the UTAUT2 model.

### 4.3 Data Privacy Concerns

Another significant barrier to the deployment of UAV and IoT technologies is privacy concerns. There are concerns regarding the security and privacy of the information acquired due to the substantial data collecting involved (Wolfert et al., 2017). To foster user trust, concerns about data ownership, security, and possible misuse must be addressed. Fostering widespread acceptance requires making sure that data is managed safely and that privacy laws are followed (Zhang et al., 2021). Resolving these issues can have a big impact on farmers' expectations for the technologies' performance and, in turn, their willingness to use them.

### 4.4 Opportunities Through Technological Advancements

Notwithstanding these obstacles, continued technological progress is opening up new possibilities for smart farming. The capabilities and prices of IoT and UAV systems are constantly being improved by advancements in sensor technology, data analytics, and machine learning (Kamilaris et al., 2019). Drones, for example, are now more widely used in agriculture due to advancements in technology that have made them more user-friendly and economical (Alreshidi, 2021). Farmers' views of effort expectation and hedonic motivation may be positively impacted by these technology advancements, which would further encourage acceptance.

### 4.5 Supportive Government Policies

In order to remove obstacles to acceptance, supportive government policies are essential. Numerous governments are putting laws in place to encourage the growth of precision agriculture as they realise its potential benefits. This includes financial support for research and development, incentives for adopting new technology, and initiatives to improve technical assistance and training (Chen et al., 2020). These programs can lessen the initial financial burden and improve farmers' technical skills, which will make it easier to incorporate IoT and UAV technology into standard agricultural practices (Yuan et al., 2020). These strategies have the potential to greatly increase the likelihood of successful acceptance by creating an atmosphere that is favourable to the acceptance of new technologies.

In summary, although obstacles like exorbitant expenses, insufficient technical know-how, and privacy issues about data must be tackled, the prospects brought about by technology breakthroughs and laws that promote them present a bright future. To overcome these challenges and fully realise the potential of IoT and UAV technologies in precision agriculture, further research, policy development, and education are needed. Stakeholders can more effectively assist farmers in their acceptance of these revolutionary technologies by using the UTAUT2 model to analyse the variables impacting technology acceptance. This new part closely correlates with your study focus on IoT and UAV technologies in smart farming, emphasising the integration of technological acceptance principles.

## 5. Relevance to the Malaysian Plantation Industry

Malaysia's plantation industry, particularly palm oil, rubber, and rice production, stands to benefit significantly from the integration of IoT and UAV technologies. The acceptance of these technologies can address some of the key challenges faced by the industry, such as labor shortages, environmental sustainability, and the need for increased productivity. By applying the UTAUT2 model to understand the factors influencing technology acceptance, stakeholders can better support plantation owners in their journey toward adopting these transformative technologies.

### 5.1 Addressing Labor Shortages

A major issue confronting Malaysia's plantation industry is a labour shortage, which is made worse by restrictive immigration laws and a decrease in the interest of the local workforce in agricultural jobs (Bala et al., 2020). Because UAVs can monitor crop health, conduct aerial inspections, and evaluate soil conditions, they can reduce the need for labour-intensive human labour. According to studies by Wang et al. (2021), UAVs can collect data across wide areas effectively, decreasing the need for human labour and boosting operational effectiveness. Additionally, regular processes like fertilisation and irrigation can be automated by IoT devices incorporated in machinery and equipment, which further reduces labour limitations (Chen et al., 2021). These technologies have the potential to improve plantation owners' perceptions of their utility and simplicity of use by addressing the performance expectancy and effort expectancy components of the UTAUT2 model. This will encourage plantation owners to adopt these technologies.

### 5.2 Enhancing Environmental Sustainability

The demand on Malaysia's plantation sector to implement environmentally friendly, sustainable methods is growing. In this sense, IoT and UAV technologies can be quite helpful as they offer accurate data on soil conditions, crop health, and resource utilisation. Plantation owners can maximise inputs like water and fertilisers, cut waste, and lessen environmental degradation by using this information to guide their decision-making processes (Kamilaris et al., 2019). Additionally, the information gathered can be used to track and lessen the effects of illnesses and pests, which will cut down on the need for excessive pesticide use and encourage more environmentally friendly pest control methods. As indicated by the UTAUT2 model, stakeholders can use the social influence and price-value perceptions of plantation owners by showcasing the beneficial effects of these technologies on environmental sustainability.

### 5.3 Increasing Productivity and Profitability

Productivity and profitability in Malaysian plantation industries can also be significantly increased by integrating IoT and UAV technologies. According to Shamshiri et al. (2019), the utilisation of these technologies facilitates precision agriculture approaches that can improve crop yields, minimise losses resulting from pests, diseases, and environmental stresses, and optimise resource allocation. According to Khanal et al. (2020), UAVs have the capability to offer high-resolution imaging that can aid in the early diagnosis of disease outbreaks. This enables prompt and focused interventions. IoT sensors can track soil moisture content and activate automatic irrigation systems to make sure plants develop and use water as efficiently as possible (Jawad et al., 2017). Stakeholders can appeal to the hedonic motivation and habit constructions of plantation owners by showcasing the favourable effects of these technologies on productivity and profitability, as described in the UTAUT2 model.

### 5.4 Overcoming Challenges and Fostering Acceptance

Although there is no denying the advantages of IoT and UAV technologies, a number of obstacles need to be overcome before they can be widely used in Malaysia's plantation sector. These comprise high upfront expenses, insufficient technological know-how, and privacy issues (Wolfert et al., 2017). Ongoing technological developments and encouraging legislative measures, however, may open up new avenues for smart farming (Kamilaris et al., 2019). Stakeholders may create focused strategies to overcome these obstacles and encourage plantation owners to adopt these transformational technologies by using the UTAUT2 model to analyse the factors impacting technology acceptance.

## 6. IoT Applications in Malaysian Plantations

By enabling real-time monitoring of crucial metrics, the implementation of Internet of Things (IoT) technology in plantations in Malaysia is revolutionising agricultural methods. IoT sensors play a critical role in monitoring soil temperature, moisture content, and nutrient levels over large plantation areas, enabling accurate resource and input management (Zhang et al., 2020). Within the framework of the Malaysian plantation industry, this integration is critical to improving sustainability and productivity, especially when considering UTAUT2 and other technological acceptance models.

### 6.1 Precision Irrigation

Precision irrigation is one of the most important uses of IoT in Malaysian plantations. Water is delivered precisely when and where it is needed thanks to IoT-based systems that combine automated irrigation controls with soil moisture sensors. This strategy provides ideal soil moisture levels while minimising water waste, which is especially advantageous for crops like rice that require a lot of water. Gonzalez et al. (2021) claim that effective irrigation systems are crucial for the sustainable development of rice and rubber since they can result in significant water savings and higher crop yields. These systems can encourage farmers to embrace new technology by showcasing performance and effort expectations.

### 6.2 Nutrient Management

By offering real-time data on soil nutrient levels, IoT devices also improve nutrient management. This information makes it possible to apply fertiliser more strategically, minimising overapplication and its negative effects on the ecosystem. IoT-enabled sensors, for instance, can track the amounts of potassium, phosphorus, and nitrogen in the soil, enabling accurate fertiliser delivery to suit the requirements of various crops (Kumar et al., 2022). This focused method lowers the cost of fertiliser inputs while simultaneously enhancing crop health. Farmers' acceptance of these technologies can be positively influenced by the perceived advantages, which is consistent with the constructs of the UTAUT2 model.

### 6.3 Pest and Disease Control

IoT sensors are useful not just for fertilisation and irrigation but also for managing pests and diseases. Plantation managers can take prompt action by implementing sensors that identify the environmental variables that lead to insect outbreaks or disease development. IoT devices, for example, are able to monitor temperature and humidity levels, which are important variables affecting the spread of disease and pest activities (Liu et al., 2021). More sustainable approaches to pest management are facilitated by early identification and focused control methods, which lessen the need for broad-spectrum insecticides. The perceived usefulness and simplicity of use of the technologies by farmers may be improved by this proactive approach.

### 6.4 Data Integration and Decision-Making

Advanced analytics combined with Internet of Things data yields useful insights for decision-making. Plantation managers can obtain a thorough grasp of crop conditions and operational efficiency by means of data gathering and analysis. This data can be processed by tools like machine learning algorithms and predictive analytics to detect insect outbreaks, optimise fertiliser regimens, and forecast irrigation needs (Aqeel-Ur-Rehman et al., 2020). This data-driven strategy improves productivity and plantation management overall, which is consistent with the UTAUT2 model's emphasis on creating environments that encourage technology acceptance.

### 6.5 Challenges and Opportunities

Notwithstanding the advantages, there are obstacles to IoT technology acceptance in Malaysian plantations, including significant upfront expenditures and the requirement for technical know-how. Long-term advantages, such as higher crop yields and resource efficiency, however, exceed these difficulties. Plantation operators should have greater access to these systems as a result of ongoing improvements in IoT technology and declining costs (Chen et al., 2021). Stakeholders may create focused strategies to get over these obstacles and encourage the use of IoT technology in Malaysia's plantation sector by addressing the UTAUT2 model's constructs.

## 7. UAV Applications in Malaysian Plantations

Unmanned aerial vehicles, or UAVs, have become extremely useful instruments in contemporary agriculture, especially when applied on plantations in Malaysia. Their uses include monitoring crop health more effectively, maximising resource utilisation, and lessening environmental impact, all of which are essential for raising industry productivity and sustainability.

Unmanned aerial vehicles (UAVs) offer a distinct benefit in aerial surveillance as they can produce high-quality imagery, which is essential for tracking crop health. UAVs fitted with thermal and multispectral cameras can identify early indicators of nutrient shortages and insect infestations in palm oil plantations (Aravind et al., 2021). UAVs' high-resolution photos allow for the accurate identification of stressed areas, which might reveal underlying problems like illness or nutritional imbalances. By applying timely treatments, like targeted pesticide applications or nutrient changes, farmers can improve crop health and productivity thanks to this early detection capabilities (Zhang et al., 2020). UAVs have the potential to positively impact farmers' acceptance of these technologies by improving performance expectancy.

Apart from monitoring pests and nutrients, unmanned aerial vehicles (UAVs) may also measure other vital characteristics including plant growth and canopy cover. For example, the Normalised Difference Vegetation Index (NDVI), which is useful in evaluating the health and vigour of plants, is one of the detailed vegetation indices that UAVs may produce (Bendig et al., 2021). This in-depth understanding is consistent with the UTAUT2 model's emphasis on the significance of creating favourable conditions for technology acceptance, and it helps plantation operations make better decisions and manage their operations.

Precision pesticide and fertiliser spraying is one of the major uses of UAVs in Malaysian plantations. When compared to conventional approaches, the amount of pesticides and fertilisers utilised can be greatly reduced by using UAVs outfitted with sophisticated spraying systems to apply chemicals in a targeted manner (Mekonnen et al., 2021). This accuracy lowers input costs overall, minimises the impact on the environment, and lessens chemical runoff. To ensure that only the necessary amounts of pesticides are administered, UAVs, for instance, can use real-time data to modify spraying settings based on particular field circumstances and crop needs (Liu et al., 2020). This feature increases the perceived usefulness of UAVs, which encourages farmers to embrace them.

Furthermore, by mapping the spatial diversity within fields, UAVs can help optimise the utilisation of available resources. This feature makes it possible to apply site-specific management strategies, in which various plantation areas are given customised care according to their unique needs. UAVs contribute to input conservation and improve the sustainability of plantation operations by deploying resources more effectively (Mousazadeh et al., 2021). This focused strategy increases operational effectiveness while also fitting in with the hedonic motivation and habit components of the UTAUT2 model, which have an impact on technology acceptance.

UAVs' usefulness in plantation management is further increased by their integration with other technologies, such as Geographic Information Systems (GIS) and Internet of Things (IoT) sensors. For example, integrating soil moisture sensors with UAV data can offer a full picture of crop and soil conditions, enabling better decisions to be made regarding fertilisation and irrigation (Chen et al., 2020). In a similar vein, the combination of GIS and UAV photography can make it easier to produce intricate maps that aid in strategic planning and precision agriculture techniques (Zhou et al., 2022). This example of a technological synergy shows how IoT and UAV integration can optimise agricultural methods and increase overall productivity.

In conclusion, precision input spraying and high-resolution aerial images provided by UAVs provide substantial advantages to Malaysian plantations. These apps help to promote more ecologically friendly and sustainable farming methods in addition to increasing operational efficiency. Through the implementation of the UTAUT2 model's elements influencing technology acceptance, stakeholders can facilitate the uptake of UAV technologies, hence revolutionising the agricultural landscape of Malaysia.

## 8. Economic and Environmental Impact

For Malaysian plantations, the combination of Internet of Things (IoT) and Unmanned Aerial Vehicle (UAV) technologies offers significant financial benefits. By enabling accurate and effective resource management, these technologies immediately raise agricultural productivity. Water, fertiliser, and pesticide consumption can be optimised with the use of IoT devices and UAVs because they allow for real-time monitoring and data collection. According to Van der Burg et al. (2019), this particular application minimises operating costs and lowers waste. To enhance crop yields, for example, UAVs fitted with multispectral sensors can offer comprehensive evaluations of crop health, directing focused treatments (Zhang et al., 2020). Stakeholders can further encourage farmers to adopt these technologies by showcasing their performance expectations.

Profitability gains are another indication of the economic benefits. Plantations can get increased yields and reduced production costs by implementing improved crop management and resource optimisation strategies. According to Kamilaris et al. (2019), plantations become more competitive in the market as a result of this efficiency, which also increases profitability. Furthermore, economic viability is improved by the decrease in human labour and operating costs related to conventional farming practices (Gao et al., 2021). By identifying the variables that affect farmers' acceptance of these technologies, the UTAUT2 model may be applied to promote their acceptance and optimise financial gains.

By lowering dependency on chemical inputs, the use of IoT and UAV technology supports Malaysia's sustainability goals from an environmental standpoint. According to Kamilaris et al. (2019), accurate monitoring and management minimise the misuse of pesticides and fertilisers, hence reducing environmental contamination and enhancing soil health. Furthermore, by offering data that promotes energy and water conservation, these technologies assist sustainable resource management techniques (Gao et al., 2021). This helps the global effort to combat climate change and promotes Malaysia's environmental sustainability goals (Chen et al., 2022). Stakeholders may increase farmers' acceptance of these technologies and add to their environmental advantages by resolving data privacy issues and fostering trust in them.

All things considered, the incorporation of IoT and UAV technologies in Malaysian plantations is a tactical step in the direction of attaining environmental sustainability and financial viability. Plantations can minimise their ecological footprint, increase operational efficiency, and support the larger objectives of sustainable agriculture by utilising these technologies. To maximise the impact of these advances in the agriculture sector, it will be crucial to comprehend the socio-psychological aspects (described in the UTAUT2 model) driving technology acceptance.

## 9. Findings

### (i) **Performance and Efficiency**

Research shows that IoT and UAV technologies improve agricultural operations' performance and efficiency considerably. IoT devices make it possible to precisely monitor and manage farming operations, which maximises resource consumption and boosts output. To help farmers make educated decisions regarding irrigation and fertilisation, IoT sensors, for example, can track soil temperature, moisture content, and nutrient levels (Bojanova et al., 2021). By ensuring that resources are used effectively, this precision agricultural method lowers waste and increases crop yields. Similar to this, unmanned aerial vehicles (UAVs) offer precise aerial photography and data analytics, which are essential for prompt interventions and better crop management. UAVs can detect pest or disease-affected areas early on, allowing for timely and focused treatments that can save crops and improve farm productivity overall (Cheng et al., 2020). By demonstrating the performance expectancy of these technologies, stakeholders can further encourage their acceptance among farmers.

### (ii) **Cost and Economic Impact**

Although there may be a significant upfront cost associated with IoT and UAV technologies, these expenses are frequently offset by long-term economic gains. Farmers may see significant cost savings and enhanced profitability as a result of these technologies' potential to lower labour costs and increase crop yields (Van der Burg et al., 2019). For instance, typical chores like fertilisation and irrigation can be handled by automated equipment, which eliminates the need for manual labour and the related expenses. Furthermore, larger crop yields and higher-quality products can result from timely interventions and precise monitoring, which boost productivity and bring in more money for farmers (Aravind et al., 2021). Identifying the elements that affect farmers' acceptance of these technologies by examining the economic impact via the lens of the UTAUT2 model can ultimately lead to their acceptance.

### (iii) **Environmental Sustainability**

Because IoT and UAV technologies utilise less water, fertiliser, and pesticide, they greatly contribute to sustainable farming methods. The precise application of these inputs minimises their environmental impact, thanks to real-time data from IoT devices. In order to avoid over-irrigation and preserve water resources, soil moisture sensors, for example, assist farmers in applying water only when necessary (Gonzalez et al., 2021). Unmanned Aerial Vehicles (UAVs) provide precision application of pesticides and fertilisers, hence lowering chemical usage and averting contamination of soil and water. This focused strategy supports the wellbeing of crops and the surrounding ecosystems in addition to safeguarding the environment (Zhang et al., 2020). Through the implementation of the UTAUT2 model's environmental sustainability aims, these technologies can gain greater acceptance among farmers who prioritise environmental sustainability.

(iv) **Social and Cultural Factors**

The social and cultural aspects of agriculture have a big impact on the acceptance of IoT and UAV technology. If farmers see favourable results from their peers or hear positive feedback from reliable sources, they are more likely to implement this technology. Farmers make decisions based in large part on social impact and cultural approval (Rose et al., 2021). Programs for training and assistance are also necessary to help farmers become more competent and confident. Farmers are more likely to incorporate these technologies into their farming methods when they get practical training and continuing support that enables them to comprehend the features and advantages of these technologies (Li et al., 2021). By aligning these training initiatives with the constructs of the UTAUT2 model, stakeholders can effectively promote technology acceptance and enhance the successful implementation of IoT and UAV technologies in Malaysian plantations.

## 10. DISCUSSION

Precision agriculture has shown significant benefits in terms of sustainability, cost-effectiveness, and efficiency from the integration of IoT and UAV technology. Crop conditions, soil moisture, temperature, and nutrient levels may all be monitored in real time with the help of Internet of Things devices like sensors and automated systems. According to Zhang et al. (2020), accurate monitoring enables farmers to maximise the utilisation of resources, resulting in higher agricultural yields and decreased waste. With their sophisticated imaging capabilities, unmanned aerial vehicles (UAVs) enable comprehensive evaluations of crop health and focused treatments, leading to a substantial decrease in labour expenses and an increase in production (Torres-Sánchez et al., 2021). Stakeholders can further encourage farmers to embrace these technologies by demonstrating their performance expectations.

However, a number of factors, such as societal acceptance, technological know-how, and economic considerations, affect the acceptance of these technologies. Small and medium-sized farmers may be discouraged from implementing IoT and UAV technologies due to their potentially high initial costs (Sundmaeker et al., 2016). Another major obstacle is the technical knowledge needed to run and maintain these sophisticated systems. To effectively use IoT and UAV technologies, farmers require sufficient training and support (Kumar et al., 2020). Overcoming these obstacles and fostering technological acceptance require addressing the facilitating conditions listed in the UTAUT2 model.

Another important issue is social acceptance. According to Venkatesh et al. (2012), societal norms and the perceived utility and simplicity of use of new technology influence farmers' propensity to accept them. Programs for raising awareness in the community and demonstration projects that highlight the practical advantages of precision agriculture technologies can foster confidence. These projects have the potential to greatly increase the acceptance rates of IoT and UAV technologies in the agricultural industry by utilising social influence and cultural acceptance. Acceptance of intelligent agricultural techniques can be accelerated by addressing these issues through encouraging legislation and educational initiatives. To reduce the obstacles to entry for farmers, governments and agricultural organisations should think about offering financial incentives, subsidies, and technical help. Furthermore, creating thorough training curricula that address the technological as well as practical aspects of IoT and UAV technologies will provide farmers with the know-how to successfully use these advancements (Fielke et al., 2018). These kinds of programs have the potential to boost farmers' self-assurance and proficiency, which will ultimately result in higher acceptance and use of technology.

In summary, even though precision agriculture can greatly benefit from the integration of IoT and UAV technologies, their widespread acceptance will necessitate a holistic strategy that tackles social, technological, and economic obstacles. Establishing an environment that is favourable to the acceptance of smart agricultural methods requires supportive legislation and focused training initiatives. Stakeholders may better assist farmers in adopting these revolutionary technologies by using the UTAUT2 model to identify the factors impacting technology acceptance. This would ultimately increase agricultural productivity and sustainability in Malaysia.

## 11. CONCLUSION

IoT and UAV-powered smart farming has enormous potential to revolutionise the agricultural industry. By incorporating these cutting-edge technologies, agricultural methods can become more sustainable, productive, and cost-effective. For example, real-time monitoring of soil temperature, moisture content, and nutrient levels is made possible by IoT technologies, giving farmers precise information to optimise fertilisation and irrigation procedures (Jones et al., 2020). This saves water and lessens the usage of fertilisers while improving crop health and yields. Stakeholders can persuade farmers to embrace these technologies by showcasing their performance and effort expectancies.

On the other hand, UAV technology present creative approaches to crop management and monitoring. Early detection of illnesses, nutrient deficits, and pest infestations is possible using UAVs fitted with multispectral and infrared cameras, enabling prompt interventions (Zhang & Kovacs, 2012). By lowering the use of pesticides and herbicides, early detection and precise application of agrochemicals reduce environmental effect while simultaneously increasing crop yields (Sishodia et al., 2020). The UTAUT2 model's sustainability aims can be greatly aided by the integration of IoT and UAV technologies, which will increase farmers' acceptance of these technologies among eco-aware farmers.

Furthermore, these technologies have significant economic advantages. The profitability of agricultural operations can be increased by IoT and UAV technology through labour cost reduction and operational efficiency improvements. Research has indicated that the implementation of precision agriculture technologies can result in a noteworthy return on investment as a result of heightened productivity and optimised resource utilisation (Mulla, 2013). Furthermore, by encouraging eco-friendly practices and lowering agriculture's carbon footprint, these technologies support global sustainability goals (Walter et al., 2017). By examining the economic impact via the UTAUT2 model, it is possible to determine the elements that affect farmers' acceptance of these technologies and, eventually, propel their acceptance.

There are still obstacles standing in the way of the extensive use of IoT and UAV technology in agriculture, despite their many benefits. These consist of expensive start-up expenses, insufficient technical know-how, and privacy issues with data (Wolfert et al., 2017). Subsequent investigations ought to concentrate on tackling these obstacles and investigating inventive uses of IoT and UAV technology. Acceptance can be facilitated by, for example, creating affordable solutions and offering farmers training courses. Agronomists, engineers, and data scientists working together on multidisciplinary research can also result in the development of more sophisticated and user-friendly systems that are suited to the unique requirements of various crops and geographical areas. By aligning these research initiatives with the constructs of the UTAUT2 model, such as facilitating conditions and social influence, stakeholders can effectively promote technology acceptance and enhance the successful implementation of IoT and UAV technologies in precision agriculture.

In conclusion, smart farming has enormous potential to transform the agricultural industry. To get over the obstacles in the way of sustainable and effective agriculture operations, more research and development in IoT and UAV technologies is essential. Accepting these technologies as the agriculture industry develops will be essential to maintaining environmental sustainability and food security for coming generations. Stakeholders can better support farmers in adopting these transformational technologies, which will ultimately lead to enhanced agricultural production and sustainability in Malaysia, by using the UTAUT2 model to understand the factors driving technology acceptance.

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