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# Future Scenarios for IoT Implementation in the Farming Industry

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**Abstract**

Smart farming is essential for enhancing crop quality and meeting the rapidly increasing global food demand projected until 2050. The growing human population will significantly impact future farming demand and supply. However, IoT technology faces security challenges, particularly when older devices connect to the internet using public networks. This study aims to identify the issues, challenges, and trends of IoT implementation in the farming industry and develop four possible future scenarios. A questionnaire was distributed to 384 farmers, with 124 valid responses, resulting in a 32.3% response rate. The study employs the STEEPV method for analysis, utilizing scenario building to identify study objectives and impact-uncertainty analysis to assess decision-making variables. The leading drivers identified are "IoT provides meaningful farming data" and "IoT helps increase crop production." These drivers were used to develop four scenarios: 'Smart Agriculture,' 'Doom of Technology,' 'Disqualified Technology,' and 'Rejected Technology.' Implementing IoT in future farming can simplify farmers' tasks and reduce time spent in the field. For all scenarios, collaboration between policymakers and industry stakeholders is essential. Policymakers need to create an enabling environment through supportive policies and regulations, while industry stakeholders must focus on innovation, security, and education to ensure the successful implementation of IoT in farming. By addressing these implications, both groups can help drive the agricultural sector towards a more efficient and sustainable future.

## 1. Introduction

The Fourth Industrial Revolution (IR4.0) is anticipated to significantly transform our daily lives, work methods, and communication techniques (Eleyyan, 2021). This era is expected to bring substantial changes to business models and employment trends. Over recent decades, the manufacturing sector has evolved rapidly from labor-intensive production lines to the use of robotics, which enhance efficiency with minimal labor. The next phase of IR4.0 involves further integration of robotics and automation into daily production processes. The Internet of Things (IoT) is a pivotal technology in this revolution, enabling seamless and secure integration through internet infrastructure. IoT technology can collect and analyze meaningful data, supporting various applications from smart home appliances to smart workplaces, industries, and societies (Abbas, 2018). The IoT is growing in social, technological, environmental, economic, and political significance. It encompasses sensors, software, and connectivity technologies that facilitate data exchange over the internet (Minoli, Sohraby, & Occhiogrosso, 2017). In 2020, the number of connected IoT devices was projected to reach 10 billion, with an expected increase to 22 billion by 2025. However, the current number stands at 7 billion (Prathibha, Hongal, & Jyothi, 2017). By 2025, IoT is predicted to have an $11 trillion impact on the global economy, with 100 billion devices contributing to this impressive economic growth (Yoon, 2020). Despite concerns about internet hacking and privacy issues, IoT holds significant potential and benefits for the public. Addressing these challenges requires complex, multi-perspective approaches to continue engaging the public with IoT concepts (Baker, Xiang, & Atkinson, 2017).

Farmers can leverage IoT technologies, including sensors and network systems, to monitor their fields in real-time and address issues promptly when emergencies arise (Goumopoulos, Brendan, & Achilles, 2014). Implementing IoT in smart agriculture enhances efficiency compared to traditional farming methods. IoT systems can detect climate changes, soil humidity, and crop health through sensors and internet-based software, providing farmers with clear, actionable data. This enables them to reduce crop damage, improve crop quality, and minimize resource wastage (Wolfert, Ge, Verdouw, & Bogaardt, 2017). Farming is traditionally labor-intensive and time-sensitive, requiring precise timing for planting and harvesting to prevent crop failure due to diseases. By integrating IoT into traditional farming, farmers can collect valuable data on soil humidity, climate changes, and labor force requirements, allowing for more accurate decision-making. However, maintaining crop quality and increasing production through IoT presents challenges, particularly due to the variability of data that changes every minute or second. Smart farming involves managing unpredictable issues and ensuring labor force cooperation with system workflows. Despite these challenges, IoT in farming offers significant advantages, such as maintaining crop quality and increasing productivity without additional workforce. This is crucial as the global population continues to grow, leading to higher demand for food. IoT implementation can help meet this demand by boosting productivity, whereas traditional farming methods may struggle to do so. The adoption of IoT in agriculture will transform various aspects of farming, making it more efficient and changing public perceptions of farming (Ng & Wakenshaw, 2017). An IoT ecosystem uses smart devices to transfer data from farms to the internet, utilizing sensors, communication hardware, and internet connectivity to relay information to farmers without the need for physical presence on the farm (Arshad, 2016).

The Internet of Things (IoT) is a network of interconnected computing devices, mechanical and digital machines that can transfer data over a network without requiring human-to-human or human-to-computer interaction (Gillis, 2020). IoT devices collect data and share it via connecting software or by sending it to the cloud for analysis, either locally or remotely. This automated data sharing process eliminates the need for manual uploads, allowing seamless communication between connected devices. This data can assist farmers in making informed decisions and providing clear instructions based on real-time information (Gillis, 2020). However, the high variability of data in the agricultural industry poses challenges for consistent data collection. While data from fields and sensors can be processed analytically, ensuring the safety and sharing of this data remains a significant challenge in smart farming (Chalimov, 2021). IoT technology in smart farming can help farmers increase productivity and reduce waste by monitoring soil humidity and other conditions. For instance, sensors can detect when crops need watering, thereby preventing resource wastage due to over-irrigation. Farmers can monitor crop conditions and take precise actions based on the collected data from anywhere, making smart farming more efficient than traditional methods (Cakir *et al.*, 2019). IoT in the farming industry enables farmers to respond immediately to emerging issues, maximizing crop production while minimizing damage. The future of IoT holds limitless potential, especially when integrated with artificial intelligence (AI). This integration can connect devices with big data to automate business processes, overcoming challenges and opening new revenue streams in the farming industry (R & Chandran, 2018).

Revenue loss due to crop damage and competitive pricing directly impacts farmers' purchasing power for subsequent crop cycles. Logistics and storage challenges also affect the freshness of crops delivered to consumers (IHS Markit, 2020). The Food and Agriculture Organization (FAO) described the situation in the Horn of Africa as "extremely alarming," with widespread breeding and new swarms forming, posing an unprecedented threat to food security and livelihoods at the start of the cropping season (FAO, 2016). In early 2021, the Pakistani government declared a national emergency due to risks to food production from rainfall and renewed surges threatening the western part of the country (IHS Markit, 2020). To meet global food supply demands, crop production must adapt. By 2050, the demand for food crops is expected to increase by 59% to 98%. Agricultural markets will need to evolve, increasing crop production and expanding agricultural land through improved productivity and smart farming methods (Elferink & Schierhorn, 2016). Climate change significantly impacts crop production, stressing limited natural resources, especially for landless and poor small farmers. It remains one of the main unpredictable issues affecting food supply (Candid, 2007). In Malaysia, there is a focus on organic agriculture, which has long been implemented in the agricultural industry. Organic agriculture, often sourced from jungles or naturally grown, emphasizes food quality and environmental movements initiated by Non-Profit Organizations (NGOs). Awareness of high chemical inputs is crucial for alternative food sources (Partap, 2010). IoT combines wireless sensor networks with traditional methods to modernize agriculture. This network collects data from sensors and uploads it to a main server using a wireless system. Factors affecting productivity include insect and pest attacks, which can be mitigated through targeted insecticide and pesticide use. Crop yields can decline due to unpredictable weather, such as rainfall and improper water usage. IoT can help reduce labor force issues and climate change impacts, enabling farmers to take more accurate and efficient actions (Matin & Islam, 2012). This study aims to identify the STEEPV (Social, Technological, Economic, Environmental, Political, and Values) factors of IoT implementation in future farming and to develop future scenarios for the farming industry regarding IoT adoption.

## 2. Literature Review

### 2.1 Farming Industry in Malaysia

The agricultural sector is a vital component of Malaysia's economy, contributing between 7% and 12% to the national GDP and providing employment for 16% of the population (Yahya, 2010). Although Malaysia's share of global rubber and palm oil production has declined over the past two decades, the country continues to produce a variety of fruits and vegetables for the domestic market, including bananas, coconuts, durian, pineapples, and rice. The tropical climate of Peninsular Malaysia is particularly conducive to the cultivation of these exotic fruits and vegetables, as the region rarely experiences hurricanes or droughts (Zakaria & Rahim, 2014). The Centre for Environment, Technology, and Development Malaysia (CETDEM), an NGO, initiated an experiment to grow multiple organic vegetables and fruits on one acre of land. Within a few years, the produce from these farms reached supermarkets in Kuala Lumpur. The success of this experiment and the growing consumer demand for organic produce led to the establishment of the first organic shop in 1999 to serve the Klang Valley market. Private companies have also capitalized on this market by producing and supplying organic fertilizers to farmers (Hazell, 2010). The organic agriculture industry in Malaysia has seen significant growth, with the number of farmers increasing from 900 in 2010 to over 1,500 in 2012. By 2014, 1,700 hectares of farmland were classified as organic, producing various fruits and vegetables. The number of farms accredited by myOrganic has also increased over time (Ibrahim, Wahab, & Suhaimee, 2016). This growth is driven by rising consumer demand, both locally and internationally, for organic products. A study by MARDI in 2010 found that over 90% of Malaysian consumers were aware of organic products and associated them with being chemical-free, healthy, and natural. The study also revealed that 53.8% of consumers had consumed organic products at least once in six months, with vegetables being the most commonly consumed, followed by fruits, food supplements, and meat (Ibrahim *et al.*, 2016). The availability of organic products in supermarkets, wet markets, and specialized organic stores influences their consumption. Organic products are purchased by all ethnic groups in Malaysia, including Malays, Chinese, and Indians. Health concerns, NGO promotions, and the physical appearance of the products are key factors driving these purchases. Advances in technology have enabled farmers to produce high-quality organic products. The demand for organic products in Malaysia is projected to grow by more than 12.4% annually, with a financial value exceeding RM20 million per year (Ibrahim *et al.*, 2016).

### 2.2 Internet of Things (IoT)

The fundamental components of the Internet of Things (IoT) are devices that collect data. These internet-connected devices use IP addresses to ensure data is accurately gathered, processed, filtered, and analyzed. Data collection involves transmitting information from devices to a central point, which can be done wirelessly using various technologies or through wired networks. The data can then be sent over the internet to a data center or cloud with storage and computing power, or it can be staged through intermediary devices that aggregate the data before forwarding it (Fruhlinger, 2020). Data processing typically occurs in data centers or the cloud, but for critical devices like shut-offs, the delay in sending data to a remote center can be problematic. In such cases, edge computing is utilized, where smart edge devices aggregate, analyze, and respond to data locally, reducing latency. These edge devices also have upstream connectivity to send data for further processing and storage (Fruhlinger, 2020). IoT solutions in agriculture aim to bridge the supply-demand gap by ensuring high yields, profitability, and environmental protection. This approach, known as precision farming, involves the optimal application of resources to achieve high crop yields and reduce operational costs. IoT technologies in farming include specialized equipment, wireless connectivity, software, and IT services. A Business Intelligence survey projected that the adoption of IoT devices in agriculture would reach 75 million by 2020, growing at an annual rate of 20%. Additionally, the global smart agriculture market size is expected to triple by 2025, reaching $15.3 billion, up from just over $5 billion in 2016 (Vinothini, 2020). Implementing the latest sensing and IoT technologies in farming practices can fundamentally transform traditional farming methods. The seamless integration of wireless sensors and IoT in smart farming can elevate agricultural practices to unprecedented levels. By adopting smart farming practices, IoT can address many traditional farming challenges, such as drought response, yield optimization, land suitability, irrigation, and pest control (Zhang *et al.*, 2018).

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## 2.3 Advantages of IoT in Farming Industry

Crop monitoring significantly reduces costs and provides valuable information on crop health, humidity, precipitation, temperature, and other parameters. This enables farmers to identify problems early and take appropriate actions. Sensors also help determine the optimal times for planting and harvesting crops (Kuprenko, 2019). IoT-based farming relies on data collected from field sensors to allocate resources efficiently, even down to individual plants (Digiteum Team, 2021). However, the high variety of data collected can make ensuring data collection frequency challenging, though it ultimately helps reduce resource costs (Chalimov, 2021). IoT benefits farmers by simplifying their tasks. Sensors can collect data on rainfall, humidity, temperature, soil content, and other factors, automating many farming techniques (Kuprenko, 2019). Cost management and waste reduction are among the most significant advantages IoT offers to the farming industry. It helps detect inconsistencies and anomalies in crop production, control costs, reduce waste, and increase production (Dutta, 2021). Enhanced control over crop health monitoring can mitigate the risks of yield loss (Chalimov, 2021). Implementing IoT in future farming can reduce costs by optimizing resource use, such as water, energy, and land (Digiteum Team, 2021). Additionally, IoT sensors can detect unusual chemicals and toxins in crops, ensuring better quality produce for consumers (Sean, 2018). Data-driven agriculture, using soil and crop sensors, helps farmers understand crop conditions and quality better. Connected systems allow farmers to recreate optimal conditions, increasing the nutritional value of their products (Digiteum Team, 2021). This technology enables farmers to make effective decisions and achieve maximum production of healthy crops efficiently (Sean, 2018).

## 2.4 Disadvantages of IoT in Farming Industry

While IoT offers numerous benefits to farmers, it also presents several disadvantages. One major concern is the lack of security in IoT devices, especially when connected to older devices with internet access. These systems gather large quantities of data that are difficult to secure, making them vulnerable to hacking and data theft (Dane, 2020). As the number of connected devices increases and more information is shared, the risk of hackers stealing confidential information also rises. Despite security measures, IoT systems offer limited control and can be susceptible to various network attacks (Riyo, 2019). Another significant challenge is the dependence on connectivity and power. IoT devices require continuous power and internet connectivity to function properly, which can be problematic in developing countries where these resources are not consistently available. Slow internet connections can hinder the implementation of IoT, and any disruption in connectivity or power can render the devices and their connected systems inoperative (Borgini, 2021). Additionally, if there is a bug in the system, it can corrupt all connected devices. The cost of implementing IoT is also a major drawback. Transforming equipment to be compatible with IoT technology can be expensive, and the farming industry, which often operates on thin profit margins, may find it difficult to justify such investments. Even after acquiring the necessary machines, there is a risk that farmers might misuse them, leading to damage and high maintenance costs (Curry, 2016).

## 2.5 STEEPV Analysis

Social factors encompass the external environment reflecting society as a whole, including elements such as culture, demographics, lifestyle, health consciousness, age distribution, safety importance, and population rate (Nazarko & Kuźmicz, 2017). From the STEEPV analysis, high output performance and the replacement of human tasks are frequently highlighted by authors. According to Chandler (2021), IoT technology can enhance sustainable farming practices, improve crop yields, and optimize agricultural resource use. Transitioning from traditional agriculture to agrotech is essential to ensure global food access while minimizing time and labor requirements (Puzhevich, 2021). Implementing IoT in future farming can replace human tasks and increase farmers' output performance, leading to better field performance compared to traditional methods. However, further research and testing are necessary to confirm its future implementation. Technological factors, as noted by Nazarko and Kuźmicz (2017), include R&D activity, technology incentives, and the rate of technological change, all of which can affect costs, quality, and innovation. Meaningful data provision is a key factor emphasized by multiple authors. Sajoy (2021) mentioned that IoT enables farmers to obtain real-time information about crop health, weather conditions, and soil quality, helping them make informed decisions.

Environmental factors involve ecosystem elements such as wind, soil, food, and energy. Key terms related to the farming industry and IoT technology in future farming include minimizing waste and increasing productivity through efficient use of resources like water and electricity (Puzhevich, 2021). This approach promotes resource conservation and environmental sustainability. Economic factors pertain to individuals' capacity to obtain products or services under given economic conditions, including aspects like economic growth, interest rates, and exchange rates (Nazarko & Kuźmicz, 2017). Key economic issues include optimizing supply, maximizing cost efficiency, and increasing productivity. Suma (2021) highlighted the importance of cost-effectiveness in IoT devices, focusing on reducing hardware and software costs without compromising system precision. Political factors significantly influence the implementation of IoT in future farming. Government initiatives play a crucial role in this context. Value factors refer to lifestyle preferences related to work-life balance, quality of life, and social preferences. Pathak (2020) noted that IoT-based farming allows farmers to monitor field conditions remotely, offering greater efficiency compared to conventional farming methods.

**Table 1** *STEEPV analysis (issues, challenges, and trends)*

| Social | Technological | Environment | Economic | Political | Value |
|---|---|---|---|---|---|
| 1. Networking framework | 1. Replacing human task | 1. Provide meaningful data | 1. Maximizing the cost usage | 1. Government initiatives | 1. Improve quality of life |
| 2. Demand of humans increase | 2. Provide meaningful data | 2. Minimizing the waste | 2. Optimum the supply | 2. Government initiatives | 2. Improve quality of life |
| 3. New working ways | 3. Product increase | 3. Minimizing the waste | 3. Maximizing the cost usage | | 3. More quality time usage |
| 4. High output performance | 4. Connect the networking | 4. Reduce the harm of crops | 4. Optimum the margin | | 4. Real Time |
| 5. Replacing human task | 5. Provide meaningful data | 5. Maintain the quality of soil | 5. Maximizing productivity | | 5. More quality time usage |
| 6. High output performance | 6. Minimizing the waste | 6. Environment friendly (Put more) | 6. Maximizing productivity | | 6. Improve quality of life |
| 7. Product quality control | 7. Provide meaningful data | 7. Minimizing the waste | 7. Supply of crops increase | | 7. More quality time usage |
| 8. High output performance | 8. Provide meaningful data | 8. Control the climate | 8. High output performance | | 8. Improve quality of life |
| 9. Replacing human task | 9. Energy saving | | | | 9. New lifestyle |
| 10. High output performance | 10. High output performance | | | | |
| 11. Replacing human task | 11. Energy saving | | | | |
| 12. Replacing human task | 12. Provide meaningful data | | | | |
| | 13. Provide meaningful data | | | | |
| | 14. Minimizing the waste | | | | |
| | 15. High output performance | | | | |
| | 16. Efficiency increase | | | | |
| 12 | 16 | 8 | 8 | 2 | 9 |

The horizon scanning process has been completed to identify the emerging issues, challenges, and trends related to IoT in the farming industry, as summarized in Table 1. Through this process, the most significant drivers were identified by merging various issues, challenges, and trends. These drivers will be further explored by distributing questionnaires to relevant respondents within the farming industry. A total of ten drivers were generated by combining key terminologies related to the identified issues, challenges, and trends. These drivers were included in the data-gathering questionnaire. Table 2 consolidates and merges all issues related to the implementation of IoT in future farming. The combination of these factors forms the basis of the statements used in the survey questionnaire. The most common issues that past studies had highlighted were that IoT in farming industry have been a technology that provide meaningful data, giving high output performance, replacing human task and minimizing the waste.

**Table 2** *Merged issues, challenges, and trends*

| No. | Drivers | Combination of factors | Statement Code | Frequency |
|---|---|---|---|---|
| 1. | Provide meaningful data | Technological | T2, T5, T7, T8, T12, T13 | 6 |
| | | Environment | EN1 | 1 |
| 2. | High output performance | Social | S4, S6, S8, S10 | 4 |
| | | Technological | T10, T15 | 2 |
| | | Economic | EC8 | 1 |
| 3. | Replacing human task | Social | S5, S9, S11, S12 | 4 |
| | | Technological | T1 | 1 |
| 4. | Minimizing the waste | Technological | T6, T14 | 2 |
| | | Environment | EN2, EN3, EN7 | 3 |
| 5. | Improve quality of life | Value | V1, V2, V6, V8 | 4 |
| 6. | More quality time usage | Value | V3, V5, V7 | 3 |
| 7. | Maximizing productivity | Economic | EC5, EC6 | 2 |
| 8. | Maximizing the cost usage | Economic | EC1, EC3 | 2 |
| 9. | Energy saving | Technological | T9, T11 | 2 |
| 10. | Government initiatives | Political | P1, P2 | 2 |

## 3. Methodology

The social, technological, economic, environmental, political, and value (STEEPV) factors form the external context within which foresight operations are embedded and influenced. This study analyzes the drivers of future factors that influence and change the trend of IoT in farming activities using scenario building analysis. The unit of analysis, which is the entity being studied, is individual farmers in Malaysia (Dolma, 2010). This unit frames the critical thinking and planning of the research study and serves as the basis for data measurement (Neuman, 2014). Approximately 250,000 people work in the agriculture industry in Malaysia (Hirschmann, 2021). Based on Krejcie and Morgan's (1970) formula, the minimum sample size required for this study was 384. However, only 124 respondents successfully completed the survey, resulting in a response rate of 32.3%. The low response rate can be attributed to the Movement Control Order (MCO), which required many workers to spend time caring for crops affected by disease, reducing the workforce available in the field. All questionnaires were distributed using Google Forms. The sampling technique used in this study is convenience sampling, a non-random method that may not produce a representative sample of the population (Neuman, 2014). This technique was chosen to target farmers in Malaysia and distribute the Google Survey to them. To ensure the reliability of the questionnaire, a pilot study was conducted, and Cronbach's Alpha (α) was used to analyze the consistency of the questionnaire. The pilot study helped identify which questions needed to be rejected or maintained based on respondents' understanding. A Cronbach's Alpha value of less than 0.5 is considered unacceptable and indicates that the data cannot be used (Tavakol & Dennick, 2011). Conversely, a value closer to 1 indicates excellent data reliability. In the pilot testing, 30 sets of questionnaires were distributed, testing 10 questions each on Importance, Impact, and Uncertainty variables, totaling 30 questions. SPSS software was used to check the reliability of the questionnaire, with overall Cronbach's Alpha values of 0.903, 0.892, and 0.947 for Importance, Impact, and Uncertainty, respectively. Generally, a score above 0.7 is considered acceptable (Taber, 2016). Therefore, all items were retained for further analysis.

## 4. Results and Findings

### 4.1 Demographic Statistics

The demographic profile of 124 farmers from Batu Pahat, Johor, as presented in Table 3 reveals that the majority are male (74.2%) and predominantly aged between 21 and 50 years (66.2%). With a significant majority of male farmers (74.2%), there may be a need to encourage more female participation in the farming sector. The concentration of farmers aged between 21 and 50 years suggests a relatively young and potentially adaptable workforce, which could be beneficial for adopting new technologies and practices. Most respondents have completed secondary education (SPM, 44.4%) or hold a degree (33.1%). The high percentage of farmers with secondary education and bachelor degrees indicates a reasonably educated workforce, which is advantageous for understanding and implementing modern farming techniques, including IoT technologies. A significant portion of the farmers have less than 10 years of experience in the farming industry (62.1%), and the majority work as farm workers (71.0%). With farmers having less than 10 years of experience, there might be a need for more training and support to enhance their skills and knowledge in farming practices. The majority of respondents are farm workers, which highlights the importance of providing adequate training and resources to this group to ensure they can effectively contribute to and benefit from technological advancements in farming. Regarding IoT technology in farming, 48.4% are aware of its implementation, with sensors (66.9%), drones (66.1%), and connection systems (58.1%) being the most familiar technologies. Nearly half of the respondents are aware of IoT technology in farming, with sensors, drones, and connection systems being the most familiar. This indicates a growing interest and potential for integrating advanced technologies to improve farming efficiency and productivity. Many respondents lack extensive knowledge about the implementation of IoT in the farming industry. However, drones and connection systems are more familiar to them due to their presence in daily life. Drones are widely recognized for their ease of use in monitoring farm conditions and are well-known in the public sphere. Similarly, various types of sensors, which can detect conditions such as humidity and weather, are also familiar to respondents. On the other hand, IoT software is less familiar because it requires more specialized knowledge and a connection system for implementation in the farming industry.

**Table 3** *Demographic profiles of respondents*

| Demography | Item | Frequency (n=124) | Percent (%) |
|---|---|---|---|
| Gender | Female | 32 | 25.8 |
| | Male | 92 | 74.2 |
| Age | 20 & below | 2 | 1.6 |
| | 21~30 | 40 | 32.3 |
| | 31~40 | 6 | 4.8 |

| | | | |
|---|---|---|---|
| | 41~50 | 42 | 33.9 |
| | 51~60 | 28 | 22.6 |
| | 61 & above | 6 | 4.8 |
| Education level | PMR | 6 | 0.8 |
| | SPM | 55 | 44.4 |
| | Diploma | 14 | 11.3 |
| | Degree | 41 | 33.1 |
| | Master | 4 | 3.2 |
| | PHD | 4 | 3.2 |
| Working experience in farming industry | Below 10 Years | 77 | 62.1 |
| | 11~20 Years | 18 | 14.5 |
| | 21~30 Years | 21 | 16.9 |
| | 31~40 Years | 8 | 6.5 |
| Current Position in farming industry | Owner of the farm | 16 | 12.9 |
| | Share holder of farm | 14 | 11.3 |
| | Intern | 5 | 4.0 |
| | Workers | 89 | 71.0 |
| Do you know any IoT technology implementation in farming? | Yes | 60 | 48.4 |
| | No | 31 | 25.0 |
| | Maybe | 33 | 26.6 |
| Which IoT technology that you familiar with? | Automated irrigation system | 1 | 0.8 |
| | Connection System | 72 | 58.1 |
| | Drone | 82 | 66.1 |
| | Sensor | 83 | 66.9 |
| | Software | 50 | 40.3 |
| | None | 4 | 3.2 |

## 4.2 Impact-Uncertainty Analysis

Cronbach's Alpha value for Importance is 0.868, for Impact is 0.841 while for Uncertainty is 0.914. These α values surpass 0.7 which means the items are reliable and represent the variable. Table 4 exhibits the mean scores of importance variables. All of the items were re-coded with a new code according to the highest mean scores of importance. The mean values obtained from SPSS is based on respondents votes in the manner of consent by agreeing on the importance drivers that could illustrate the future for the industry. The top six leading drivers were selected to be based line in the next analysis which is the descriptive for impact and uncertainty variables.

**Table 4** *Mean score of importance*

| Code | Issues, Challenges, and Trends | Mean | New Code |
|---|---|---|---|
| IM1 | IoT provides meaningful farming data to help farmer (PH value, climate change, soil humidity) | 4.75 | D1 |
| IM2 | IoT helps the farmer to gain higher output performance of the farming activities. | 4.61 | D6 |
| IM3 | IoT reduces the use of labour force by replacing human task in some farming activities. | 4.61 | D7 |
| IM4 | IoT helps minimizing the waste of the resources and crops. | 4.65 | D4 |
| IM5 | IoT helps to improve the quality of life of the farmer. | 4.62 | D5 |
| IM6 | IoT gives the farmer resourceful time in managing the farm. | 4.71 | D2 |
| IM7 | IoT helps the farmer to increase the crops production. | 4.71 | D3 |
| IM8 | IoT helps farmer to maximize the profit margin. | 4.57 | D9 |
| IM9 | IoT helps the farmer to minimize the energy consumption (fuel, electricity) | 4.60 | D8 |
| IM10 | IoT implementation in farming industry can be promoted with Government initiatives. | 4.53 | D10 |

The most importance items are IM1- IoT provides meaningful farming data to help farmer; IM6- IoT gives the farmer resourceful time in managing the farm; IM7- IoT helps the farmer to increase the crops production; IM4- IoT helps minimizing the waste of the resources and crops; and IM5- IoT helps to improve the quality of life of the farmer. The most critical issue, challenge, and trend in the importance of IoT in farming is its ability to provide meaningful data. Traditionally, farmers rely on their experience and studies to detect issues, but IoT offers precise, data-driven insights. Secondly, IoT technology saves farmers valuable time in managing their

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farms, allowing them to focus on other activities. Additionally, IoT helps increase crop production to meet the growing consumer demand driven by population growth. By minimizing resource and crop waste, IoT enhances farmers' profitability. Lastly, IoT improves farmers' quality of life, giving them more time to explore new species and technologies. These five most important drivers were arranged in descending order as shown in Table 5. The data in Table 5 were used to formulate impact-uncertainty analysis to find the two top drivers with the highest importance outcome on impact and uncertainty in the future possibility. The result of the analysis was presented in Figure 1.

**Table 5** *Mean score of impact and uncertainty according to 5 most importance*

| Code | Drivers | Issues, Challenges, and Trends | Mean | |
|---|---|---|---|---|
| | | | Uncertainty (X-axis) | Impact (Y-axis) |
| D1 | Provide meaningful data | IoT provides meaningful farming data to help farmer (PH Value, Climate Change, Soil Humidity, etc.). | 4.63 | 4.78 |
| D2 | More quality time usage | IoT gives the farmer resourceful time in managing the farm. | 4.58 | 4.67 |
| D3 | Maximizing productivity | IoT helps the farmer to increase the crops production. | 4.58 | 4.75 |
| D4 | Minimizing the waste | IoT helps minimizing the waste of the resources and crops. | 4.63 | 4.65 |
| D5 | Improve quality of life | IoT helps to improve the quality of life of the farmer. | 4.53 | 4.76 |

The outcome of the study was shown in Figure 1. The top two drivers will be selected with high impact and uncertainty. The D1 (4.63, 4.78) and D3 (4.58, 4.75) coordinates were chosen as D1 is the highest impact while D3 is the most uncertain. It describes two leading drivers of provide meaningful data and maximizing productivity as "IoT provides meaningful farming data to help farmer (PH Value, Climate Change, Soil Humidity, etc.)" and "IoT helps the farmer to increase the crops production". Therefore, these two drivers lead to adoption in future farming have been identified that related to provide meaningful data and increase productivity as the top drivers and would be used to create scenarios building analysis.

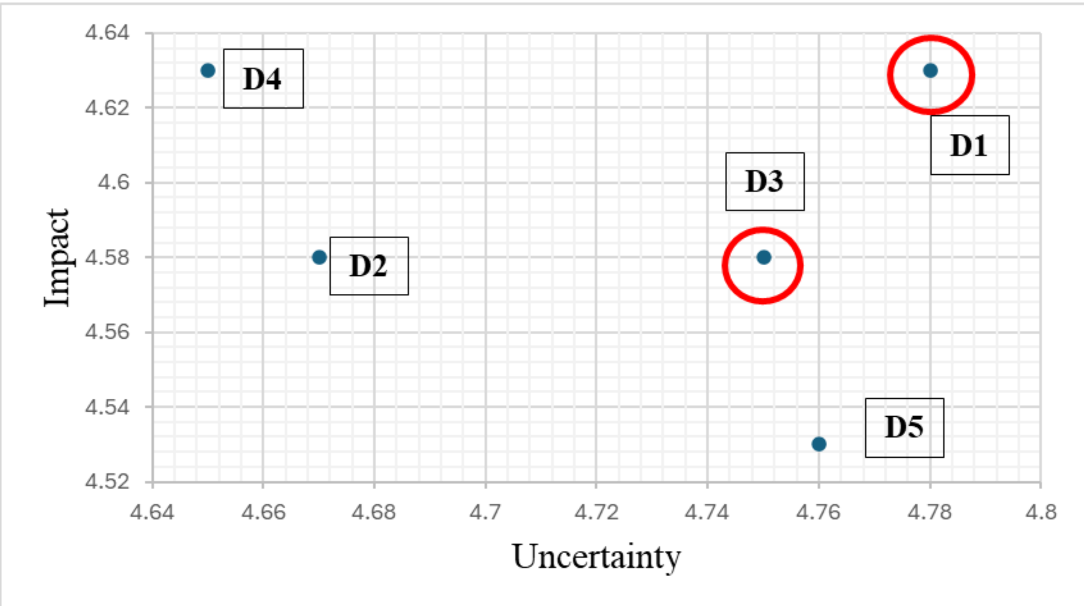


**Fig. 1** *Impact-uncertainty analysis*

## 5. Conclusion

The study identified IoT's provision of meaningful farming data as the top driver, ranking it among the five highest in terms of importance, impact, and uncertainty. It scored 4.63 for uncertainty and 4.78 for impact, out of a total of 5.00. Respondents viewed IoT technology as highly impactful due to its potential to provide predictive insights into farming outcomes, such as yield and feed intake models, drive real-time operational decisions, and transform business processes for faster, innovative actions (Wolfert *et al.*, 2017). The implementation of IoT in future farming is crucial for providing farmers with meaningful data, enabling them to monitor crop fields and take accurate actions based on the data provided (Chalimov, 2021). IoT technologies, such as sensors, can deliver real-time information on soil quality, crop health, and other critical factors (Sajoy, 2021). This real-time data collection allows farmers to address issues promptly, even when they are not physically present in the field, thereby preventing the spread of diseases through immediate action (IoT Solutions World Congress, 2019). Meaningful data from IoT helps farmers make informed decisions, significantly reducing the risk of crop failure, especially for those new to the farming industry. IoT supports detailed and accurate decision-making, which is particularly beneficial for inexperienced farmers who might otherwise make incorrect decisions leading to failure. Thus, IoT technology offers substantial advantages by providing critical data that enhances farming efficiency and productivity. The second driver, "Maximizing productivity," emerged as one of the top five drivers in terms of importance and ranked second in impact and uncertainty. It scored 4.58 for uncertainty and 4.67 for impact, out of a possible 5.00. IoT technology enhances productivity by optimizing fertilizer use and leveraging predictive analytics to improve crop yields and reduce failures (Puzhevich, 2021). This technology boosts farming efficiency and innovation by providing real-time data, enabling timely and accurate actions to minimize crop failures and disease spread, thereby increasing crop production to meet consumer demand (Graticola, 2020; Myler, 2015).

Farmers need to maximize productivity to achieve higher revenue, especially given the rapidly increasing population. IoT supports this goal by enhancing crop productivity and profitability. The second objective of this research is to develop scenarios for implementing IoT in future farming. Understanding the issues and drivers is fundamental to identifying factors that will shape future farming practices. Two main drivers, selected based on their impact and uncertainty, were identified from a total of ten drivers. These drivers will help study the future scenarios of IoT implementation in farming, focusing on issues, challenges, and trends. The research aims to recognize trends that will influence the future of IoT in farming by selecting the top two drivers with the highest impact and uncertainty. From these drivers, four future scenarios will be generated, each representing different possibilities over a 10 to 15-year horizon, from 2021 to 2036. These scenarios, illustrated in Figure 2, are divided into quadrants based on the highest impact and highest uncertainty. Each predicted scenario will be discussed in detail.

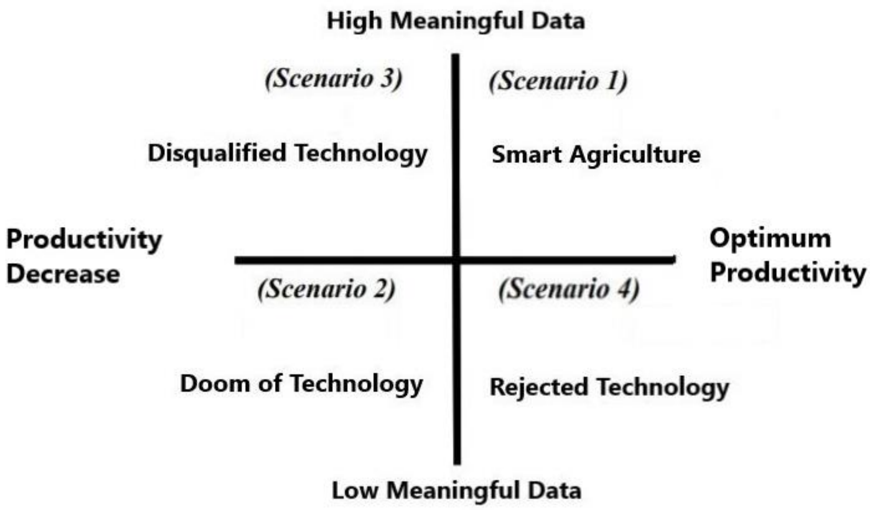


**Fig. 2** *Future scenarios analysis*

*Scenario 1: Smart Agriculture*

In the first scenario, "Smart Agriculture," the implementation of IoT in future farming achieves high levels of meaningful data provision and increased crop production. As the global population continues to grow rapidly, ensuring an adequate food supply becomes a critical focus. There is a strong interrelation between these two aspects, which enhances the implementation of IoT in future farming. By integrating IoT, crop production can be increased to meet rising demand. The meaningful data provided by IoT enables farmers to take accurate and timely actions, further enhancing future farming practices. In general, effective crop production requires farmers to take precise actions based on accurate data. When IoT provides meaningful and accurate information about pests and pesticide levels, farmers can act promptly to minimize crop damage and maintain production levels. IoT applications in farming aim to address the issue of increasing demand by reducing production losses. IoT technologies, such as sensors and drones, are used to collect data for monitoring and learning about crops. According to Cropin (2020), IoT provides farmers with data that allows them to increase crop production efficiently. Meola (2021) notes that IoT sensors placed in fields help farmers detect climate changes and predict weather patterns in the coming hours, days, or weeks. This capability is highly beneficial for farmers implementing IoT in their operations. The “Smart Agriculture” scenario represents an ideal future farming industry that is significantly more advanced than traditional farming. With the support of data provided by IoT, the industry can focus on increasing crop production, benefiting farmers. This scenario aligns with the goal of providing meaningful data and increasing crop production through IoT implementation. By closing the supply-demand gap, IoT helps farmers increase production, profitability, and environmental protection. This approach enables farmers to produce higher yields with optimal resource use and reduced operational costs (IoT Solutions World Congress, 2019). For Malaysia, this scenario offers substantial benefits, strengthening the country’s position in the global agricultural market. Primary crops, which are staple foods for more than half the world’s population, will be in high demand and of great importance.

*Scenario 2: Doom of Technology*

The “Doom of Technology” scenario represents a situation where the implementation of IoT in future farming results in low-quality data and reduced crop production. This scenario is considered the worst-case scenario for future farming, as it combines low-value data with declining crop yields, leading to an ineffective and inefficient agricultural industry. In this scenario, new technology fails to improve or support the industry’s issues, challenges, and trends. The agricultural industry, which plays a crucial role in providing food and raw materials, is often regarded as the backbone of a country’s economic system (Dane, 2020). When the “Doom of Technology” scenario occurs, it poses a significant challenge to the future farming industry. Accurate and meaningful data are essential for developing IoT technology. Without it, the industry struggles to achieve high crop production and instead maintains low production levels due to the failure of technology to provide valuable insights. In this scenario, the agricultural industry hesitates to adopt new technologies, resulting in stagnation and inefficiency. IoT has the potential to enhance crop production by minimizing losses and increasing profitability for farmers (Sajoy, 2021). However, in the “Doom of Technology” scenario, Malaysia has already experienced the negative impacts of low technological support in farming. Historically, low crop productivity was exacerbated by the inability to transfer knowledge effectively from one generation to the next. To avoid this scenario, farmers must take immediate action to integrate IoT effectively and improve their farming practices.

*Scenario 3: Disqualified Technology*

The “Disqualified Technology” scenario envisions a future where IoT implementation in farming provides highly accurate and meaningful data, but crop production remains low. This scenario highlights an industry striving for improvement but failing to increase crop yields despite the availability of precise data. Consequently, farmers’ economic conditions deteriorate due to stagnant crop production. A lack of technological knowledge among farmers can lead to ineffective use of IoT data, causing them to lose confidence in IoT’s potential benefits for farming. The agricultural industry, crucial for economic growth and food production, must substantially advance over the next decade. Technological advancements, such as sensors and IoT networks, offer significant benefits, particularly in daily farm operations. However, without proper implementation and understanding, these technologies cannot enhance crop production. Farmers must not only adopt IoT technology but also learn to use it effectively to take appropriate actions in the field. If farmers fail to utilize the data correctly, IoT technology will be deemed ineffective, as it does not contribute to improved crop yields. Despite this, the industry must continue to strive for improvement by sharing knowledge and skills related to IoT implementation in farming. In this scenario, the agricultural industry lacks confidence in continuing with IoT technology unless the issue of low crop production is resolved. Although IoT can monitor crop conditions and provide data on optimal pesticide and fertilizer use (Chalimov, 2021), the technology is rendered ineffective if crop production does not increase. According to Tijani (1993), low education levels discourage farmers from adopting new technologies like IoT, making it difficult for them to understand and use the data provided. To address this scenario, government intervention is necessary to support farmers in acquiring the knowledge needed to effectively use IoT technology, thereby improving crop production and ensuring the industry’s growth.

*Scenario 4: Rejected Technology*

The “Rejected Technology” scenario envisions a future where IoT implementation in farming results in low-quality data, yet crop production remains high. Despite IoT technology’s inability to provide accurate data, crop yields continue to increase to meet consumer demand. This scenario highlights the failure of IoT to assist farmers effectively, leading them to rely on traditional farming methods. In this scenario, the low-quality data provided by IoT applications fails to offer valuable insights, causing farmers to lose confidence in the technology. Human errors and climate change further exacerbate the issue, as unpredictable conditions affect sensor functionality, leading to inaccurate data and ineffective actions. Consequently, farmers may reject IoT technology, believing they can achieve high crop production without it. However, this scenario can be improved if the industry becomes aware of the benefits of IoT and takes steps to enhance data accuracy and utility. If IoT data quality does not improve over time, farmers will likely continue to reject the technology. This scenario is particularly relevant to Malaysia, where farmers often rely on their experience rather than low-quality IoT data to manage risks and solve problems. To transition from this scenario to a more favourable one, such as "Smart Agriculture," the government and NGOs must collaborate to improve IoT data quality and support farmers in adopting and effectively using IoT technology. This collaboration can help Malaysia achieve optimal crop production and stand strong in the global agricultural market over the next 10 to 15 years.

The current advancements in IoT technology have the potential to significantly propel the farming industry forward. This study offers recommendations for future research on the implementation of IoT in agriculture. As IoT technology continues to spread globally, it is poised to meet the increasing market demand for enhanced crop production. Although IoT technology in farming is not yet perfect, this study provides valuable recommendations for both industry practitioners and future researchers. Farmers and industry stakeholders should develop strategic plans to transition from traditional farming methods to IoT-based practices. This research aimed to identify the issues, challenges, and trends associated with IoT implementation in future farming and to develop scenarios for its application. The selection of respondents was crucial, as their perceptions of impact and uncertainty significantly influenced the study's results. Future researchers should ensure a more representative sample by including respondents from diverse locations and considering cultural and personal backgrounds to accurately capture views on the future prospects of the farming industry. IoT technology can provide meaningful data to increase crop production, reduce waste, and minimize crop damage. The study identified four potential scenarios based on two main drivers: the meaningfulness of data and crop production levels. These scenarios have both positive and negative implications for the future development of IoT in farming. The industry must develop contingency plans to mitigate negative outcomes and continue advancing IoT technology. In conclusion, the implementation of IoT in future farming could lead to the realization of four distinct scenarios, each with its own set of implications. Developers and industry stakeholders should formulate contingency plans to address potential negative impacts based on scenario analyses, ensuring the continuous development and adoption of IoT technology in agriculture.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contribution to the paper as follows:* ***study conception and design:*** *Tan, Ahmad;* ***data collection:*** *Tan;* ***analysis and interpretation of results:*** *Tan, Ahmad, Shafi;* ***draft manuscript preparation:*** *Ahmad, Shafi. All authors reviewed the results and approved the final version of the manuscript.*

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