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Exploration of the Challenges in Adopting Smart Farming Among Smallholder Farmers: A Qualitative Study

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ABSTRACT

Applications of smart farming have been introduced as a way out of various production issues in the agriculture sector, especially during the occurrence of COVID-19. Several technical studies have also been done to develop the modules that meet the operational requirements in Malaysia and determine their benefits and impacts on farmers. Despite the availability of smart farming technologies and their benefits to farmers' productivity and profitability, adoption of smart farming among Malaysian farmers, especially in rural areas, remains a challenge. Therefore, a qualitative study among farmers in Sarawak and Sabah was conducted to determine the challenges that arise with the adoption of smart farming technologies. The results highlighted that farmer faced challenges in regard to the high startup cost of technology, lack of expertise and knowledge on technologies, connectivity and access in rural areas, farm size, and governmental support. In practice, this study also discussed the challenges of adopting smart farming mentioned by participants and some possible solutions for future attention.

1. Introduction

Recently, smart farming has been a popular concept to explore among the diverse layers of the community. Smart farming refers to the application of different technologies in the agriculture sector that are linked to the current Fourth Industrial Revolution, or Industry 4.0 [1]. In general, smart farming is based on the integration of digital technologies with sensors and farm equipment, enabling the management of farm operations to be data-driven and data-enabled [2,3]. It emerged as a

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revolutionary technology for the agrifood sector that intends to meet the needs and characteristics of different agrifood production and distribution methods [4]. It can be divided into many categories and integrated with many technologies. Some of the key trends in smart farming included the use of drones for monitoring and crop maintenance activities, the Internet of Things (IoT), machine learning, sensors or actuators, automation, imagery, artificial intelligence (AI), block chain, computer vision, and big data [5,6].

In Malaysia, the application of smart farming in the agricultural industry is still in its initial development phase and has not been thoroughly applied [5,7,8]. However, special attention has been given to the major crops in Malaysia, i.e., oil palm and paddy, to modernize the production operations of these crops through smart farming. To date, there have been several publications related to the application of technologies such as drones, remote sensing, IoT, machine learning, and variable rate technologies (VRT) that support the adoption of smart farming in oil palm and paddy fields [8,9]. The real-time data collected through these technologies allows operators to have appropriate monitoring of the plantation and enable them to manage their plantation's daily operations efficiently, such as pruning, fertilizers, harvesting, and health management, so that yield can be improved, input costs can be minimized, and resources can be optimized [10]. Introducing the application of smart farming to farmers will definitely help farmers in various farming operations issues to increase crop production [11], and this is not only for major crops but also other potential crops in Malaysia.

This insight into smart farming applications had also been actively brought forward by the government during the COVID-19 pandemic as a way out of the various production issues in the agriculture industry of Malaysia. The common issue during that time was the shortage of labour, especially in the oil palm sector. As Malaysia's agriculture sector, especially in plantations is heavily dependent on foreign labour, the MCO that occurred has negatively affected the labour market and the entry of foreign workers, resulting in a labour shortage [12,13]. The pandemic also caused interference in the international trade of agri-food products, and food security has become a concern because Malaysia heavily relies on imported food supplies, such as rice, wheat, vegetables, and fruits [14]. The disruption in logistics and transportation during the period also troubled farmers in marketing their products, causing a high level of post-harvest loss (PHL) and waste as the products are perishable. So here comes the initiative to promote the use of smart farming and digital technology in Malaysia, not only in the agriculture industry but also in other disruptive sectors. For instance, the deployment of IoT in farms, is considered the ideal solution to the problems faced by farmers in a way that lowers input costs while increasing productivity [15]. The main applications of Precision Farming and Greenhouses Monitoring with the usage of different IoT-based sensors and devices, using wireless sensor networks (WSNs), enables farmers to monitor environmental conditions and crop productivity and then collect relevant data about their crops for better decision-making [16]. The most common uses of IoT in Malaysia's agriculture industry are IoT-based fertigation systems and IoT-based hydroponic systems, which enable farmers to monitor and control their farm operations through an application installed on their smartphone or computer. Other examples of smart farming applications are use of drones for remote sensing and spraying, and the digital marketing of products using e-commerce platforms. It can also be seen that the recent COVID-19 has become a catalyst for the application of smart farming and digital transformation [17].

Other than that, technical studies have also been done on the mechanical and agronomic components of smart farming in order to determine their ability to meet the operational requirements of agriculture in Malaysia. However, despite the availability of developed smart farming technologies and their benefits to farm productivity and efficiency, the adoption of smart farming by farmers in Malaysia, especially in rural areas, remains a challenge. These challenges can

come from aspects of finances, authorities, accessibility, and knowledge of farmers to adopting and maintaining the smart farming technologies [18]. Hence, a non-technical study is necessary to understand farmers' end-user perspective on smart farming, such as their factors and challenges in adopting smart farming on their farm, which can be a reference for related bodies for future assistance. Although there have been previous studies [19,20] on the factors of adoption, there have been few social studies conducted on the challenges of adopting smart farming in Malaysia, especially among farmers in the states of Sarawak and Sabah. Despite their location, which is seen as disadvantageous for development, Sarawak and Sabah are among the main contributors to Malaysia's agricultural sector [21].

This research aims to fill the gap in the scientific literature by understanding the challenges faced by farmers towards the adoption of smart farming, particularly in Sarawak and Sabah. The findings of this research hope to be important for the government, policymakers, researchers, educators, agricultural extension workers, and other related bodies to improve, supply, and promote technology transformation in Sarawak and Sabah. Therefore, this study is conducted to explore the challenges in adopting smart farming technologies among smallholder farmers using a qualitative method.

2. Methodology

To highlight the challenges that farmers are facing with regard to the adoption of smart farming, a qualitative research method is utilized. As a research method, it can provide insights and understanding of human behaviour, experiences, conceptualizations, intentions, motivations, and perceptions of a phenomenon, on the basis of observation and interpretation [22]. The qualitative data was collected using in-depth semi-structured interviews that were conducted in Bahasa, or the local dialect, for participants' convenience. A semi-structured research question provided an open-ended nature, encouraging conversation and allowing participants to give their own account of a phenomenon, so that there are fewer restrictions on the findings that can be found out about [23].

This study was focused on Sarawak and Sabah, as both states were among the highest contributors to the gross output value for Malaysia's agriculture sector in 2021, with Sarawak contributing 30.2 percent and Sabah contributing 20.3 percent [21]. Hence, understanding the challenges of adopting smart farming among farmers in Sarawak and Sabah could be a positive measure in leading the agriculture technology transformation as part of both states' digital transformation strategies [24,25]. Sampling was done using random and convenience strategies among local farmers in Sarawak and Sabah. The procedure involved locating convenient participants who meet the required criteria and are willing to participate until the required sample size is achieved [26]. Following Guest *et al*., [27], a sample size of 12 participants was interviewed to reach data saturation. All interviews were recorded with consent, then transcribed and translated into English for analysis. For this study, thematic analysis following procedures by Creswell [28] is done until themes of similar meaning related to the farmers' challenges to adopt smart farming are highlighted.

3. Results

The following outline presents the findings of the interviews on farmers' challenges towards adopting smart farming, with direct quotes for reference.

3.1 Theme 1: High Startup Cost

When asked about their main challenge in adopting smart farming on farms, most of the participants acknowledged the high cost required to invest in the smart farming technologies:

i. *Definitely cost. When I started here, my capital around RM20,000 for the IoT-based fertigation and hydroponic system, then rent of greenhouses and inputs (Yuan)*

ii. *To apply smart farming (IoT) itself requires a huge cost, not only for the system but also for other components to ensure the system runs smoothly. Like my farm, the electricity is not stable yet, and I thought of using a solar system, but it costs quite a lot (Yazid)*

iii. *Farmers will need the technology, and to purchase the technology requires capital. For starters, they don't have huge capital (Azizul)*

iv. *The main challenge is capital, really need a high cost to purchase the equipment, and I don't think to invest there yet (Mahadi)*

v. *High cost. For me, I'm unable to invest to the usage of these new technologies yet. All the operations can still do manually (Oji)*

vi. *High cost to buy the technology. Looking at my current economy, I don't think I'm able to invest in technology yet (Azam)*

vii. *Because we want to buy technology or machines, it requires money. And their cost is not cheap unless we build them ourselves (Hamdan)*

Other than the cost of buying the technology itself, the cost of transporting the equipment to Sarawak and Sabah was also a challenge because the equipment needed to be brought in from the Peninsular. Some of the participants mentioned that the delivery cost to bring the equipment to their location is high as the products are not available locally:

i. *The cost of hardware is also a challenge because our structures are from Kuala Lumpur and brought here through cargo (Irfan)*

ii. *Self-capital is also important because if we want to hire a local contractor or supplier, it will be expensive. The price difference between here and Peninsular is obvious. I've asked the price of an IoT system from local supplier, it reached thousands, not yet the installing and maintaining cost (Izzat)*

iii. *To adopt smart farming requires huge capital, not only to buy the hardware but also to bring it here and do all the maintenance (Jamhari)*

iv. *The main challenge is cost, to buy the components and bring them here requires huge costs (Muhammad)*

3.2 Theme 2: Lack of Expertise and Knowledge on Technologies

Implementation of smart farming required not only agriculture knowledge but also knowledge and skills to operate the new technology to ensure the systems operated smoothly and increased productivity on the farm. Lack of knowledge and skills will make it inconvenient to handle the technologies. Four of the participants agreed that a lack of expertise and skilled workers was a challenge to adopting smart farming:

i. *IoT is provided here, but most farmers haven't used it because there's inaccuracy in the data on the system and inside greenhouses, but the system can still be used. We need to adjust the reading ourselves. That's why the user or farmer needs to be educated, have skills in IT and computers (Yuan)*

ii. *The main challenge is the expertise and knowledge of members here and myself to operate the system optimally to produce the products that we want (Irfan)*

iii. *We need someone who has the skills and expertise to handle that technology. That's why we need more human capital to go on internships so that we can supply them anywhere, become competent, understand, and know the latest technologies (Azizul)*

iv. *To fully adopt smart farming, or IoT, we need expertise and knowledge. Our own expertise if we build it ourselves and someone who knows coding, to inspect points that important in the system's operation (Izzat)*

In addition, the existence of a place, particularly a smart farm, which fully adopts smart farming in farm operations is needed so farmers can have a way to gain direct knowledge and experience handling smart farming technologies. One participant added that an example of a smart farm is needed so farmers can have direct sources of information on smart farming applications:

i. *We need an example of a smart farm as a place for farmers to study and gain knowledge, but there's no one here yet. That's why I want to create one so that people can come to study (Azizul)*

3.3 Theme 3: Connectivity and Access in Rural Areas

Most of the farming areas in Sarawak and Sabah are located in rural areas, where Internet connections and sometimes phone coverage are still developing. This network problem becomes a constraint for farmers to implement smart farming like IoT, as cloud-based computing requires good network performance and speed. Three of the participants stated that Internet coverage at their farm location is a challenge:

i. *Sometimes the Internet connection at my farm is not strong. I am still searching for a suitable mobile plan that has good coverage here (Yazid)*

ii. *Internet and electricity are also problems here because they've only been installed for the past 5 years. Even phone coverage is sometimes not available (Irfan)*

iii. *Internet coverage on my farm is also poor, as my farm is in an oil palm estate area (Jamhari)*

iv. *Internet coverage in this area still poor, only at night a bit fast. Electricity and water supply also haven't been installed here, although there's already electric poles and meter. Currently, we use solar energy to power the fan and charging phones (Oji)*

Beside the Internet coverage, other undeveloped infrastructures such as roads, electricity, and water supply in rural areas also pose challenges. Three of the participants indicated that other infrastructure in their farm's area needs to be improved to facilitate the use of technologies:

i. *Electricity and infrastructure in these areas still need to be improved (Azizul)*

The Internet coverage is good, but there's no electricity or water supply yet. There are electric poles already, but they can't be used yet. The road here has also just been constructed but hasn't made it to the end, to my farm (Fathi)

i. *Infrastructure, especially road access to my farm, is also not good to bring the machine in (Muhammad)*

3.4 Theme 4: Farm Size

Concerning the farm's conditions, two of the participants elaborated that their farm size is not suitable to use technologies yet because all the farm operations can still be done manually:

i. *For now, I'm just using the platform to track my plants' data, but not for precision yet because my farm is still small. I'm focusing on increasing product quality first, then farm size, and maybe using full IoT (Izzat)*

ii. *The farm size is also small, and all operations can still be done manually. I prepared the land and made drainage, still using human labour and a hoe (Azam)*

Other than that, the soil structure in Sarawak is mostly peat soil, and one participant explained that his farm's soil structure is not suitable to bring a machine in:

i. *The challenges are the peat soil structure, capital, and farm size. Not suitable to use technology or heavy machines. To bring the machine here is also a problem (Fathi)*

3.5 Theme 5: Government Support

The last but not least challenge is government support, as it's important in order to realize one's strategy so that there is no conflict. One of the participants mentioned this as a challenge to adopt smart farming:

i. *Efficiency and support from the government are important because the government has the ability to legalize these technologies (Azizul)*

Other than that, government support in terms of financial and physical resources is also necessary to aid farmers in adopting new technologies, especially among beginners. Providing knowledge in the form of courses, especially talking about smart farming or new technologies available in certain crop industries, and then providing funds or grant for farmers as a starting point can be approaches to promoting the adoption of smart farming among farmers. Two of the participants mentioned that there's no financial or knowledge support for smart farming yet available for farmers in their areas:

i. *In my area, there's no support yet for IoT. The Agriculture Department only provides support in the form of other structures such as greenhouses and a new hydroponic table (Izzat)*

ii. *Support from the government comes from aspects of finances and knowledge. I had knowledge of mechanization or new technologies in farming from colleagues or TV. There haven't been any courses exposed to us on the new technologies or smart farming yet (Fathi)*

4. Discussions

The results of this study have revealed challenges among farmers in Sarawak and Sabah in terms of adoption of smart farming, including the high startup cost, lack of expertise, connectivity and access in rural areas, farm size, and governmental support. Among these, the high cost of technology appears to be the most serious barrier for farmers, especially smallholders, to converting to smart farming. As stated by Lazim *et al.,* [11], huge financial investment is required to implement the new technology involving IR4.0, not only the initial cost to develop a module framework but also the transformative costs to adapt the technology. Deployment of smart farming, such as IoT, is divided into hardware and software costs, which involve the cost of system development, maintenance, and continuous subscription for usage of the central services or IoT platforms [15]. In *Theme 1*, a participant mentioned that his capital was at least RM20,000 when he started IoT-based fertigation and hydroponic systems at the Permanent Food Park (TKPM) Rampangi, where he participated. This cost is only for the hardware and inputs, as the IoT is equipped and rented within the farm that is managed by the Department of Agriculture (DOA). However, another participant stated that he has acquired information about the price of an IoT system from a local supplier, and it cost thousands, only for the system. While another participant mentioned that his friend in the Peninsular, who has implemented IoT on his farm, shared that the cost for one system, including hardware and software, reached a hundred thousand. Other than that, in terms of price itself, the difference between Peninsular Malaysia and East Malaysia is quite obvious. A participant mentioned that purchasing the devices from a local supplier in Sarawak or Sabah costs much more than from a supplier in Peninsular Malaysia. While purchasing directly from the Peninsular, farmer will have to deal with delivery fees, either by cargo ship or flight to Sarawak or Sabah, then from the ports to the farmer's locations. In some cases, the structures and hardware need to be purchased from the Peninsular because they're unavailable in Sarawak or Sabah. Nonetheless, most of the participants who haven't adopted smart farming or new technology, agreed that these costs are unaffordable for them to invest in. An initiative to bring down the cost of devices and systems was also a challenging issue because it involved multiple bodies from designing to developing them. Some participants bring forward the idea of developing themselves or DIYing the modules or systems, but this will require the farmer's own expertise, which is also a finding in this study.

According to Quy *et al.,* [29], a lack of knowledge and skills to handle new technologies among farmers is a significant factor slowing down the adoption of technologies in agriculture. This was conceded with responses from the participants that the lack of expertise among themselves and the workers involved is a challenge to fully adopt smart farming on the farm. Knowledge and technical skills are crucial when handling technologies, and it is more advantageous when farmers excel in both agriculture and ICT. Since the knowledge is already there, it's not possible for farmers to develop their own system or structures that are more economical in price and suitable for the climate conditions in Malaysia. As mentioned by some of the participants that had used IoT, the devices or systems they currently use are mostly from other countries, such as China, and because of the different climate factors, some adjustments need to be made to adapt the systems here smoothly. For this, farmers need to have essential knowledge and ICT skills to operate the technologies and stop relying on hired skilled workers in the long run. It can also save on the cost of hiring skilled workers on farms. This required farmers to gain knowledge not only theoretically in courses but also through exposure to the technology so they could gain direct experience handling the technology. However, compared to developed countries, farmers in developing countries, where the majority are in rural areas, have very limited access to new technologies [29]. Hence, as stated by a participant, the availability of an example smart farm that deploys smart farming and new technology is needed, where interested farmers can visit or come for training to gain direct knowledge and experience of smart farms. This can be a positive approach to the development of smart farming adoption, especially among farmers in rural areas.

Other than access to technologies, the construction of basic infrastructure must be facilitated to accommodate the transition of new technology, especially in rural areas [11]. The participants also indicated the need to improve infrastructure such as roads, electricity, and water supply in their areas. Access roads are particularly important for logistics and transportation purposes. It facilitates movement from rural to urban areas and vice versa. Farmers from rural areas can travel to urban areas to seek knowledge, assistance, purchase agricultural supplies, or market their products, whereas agricultural workers or related bodies can come to rural areas for extension services and assistance. Modern methods of agriculture and new practices such as hydroponics and aquaculture using solar panels instead of electricity can also be introduced to farmers to help improve their socio-economic situation, gradually leading to the application of new technology. Besides, the risk of damage to the fragile structure or hardware, such as a solar panel, during transportation can be avoided when the access road ahead is already smooth. However, another important thing for adopting new technology is Internet services, and in many rural areas, strong, reliable, and quality Internet access is not yet available [30]. This was also stated by some participants in this study, that Internet connectivity and sometimes mobile coverage in their areas are still not stable and limit their access to the Internet and communication. In some remote areas, the Internet coverage is only available at night and very slow or "services unavailable" during the daytime. It is a challenge for them to deploy technology like IoT because cloud computing and big data analytics require a strong Internet access and bandwidth speeds to operate smoothly [11]. Strengthening the Internet coverage in rural areas, where most of the industry players are, is necessary before any of the smart farming technologies can be successfully deployed.

In addition, some participants confessed that their small farm size is not suitable for the application of smart farming as daily operations can still be done manually. This challenge is related to the high startup cost of technology. From an economic aspect, one of the characteristics of new project investment is the low rate of profit in the early stages because of natural condition risks [29]. Farmers, who are mostly smallholders, are more inclined to the idea of producing more to profit more and then expanding their area for more profit rather than risking their investments for an

uncertain benefit-cost ratio. As a participant stated, he would focus on his farm product before expanding farm size and then considering the application of smart farming. In this case, research on crop deployment using smart farming technology should be carefully calculated to ensure a balance between implementation cost and potential profit [29]. Having a clear understanding of the costs and benefits of successful technology deployment over a period of time can attract interested farmers to invest in new technologies.

Undoubtedly, governmental intervention is important in realizing the adoption of smart farming among farmers. From the perspective of policymakers, researchers, educators, and agricultural extension providers, their roles are essential to legalizing, designing, trailing, and supplying knowledge on smart farming or new technologies to farmers, especially in rural areas. Conducting agricultural courses on smart farming technologies is necessary so farmers have knowledge of the new technologies that can be applied in their crop industry. An example of a smart farm or institution can also be built so farmers have more sources of information or a training centre that exposes them to the handling of new technologies such as IoT. In terms of financial, majority of the participants have mentioned the need for support from the government in the form of grants in order to realize the adoption of modern technologies among farmers. Most of the participants also acknowledged that they intended to adopt smart farming or modern technologies on their farm if the technologies were accessible to them, financially and physically. And all these forms of support or incentives by related institutions need to be informed or revealed to the farmers, especially in rural areas, so they're aware of available agriculture courses, incentives or support from the government. This is because most of the participants in this study revealed that they have no knowledge of any form of support from the local agriculture agencies, even some haven't ever joined any related agricultural courses. Last but not least, the high-cost technology needs to be focused on and constantly revised and optimized to reduce the cost so that it's possible for farmers to adopt smart farming on their farms.

5. Conclusions

Using a qualitative research approach, this study has highlighted the challenges farmers in Sarawak and Sabah face in adopting smart farming on their farms. Although the responses provided by farmers were not new, the objectives of this study have been achieved and presented. To promote the adoption of new technology, it is necessary to understand the difficulties and motivations farmers face in implementing these technologies. Besides, some solutions can also be heard from farmers' end-user perspectives, such as the availability of smart farm and exposure to the government support. These findings hope to be useful for related bodies, especially policymakers, agriculture agencies, researchers, and educators, to tackle these challenges through integration and cooperation. Future studies also need to be done to explore more about smart farming implementation in Malaysia, either technically or non-technically, not only on major crops but also other potential crops. For the transformation of technology in agriculture in Sarawak and Sabah, with the abundance of resources and proper management, it is not possible to make it happen.

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