Review Article

Adoption of IR4.0 in Agricultural Sector in Malaysia: Potential and Challenges

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Abstract: Agriculture remains as one of the most important economic sectors in Malaysia, which provides an employment for more than 1.6 million people. However, the growth of this sector can be hampered by a small-scale production, limited technological application, declining number of arable lands, environmental degradation due to climate change, rapid urbanization and aging farmers. In order to improve the competitiveness of agricultural sector, farmers are encouraged to fully utilize modern technologies in their farms. In this context, adoption of industrial revolution 4.0 (IR4.0) in an agricultural sector could offer many benefits, especially in minimizing the production costs and improving the quality of products. Thus, this review focuses on the adoption strategies of IR4.0 in an agricultural sector in Malaysia. A suitability of enabling technologies such as Internet of Things (IoT), autonomous robot, big data analytics and artificial intelligent. which are pillars for IR4.0 are individually evaluated. The readiness of the agricultural industry in Malaysia to embrace this new concept is also discussed. The review also investigates the potentials and possible challenges would be faced by the industry in embracing IR4.0. The recommendations are also targeted towards our fellow farmers, industrial players and policy makers to ensure a smooth adoption of IR4.0 in agricultural sector in Malaysia.

Keywords: agriculture; IR4.0; production; autonomous robot; Internet of Things (IoT); enabling technologies.

1. Introduction

Agriculture remains as one of the most important economic sectors in Malaysia, which provides an employment for more than 1.6 million people (Dardak, 2015). In 2017, this sector contributed around 8.2%, which was equivalent to RM 1.2 trillion (USD 314.5 billion) of national Gross Domestic Product (GDP), where oil palm (46.6%) and other agricultural produce (18.6%) as the main contributors (DOS, 2018). Agriculture is regarded as one of the most important components under the National Key Economic Areas (NKEA), due to its potential to accelerate economic growth by creating more job and increasing income for farmers. In the latest, 11th Malaysian Plan: 2016–2020, modernization and transformation of the agricultural sector is given a priority in order to guarantee food security, increase crop productivity, increase farm profitability, strengthen agro-food supply chain and enhance related support and delivery services for all stakeholders (Bujang & Bakar, 2019).

Generally, agricultural sector in Malaysia can be divided into two categories, namely: food crops and industrial crops (Ng, 2016). In one hand, food crops refer to the production of vegetables, fruits, tubers, and grain crops which are dominantly grown by smallholders. In another hand, industrial crops refer to the production of commodity crops like oil palm, rubber, tea and cocoa which are normally planted by large estates or companies.

Several national initiatives have been implemented to enhance the farm productivity by addressing issues such as volatile prices, unfavorable market outlook, threat of pests and diseases, sustainable use of fertilizers and pesticides and ageing farmers (Nordin, 2018). However, the agro-food sector in particular, facing structural and supply-side challenges due to scarcity of land, labour, input and capital (Ahmad & Suntharalingam, 2009). At the regional level, limiting factors for the growth of agricultural sector are contributed by a small-scale production, limited technological application, declining number of arable lands, scarcity of water resources, environmental degradation due to climate change, rapid urbanization and labour shortage (Dung & Hiep, 2017).

To overcome these problems, precision agriculture (PA) technique has been proposed to be implemented in the agricultural sector. PA is defined as an integrated, information and production-based farming systems, which could increase the efficiency, productivity and profitability, as well as reducing undesirable excessive chemical application that could negatively impact the environment, thus reducing profitability (Liaghat & Balasundram, 2010). Recently, due to the advancement of technology, while PA is implemented to measure in-field variability, smart farming concept is introduced, which goes beyond PA by management-based tasks, not only on location, but also on data, which have been enhanced by context, situation awareness and triggered by real-time events (Wolfert *et al*., 2014). Smart farming refers to the application of Internet of Things (IoT) and cloud computing technology to collect real-time data and connect sensors with smart machines so that farm management will be data-driven and data-enabled system (Sundmaeker *et al*., 2016). This real-time

intelligent assisting system is important feature to carry out farm operation, which is always subjected to abrupt environmental change due to unfavorable weather or disease. Figure 1 summarizes the concept of smart farming along the management cycle as a cyber-physical system (CPS), indicating that smart devices which are connected to the internet can control the farm system (Sung, 2018).
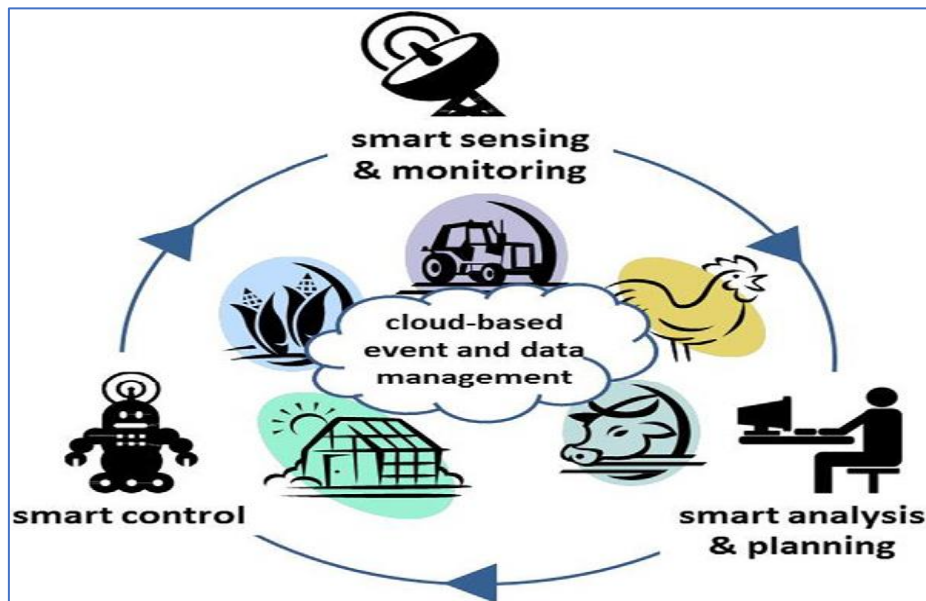

Figure 1. The cyber-physical environment for smart farming concept (Wolfert *et al.*, 2014).

The application of smart farming is in-line with the advent of industrial revolution 4.0 (IR4.0). Even though the revolution was meant for manufacturing sector, this revolution can also be adopted as a new approach into agricultural industry. In fact, agricultural industry has also undergone revolution in several stages. According to Dung and Hiep (2017), the first stage began in the early 20th century, is characterized by a low productivity and labor-intensive farming system. The second stage, which was known as the Green Revolution, is characterized by an efficient agronomic management practices with a higher yield potential and growing returns to scale at all levels. The third stage is characterized by farming industries with a higher efficiency and profitability, which enhanced the quality of the products. The fourth stage happened in parallel with similar evolution in the industrial world, which is pronounced as IR4.0. In terms of definition, agricultural revolution 4.0 (AR4.0) stands for the integrated internal — (within the farm) and external — (outside the farm, which includes suppliers, customers, service providers and *etc*.) networking related to a particular farming operation. This revolution will observe the digital information from all farm sectors to be electronically collected, processed, transmitted, analyzed and shared with all people involved in the supply chain.

Adoption of IR4.0 into agriculture could reduce the cost of crop inputs, increase the value of the products and sustain healthy environment. To realize these benefits, farmers are

encouraged to use modern and appropriate technologies, which are more economical and efficient than the conventional technologies. The selected technologies must be suitable with the climate, weather and soil conditions of the farm. The application of the technologies should also be able to ensure constant production without jeopardizing the biodiversity, environment, ecosystem and human health (Dung & Hiep, 2017). Thus, this paper aims to review the potential application of IR4.0 for sustainable agricultural development in Malaysia. This review provides a brief introduction to IR4.0, its enabling technologies, potential applications and challenges in adopting this revolution in Malaysia.

2. Technological Readiness for the Agricultural Industry in Malaysia

Paddy and oil palm are the major crops in Malaysia. Thus, the government and related industries have given a special attention to modernize and revolutionize the production systems of these crops. In order to increase the yield and farm efficiency, smart farming has been introduced to assist farmers in utilizing modern machinery and technologies in their farming activities. To date, due to the availability and affordability of the technologies, there are many studies have been published regarding the application of sensing and IoT technologies in supporting the adoption of smart farming either in paddy or in palm oil productions (Mekala & Viswanathan, 2017; Rajeswari *et al.,* 2017). The use of these technologies could allow several agricultural parameters to be monitored in order to improve the crop yield, reduce cost and optimize inputs such as environmental conditions, growth status, soil status irrigation, pest and fertilizers, weed management and greenhouse gas emission (Nukala *et al.,* 2016).

In the paddy production, several studies have been published regarding the adoption of smart farming in the development of spatial decision support system for efficient management of paddy farms. For example, Kamal and Amin (2010) developed a Geographical Information System (GIS), a user-interface technique for monitoring and scheduling daily crop water requirement for paddy. In terms of image sensing technology, Jamil and Bejo (2014) investigated the potential use of thermal imaging camera to differentiate between husk and seeds of paddy. Recently, an autonomous robot such as drone has been employed as a platform to carry imaging sensor to get an overall survey and view of the farming area (Tripicchio *et al.,* 2014). The latest application for smart farming in paddy crop management is developed by Athirah *et al.* (2020). In their study, the authors developed the mobile application known as Padi2U that have multiple features in one platform. This application contains aerial images, normalized difference vegetation index (NDVI) and red, green, blue (RGB) map as inputs. The map can be used by farmers to manage their paddy field according to good agricultural practices.

In the oil palm plantation, remote sensing is the core technology employed to support the adoption of smart farming. Remote sensing has been used in various applications including land cover classification, automatic tree counting, change detection, age estimation, above ground biomass estimation, carbon estimation, pest and disease detection and yield estimation (Chong *et al., 2017*). There are three main technologies used in remote sensing to obtain these data namely Global positioning systems (GPS), GIS and satellite images. In addition, light detection and ranging (LiDAR) sensors were also used in oil palm plantation to obtain geographic information and the soil elevation map (Shafri *et al., 2012*). Soil electrical conductivity (EC) mapping was also used in plantation area to obtain soil characteristics and properties including chemical and physical properties (Aimrun *et al., 2007*). Kalantar *et al.* (2017) applied unmanned aerial vehicle (UAV) as a platform for remote sensing application in taking stock of the number of palm trees. Another application of smart farming was proposed by Ishak *et al.* (2011) who developed intelligent system for automated weeding for oil palm plantation. Chong *et al.,* (2017) also applied multiple sensors to measure various temporal parameters such as age, breed, rainfall and soil fertility to estimate the yield for oil palm.

Based on the above evidence, it can be suggested that most of the technologies needed for IR4.0 are readily available and accessible by the industries. Thus, the industries would not face a major problem in adopting IR4.0. Their experiences in implementing smart farming technologies would provide a very good foundation to embrace IR4.0. Since IR4.0 is an extended version of smart farming, most of the sensors and data acquisition equipment which are used for smart farming can also be applied for the adoption of IR4.0. The most important thing for IR4.0 is how to make the sensors communicate among them under CPS.

3. Industrial Revolution 4.0 (IR 4.0)

IR4.0 refers to the convergence of artificial intelligence and data technology to provide a new solution to industrial and manufacturing problems across the globe, by integrating cyber and physical fields (Sung, 2018). The term IR4.0 is originated from industrial revolution, which begun with revolution 1 (invention of steam engine), revolution 2 (invention of electrical power), revolution 3 (invention of sensor and actuator) and revolution 4 (connectivity between sensors through CPS) (Kagermann *et al.*, 2013). Figure 2 shows the progress of industrial revolution from revolution 1 to revolution 4.
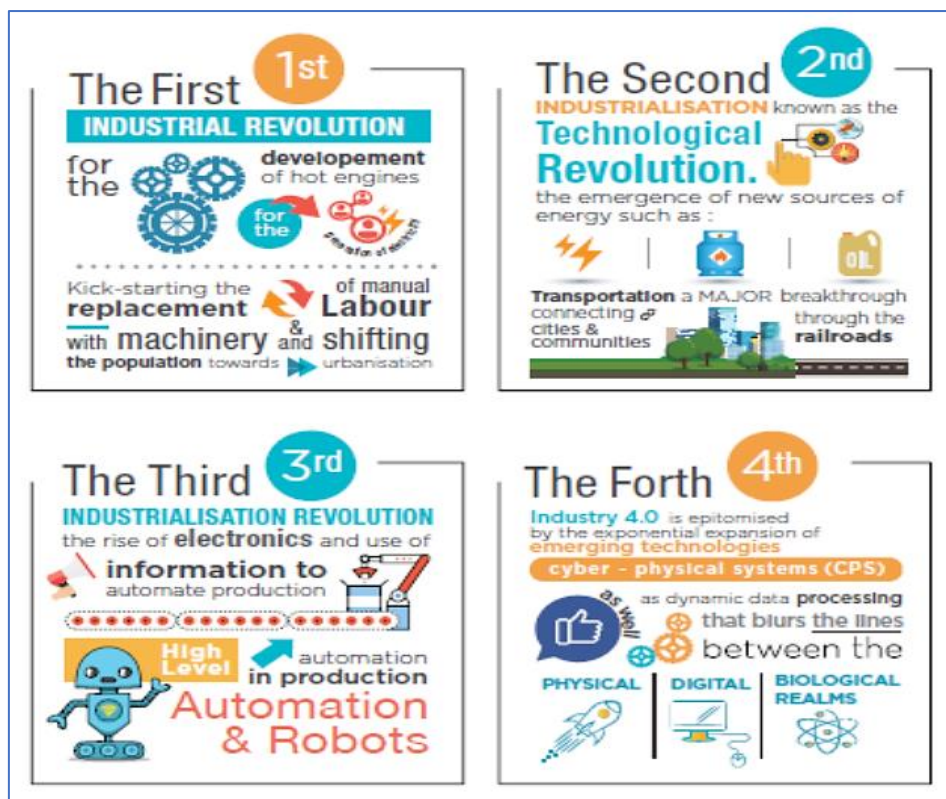
Figure 2. Stages involved in industrial revolution (MPC, 2018).

CPS is the main characteristic of IR4.0, which refers to a combination of physical and cybernetic systems (Lee *et al.*, 2015). These two systems can control everything that happens in the physical impacts on the virtual and vice versa (Lee, 2010). In manufacturing, CPS enables the development of autonomous productive processes through communication between sensors and smart machines using decision algorithms, which will allow the systems to decide on their configuration and their path in the production line (Lee *et al.*, 2015). IR4.0 typically involves the use of software (apps) to synchronize the physical and digital entities in order to stimulate and innovate industrial efficiency. The apps can also be used to enhance the connectivity between humans and machines, thus, increasing the manufacturing efficiency. In other words, IR4.0 can digitize, automate and interconnect all the processes within the production lines.

Nowadays, IR4.0 has been adopted in many sectors including telecommunication, automobile, energy, manufacturing services, security, medicine, robotics and agriculture (Hellinger & Seeger, 2011). In terms of management sectors, IR4.0 was utilized in the digitalization of accounting service, digitalization of legal service and digitalization of human resource management services. More specific examples include fully automated production process in factory, the process of loading or unloading containers at ports, robot waiters in restaurants, remotely managing the power of buildings from smart phones or other devices (Sung, 2018).

4. Enabling technologies for IR4.0

IR4.0 is about modern revolution, in which information and communication technology (ICT) is utilized as one single system. The revolution is growing due to existing of several enabling technologies such as artificial intelligence, big data analytics, augmented reality, IoT, cloud computing, autonomous robots, system integration, simulation and a few more (Figure 3). Details description of the enabling technologies are provided in Table 1. For agriculture, the major enabling technologies are IoT and sensors, which could enhance the implementation of smart farming that involve several field operations such as yield monitoring, diagnosing insect pests, measuring soil moisture, diagnosing harvest time, and monitoring crop health status. IR4.0 could also potentially be applied to remotely control all crop sensors at a field using mobile devices.

IR4.0 would permit smart devices with built-in intelligence to be connected to conventional tools (e.g. rain gauge, tractor, implement, sensor, notebook) in order to create an autonomous system, which is capable to execute autonomous actions or doing this remotely. By adopting IR4.0, workers will minimally involve in the whole process especially at a higher intelligence level, while the operational activities will be performed by smart machines or robotics. Thus, connectivity and IoT are the key factors for the success of this transformation.

Table 1. Pillar of enabling technologies for the adoption of IR4.0.

No.	Pillar	Description
1.	Additive manufacturing	Producing a product from new materials using 3D printing technology. For example, producing artificial bone from composite materials.
2.	Artificial intelligence (AI)	Application of machine learning to develop computer programs that can train actuator/robot to perform a duty as described by programmer. AI technology can be used to build a smart plant factory, in which data from supply chains, design teams, production lines and quality control are linked to form a highly integrated and intelligent systems.
3.	Big data analytics (BDA)	Analysis of data collected by sensors and observe the trend of the data to make real-time decision. BDA can be applied to improve product quality, energy efficiency and perform predictive maintenance.
4.	Advanced materials	Development of new materials and nano-structures components with better durability and strength. For example, material with good shape retention and thermoelectric efficiency.
5.	Cybersecurity	The communication level in many industries is becoming complex and strongly connected. Thus, digital security becomes a critical aspect to protect any online system from being hacked by outsiders.
6.	Simulation	Simulation is applied by engineers to predict the product behaviour under different conditions. In a field, simulation in used to predict crop yield due to

|		different agronomical practices and varied climatic condition. Simulation is performed to find the optimal way to produce a crop.
7.	Cloud computing	With the availability of cloud computing system, small companies can access cloud service on rental basis to leverage cloud-based product design, simulation, AI and big data solutions to improve their production.
8.	Augmented reality	Augmented reality can be used to deliver part replacement instructions to maintenance staff in the field.
9.	Internet of things (IoT)	IoT is the platform which connect different sensors at one time. IoT can be combined AI and big data to develop autonomous systems which can transform crop production.
10.	Autonomous robots	Autonomous robots such as drone or unmanned tractor can perform their jobs based on the prescribed order programmed to them. Autonomous robot can think, act and react autonomously similar to common human movements.
11.	System integration	System integration is created to share the data and information amongst the industry players. The system exists within the industry value chain and also across multiple value chains.
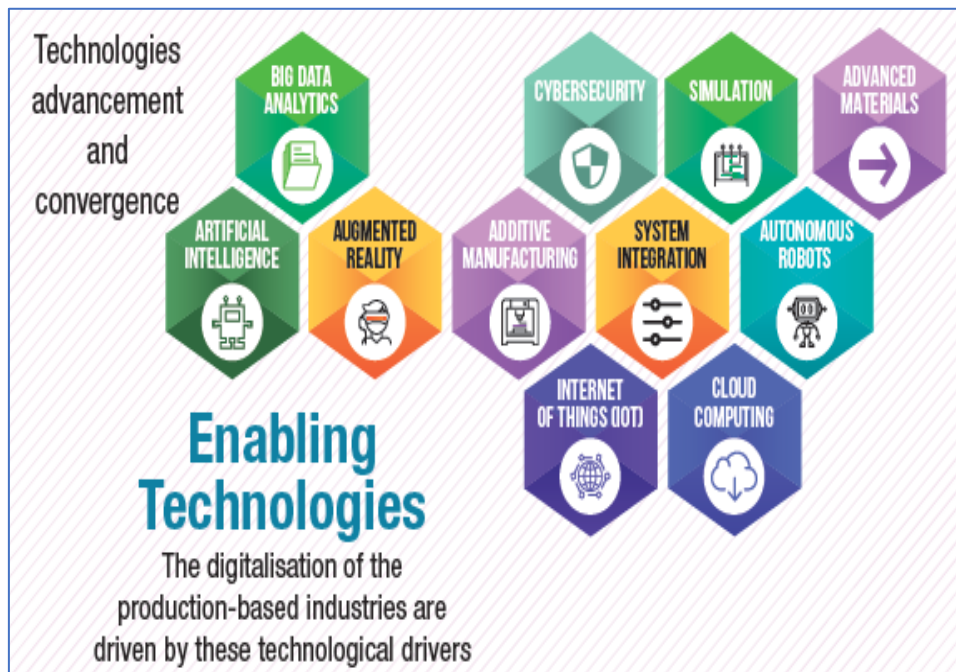
Figure 3. Enabling technologies for adoption of IR4.0 (MITI, 2018).

Another important pillar for IR4.0 in agriculture is an autonomous robotic. An autonomous robot is typically programmed to move in the field on assigned routes and is able to make decision in facing different situations or obstacles. Modern autonomous robot

can also imitate human movements and recognizes the external environment for accurate responses. Ideally, agricultural robot should be designed to effectively work in the open-field system, closed processing facility, and livestock production environment. The use of autonomous robotics could improve productivity through automation, unmanned farming, and the promotion of eco-friendly farming (Sung, 2018).

5. Potential benefits of IR4.0 in agriculture

At present, there are only 5% of the world's population, who involves in agriculture, where majority of them are elderly. To overcome this problem, several developed nations such as the US, Germany and Japan are trying to modernize their agricultural sector through mechanization, automation, and digitalization. As a result, the future farming is expected to evolve into high-tech industries, which will fully embrace IR4.0, benefiting from the advent of artificial intelligence, IoT, robotics and big data analytics. IR4.0 could facilitate the development of a modern multi-tasking farm machinery equipped with multiple sensors, which is capable of performing several farm operations and recorded different field data in a single run. This modern technology will certainly catch the interest of younger generations to involve in agriculture. In Malaysia, out of 13.9 million youngsters in the country, only 15% of them involve in agricultural industries.

The adoption of IR4.0 will enhance the implementation of PA in the agricultural sector. Comprehensive improvement in this sector can be gained, when IR4.0 facilitate the development of the optimized agricultural system which connects production, distribution, and consumption. This system will ensure that there is no crop will be wasted because it will be produced according to the current demand.

Since agricultural sector can severely be affected by the weather, the industry is highly dependent on intelligence and wisdom, including human experience to predict the weather condition. Thus, application of IR4.0 in dealing with weather-related problems would be very useful. For example, IR4.0 can offer a simulation model to precisely predict the oncoming weather pattern so that farmers can be ready with a proper mitigation plan. IR4.0 can also be considered as an agro-friendly revolution.

IR4.0 could also benefit medium and large plantation sectors by lowering their production costs because it can offer complete or partial changes in production and operational activities. A lower production costs may lead to a lower price, thus making our plantation products to be more competitive in the international market. As a result, more competitive exports have the potential to boost export volume and stimulate the Malaysian economy. In other words, IR4.0 could improve the competitiveness of Malaysian exports, thereby raising our Gross Domestic Product (GOP).

IR4.0 also has a potential to expand the traditional agriculture into different fields, such as culture, welfare, and tourism. IR4.0 can be a platform to convert an agricultural into

agro-tourisms activities, such as combining agriculture with games and leisure, human welfare agriculture in the age of aging, and agricultural activities with plants and animals (Anonymous, 2016). It is expected that IR4.0 would also enhance the traditional agriculture into modern agriculture in all aspects, including crop production, distribution, and consumption.

Agricultural facility such as a plant factory would be the first system to be modernized by smart farming technologies during IR4.0. IR4.0 technologies could effectively control the growth environment of the planted crops. Farmers who manage the facility should be able to monitor the growth status of the planted crops by using mobile devices from their offices, without physically going to the facility. This technology could increase the farm profits due to precise control and optimal prescription of agriculture. Ideally, IR4.0 would also permit all sensors and smart machines in the facility to be automated or remotely controlled. As shown in Figure 4, for open-field farming, IR4.0 can be fully utilized for monitoring the crop growth, analyzing data and carrying out variable rate application using smart farm machinery.

Monitoring the area for crop growth environment may include the health status of crops, climatic information, environmental information and growth information. By having enough data on crop growth, weather and available farm machinery, farmers can develop a simple simulation model to help them to maximize farm production and minimize the possible hazard due to unfavorable weather condition, natural disasters, system-errors and other external factors.

Any crop data from the farm, which is monitored and collected can be analysed for the decision-making. All collected data is accumulated, processed, and analysed as big data. Big data analytics will make it possible to collect environmental data during cultivation through an agricultural service platform. Then, a precise decision can be made from the data in a way that surpasses human intelligence, wisdom, and experience. The information can be used to evaluate market sale trends according to market preference analysis, and then the data (the cultivation environment, pest information, climate and weather information, soil fertility, topographical relevance, *etc.*) can be fed back to farmers to optimize production environments (Sung, 2018).

IR4.0 would also bring change to the distribution of agricultural product. The technology could supply useful background information of the product such as the prices, climate information, place of origin, variety, and intended customers, which would help to establish an effective supply and demand system. In this way, farmers or the government can adjust timing for planting and harvesting to stabilize prices of the product.
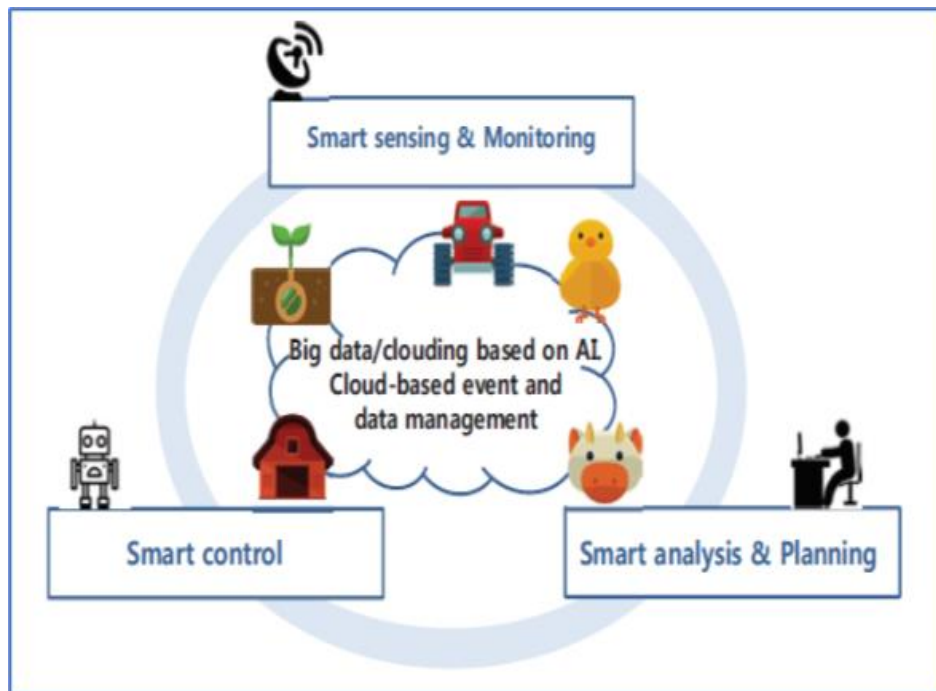
Figure 4. The Fourth Industrial Revolution and changes in agricultural production (Lee, 2017).

6. Challenges for Adoption of IR4.0 Into Agriculture

Although the adoption of IR4.0 could offer great benefit to the industry, but the actual adoption by farmers would take a long time. Harun *et al.* (2015) conducted a survey among farmers and concluded that most of the local farmers were reluctant to change or adapt to new techniques. This is because, most of the farmers, which majority are elderly, normally refuse to change their farming practices due to lack of awareness and interest. To date, many farmers are still not fully aware of the importance and advantages of IR4.0. Thus, in order to promote IR4.0 to farmers, creating awareness among them and relevant stakeholders is very necessary. Awareness and interest can be built through training, seminar, product demonstration, technical visit and subsidy award. Businesses and industrial players can play a role in improving the readiness and accessibility of the available modern technologies to rural farmers. Government agencies can build a testing platform for testing various sensors and technologies related to IR4.0, to help farmers quickly learn about the revolution.

IR4.0 has a potential to be developed to replace human intelligence by creating an autonomous robot, which can substitute labour. An increased in automation implies that employment opportunities may be reduced especially for the jobs, which requires repetitive tasks. This is good news for agricultural sector which faces a shortage in labour force. However, for other industries, extensive use of robot will minimize the number of their staff, resulting in an increase number of unemployment. However, through proper training in IR4.0-related program such as sensor integration, programming and data analysis, people will have high chance to be hired by the companies, which will implement IR4.0.

The implementation of IR4.0 will require huge financial investment. Bujang and Bakar (2019) reported that the technological adoption in Malaysia will be a challenging issue because of the cost factor. The initial cost is needed to develop an infrastructural framework that facilitates IR4.0, as well as transformative costs to adapt the technology. Thus, the government can offer incentives to companies that are willing to transform. This not only has the benefit of reducing cost of transformation, but also has the advantage of increasing the rate of transition to IR4.0. However, for the long term implication, the efficiency and innovation gains from IR4.0 could significantly outweigh the deployment and transformation costs. A study can also be conducted to identify, which sectors have the most potential to benefit from IR 4.0. An identified sector should be given the priority for the investment. It is also suggested to identify which activities are more suitable for automation.

The government must also facilitate the construction of the necessary infrastructure to meet the requirements for transition to IR4.0. One of the most important things for IR4.0 is the Internet service which have better coverage and speed nationwide especially in rural areas (Dlodlo & Kalezhi, 2015). Good internet service is very important to fully capitalize on IoT, cloud computing and big data analytics. Lastly, the fifth-generation (5G) communication network, the Internet network infrastructure and the cloud service system must maintain support for these technologies, in order to allow them to easily integrate into the agricultural industry.

7. Conclusion

IR4.0 which are supported by enabling technologies could offer an opportunity to modernize Malaysian agricultural sector to be more competitive, efficient, profitable and sustainable. This innovative technological advancement would allow farmers to produce agricultural product at a lower cost, but at a better quality. This review presented some key features of IR4.0 and how it can be adopted in agricultural production in Malaysia. A suitability of enabling technologies such as IoT, autonomous robot, big data analytics and artificial intelligent, which are among the pillars for IR4.0 are individually evaluated. The review has also investigated the potentials and possible challenges would be faced by the industry in embracing IR4.0. Recommendations are also provided for farmers, industrial players and policy makers to make sure a smooth adoption of IR4.0 into agricultural sector in Malaysia.

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