The Development Of Smart Farming Technologies And Its Application In Malaysia

Gabriel Wee Wei En, Haritharan Devanthran

Abstract : Smart farming is a development in the agriculture industry by integrating information and communication technologies (ICT) into agricultural production. New technologies such as the Internet of Things (IoT) and Cloud system are expected to enhance this development by introducing artificial intelligence and robots in farming. This paper aims to gain insight into the development of smart farming technologies based on worldwide scientific literatures and to explore the adoption of smart farming technologies in Malaysia from the perspectives of experienced farmers in this field. The research includes conducting meta-analysis to combine the results from worldwide journals on the development of smart farming technologies in Malaysia. The research on Smart Farming technology started from 1999 with 'Precision Farming', Soil Properties' and 'Sustainable Agriculture' after the introduction of the Third National Agricultural Policy (NAP3) in 1998. 'Internet of Things' was identified as the most researched Smart Farming technology in Malaysia. The trend of the development of Smart Farming technology in Malaysia is pointing towards urban farming solutions and achieving sustainable agriculture.

Index Terms: Agricultural innovation, big data, cloud computing, information technology, internet of thing.

1 INTRODUCTION

Advancement of farming technology have revolutionize the agricultural farming environment in past few years. The rapid changes trigger by new technologies creations such as the Internet of Things (IoT) and Cloud system are expected to enhance this development by introducing artificial intelligence and robots in farming (Schwab, 2017). This paper aims to gain insight into the development of smart farming technologies based on worldwide scientific literatures and to explore the adoption of smart farming technologies in Malaysia. There are multiple level of comparison such as global climate changes affects growing conditions growing conditions such as temperature, precipitation, and soil moisture, in less predictable ways. Smart farming studies will able to bring changes and reduce such negative externalities, it can keep things under control and reduce the cost of production and minimalize the environmental constraints (Braun et al., 2010). Malaysia based literature review on smart farming and smart agriculture is chosen in term of concept and terms associated with current studies.

2 LITERATURE REVIEW

This smart way of farming combine the information and communication technologies into machinery, equipment, and sensors in agricultural production systems, which allows a large bandwidth of data and information to be analyse with constant input of automation into the process of farming (Ruiz-Garcia, 2009). This allows a large transmission of big data into remote storage system which enables a various decision making process. Smart farming studies incorporate with Bibliometric and Scientific Analysis Using Text Mining Technique an important technique to guide study on agricultural production. It is to gain a comprehensive understanding of historical progression and current status, and future trend of remote sensing researches and applications in the field of crop growth monitoring in Malaysia (Bowen, 2009). Furthermore, the relationship between high-frequency keywords and the emerging hot topics were visually analyzed. This study able to reveal that Malaysian researchers paid more attention on popular keywords and less popular keywords in the field of smart farming and this will enable future researcher to explore gap of the study in frontier research of this discipline. Overall, bibliometric results from this Bibliometric and Scientific Analysis Using Text Mining Technique study provide a quantitative visualization to enrich our understanding on the historical development, current status, and future trend of smart farming technologies in Malaysia. Various trends and issues have emerged, present the complex and dynamic nature of smart farming. This study provide a comprehensive knowledge map and an overview of recent research on smart farming, peer-reviewed articles from 1957 to 2019 were analyzed to describe the empirical work in modern agricultural farming in Malaysia context. A bibliometric approach was applied to reveal the most common keywords and terms and their interactions via co-word analysis. This research is beneficial towards enterprises, smart farming developers and government to address the issues.

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3 METHODOLOGY

The first part of the research involved a bibliometric survey of Google Scholar database, powered by Google Inc. The reason why Google Scholar database was selected in favour of Web of Science database and Scopus because Google Scholar data are not limited to refereed, high-impact journals and conference proceedings only, and its downloading capabilities are effective for large-scale citation analyses (Yang & Meho, 2006). The bibliometric data described the evolution of scientific development of Smart Farming technologies in Malaysia from 1957 to 2019. The rationale behind the chosen scope was to study the development of Smart Farming technologies in Malaysia from its independence from the British Empire in 1957 to 2019. The first step is to key in the combination of keywords that would return the highest number of search results related to the study. The keywords selected were "Smart Farming technologies in Malaysia". The keywords were inserted into the search column on Google Scholar home page.

A total of 411 scientific publications were obtained from the data collection. Some of the publications were not available for access or no relation to the context of the research which was on the development of Smart Farming technologies in Malaysia. By the end of this process, 30 scientific publications were included in the bibliometric and text mining analysis (Figure 1).

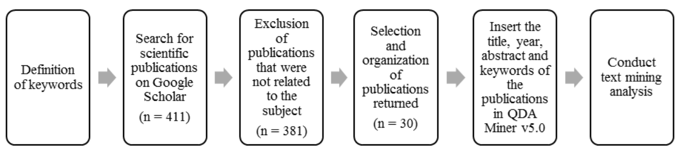

Fig. 1. *The process of collecting, selecting, organizing and extracting knowledge from scientific publications using text mining technique*

In conducting the text mining analysis, the first step was to key in the title, year of publication, abstract and keywords of the selected scientific publications in QDA Miner software version 5.0.29. QDA Miner is a software developed by Provalis Research to run data analysis. The second step involves filtering publications that were not related to the subject. The exclusion dictionary from QDA Miner was used to exclude the publications that were not relevant for the analysis. The third step involved identifying the most frequently used terms in the publications. Wordstat module of QDA Miner software was activated to analyze the title, abstract and keywords of the selected publications to identify the following parameter values: i) frequency (the number of cases a term occurred); and ii) percent cases (percentage of cases where the term occurred). Upon identifying the most frequent terms, the fourth step involved classifying the terms under three factors: i) Management; ii) Technology and Tools; and iii) Production and Environment. The fifth step involved analyzing the evolution of the scientific publication on the development of Smart Farming technology in Malaysia from 1957 to 2019 using a vertical bar chart. Lastly, the sixth step involved associating the terms in clusters based on the similarity index. The cluster analysis was illustrated using a dendrogram based on Jaccard coefficient. Jaccard coefficient compares the similarity and diversity of sample sets, assuming values from 0 to 1, to determine which members are shared and which are distinct (Niwattanakul et al., 2013).

4 RESULTS AND DISCUSSION

This section presents the results of the bibliometric analysis carried out on the scientific literature to understand the scientific development of Smart Farming technologies in Malaysia from 1957 to 2019, while at the same time contributing to new perspectives on the study of barriers of adopting Smart Farming technologies among farmers in Malaysia.

4.1 Factor Analysis

Figure 2 below presented the most popular Smart Farming technologies in Malaysia based on the selected scientific literatures, characterized by three factors: i) management; ii) technology and tools; and iii) production and environment. Although the study mainly focused on technology and tools, but management and production and environment factors were related to the development of technology and tools as well.

	Count	% Codes	Cases	% Cases
Management				
Farm Management	7	5.3%	7	23.3%
Water Management	3	2.3%	3	10.0%
Decision Support System	10	7.6%	10	33.3%
Technology and Tools				
Smart Farming	13	9.8%	13	43.3%
Vertical Farming	1	0.8%	1	3.3%
Internet of Things	15	11.4%	15	50.0%
Precision Farming	9	6.8%	9	30.0%
Irrigation System	8	6.1%	8	26.7%
Wireless Sensor Network	12	9.1%	12	40.0%
Big Data	14	10.6%	13	43.3%
Smart Phone	8	6.1%	8	26.7%
Cloud Storage	3	2.3%	3	10.0%
Production and Environment				
Soil Properties	5	3.8%	5	16.7%
Sustainable Agriculture	13	9.8%	13	43.3%
Hydrophobic Green Material	1	0.8%	1	3.3%
Livestock Farming	3	2.3%	3	10.0%
Fish Farming	1	0.8%	1	3.3%
Weather Conditions	2	1.5%	2	6.7%
Climate Change	4	3.0%	4	13.3%

Fig. 2. *Total frequency of Smart Farming terms relating to the development of Smart Farming technology in Malaysia in the scientific literatures from 1957 to 2019, characterized based on management, technology and tools, and production and environment factors.*

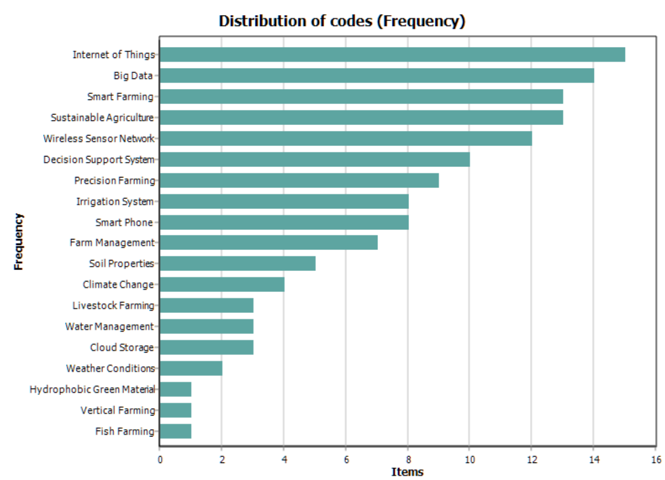

Fig. 3. *Summary of the total frequency of Smart Farming terms relating to the development of Smart Farming technology in Malaysia in the scientific literatures from 1957 to 2019.*

The term 'Internet of Things' within the category of technology and tools is the most popular term in the study of the development of Smart Farming technology in Malaysia. This term first appeared in the literatures in 2009 with increasing frequency in publications until 2019. Internet of Things (IoT) can be defined as the ubiquitous network that provides the functionality of integrating the physical world (Ibrahim et al., 2018). This can be done through the collection, processing and analyzing data generated by IoT sensors via Internet connection. IoT technologies such as sensors, RFID, drone and robotics enable real-time plants data to be transmitted to farmers for their appropriate actions (Syam & Jusoff, 2000; Mat et al., 2018). In addition, such technologies also enable farmers to monitor their farms remotely and automate farm irrigation system (Kaewmard & Saiyod, 2014). 'Big Data' is a phenomenon in which massive volumes of data can be captured through Internet of Things technologies, analysed and used for decision-making by the users (Shamsiri et al., 2018). In agriculture field, data can be captured through sensors in the ground, RFID tags installed on the plants or field scouting robots (Shiang-Yen et al., 2012; Shamsiri et al., 2018; Chuah et al., 2019). The term 'Smart Farming' refers to capital-intensive and high tech system of growing food cleanly and sustainable for the masses based on IoT technologies (Ibrahim et al., 2018). Smart Farming or smart farms help farmers to reduce waste and enhance productivity by reducing the number of journeys the farm vehicles made, the number of errors farmers made and time spent on field work through IoT, Big Data and automation (Ibrahim et al., 2018). 'Wireless Sensor Network' is the combination of hardware and software capable of measuring temperature, humidity and oxygen data in the field and send the data to the router. Generally, routers are located near the sensor field and upon capturing the data, it will be processed and transmitted to the server (cloud). The server collects the data, processes and organizes it to be understandable by the users. The end users will be able to access the data via monitoring system on mobile phone or computer (Syam & Jusoff, 2000; Kaewmard & Saiyod, 2014; Jindarat & Wuttidittachotti, 2015; Lim et al., 2017). The term 'Precision Farming' refers to site-specific practices that measure and manage variabilities such as yield, soil, weed and pest across the fields (Aimrun et al., 2007). The purpose of Precision Farming is to maximize the production and quality of crops while minimizing the environmental impact and agricultural risk (Aimrun et al., 2007; Ismail & Razali, 2011; Rizman et al., 2018). 'Irrigation System' refers to the application of controlled amount of water to plants at needed intervals using Internet of Things technologies (Lee, Najim & Aminul, 2004). IoT sensors are able to capture data about the soil moisture content, transmit to microcontroller (i.e. Arduino Uno) and the irrigation system can be activated by the user via smart devices when they receive the notification (Lee, Najim & Aminul, 2004; Mamodu, 2014; Kaewmard & Saiyod, 2014). 'Smart Phone' is a mobile computing device that facilitate software, Internet and multimedia functionality. Smart Phone is one of the Internet of Things technology that allow users to monitor the condition of their plants, receive notifications from Smart Farming system and execute command to activate Irrigation system (Aziz & Othman, 2013; Kaewmard & Saiyod, 2014). 'Cloud Storage' is internet-based computing where remote servers are networked to allow data-processing tasks to be accessed by multiple users (Abolfazli, 2015). Cloud storage allows data captured from the sensors to be stored and its analytical capabilities aid users to organize the data and make better decisions (Abolfazli, 2015). The term 'Vertical Farming' refers to an urban farming technique where farming takes place in a confined building with permanent climbing structure (Baharudin et al., 2018). Vertical farming aims to bring food nearer to the cities and cultivate sustainable urban agriculture (Baharudin et al., 2018). This method requires new practices that include water management, cultivation and harvesting techniques (Chuah et al., 2019). The usage of biocomposites and hydroponic were identified as the key ingredients of vertical farming (Chuah et al., 2019).

The analysis of the popular terms present in the scientific literatures also reveals an emphasis on sustainability and environment, as observed from the terms 'Sustainable Agriculture', 'Soil Properties' and 'Climate Change'. One of the objectives of the development of Smart Farming technology is to reduce and mitigate the negative impact of farming towards the environment (Othman, 2012).

4.2 The Evolution of Scientific Literature

Based on Figure 4, 5 and 6 below, the first publication on the development of Smart Farming technologies in Malaysia was in 1999 on precision farming along with publications studying soil properties and sustainable agriculture. Othman (2012) found that the research interest in Smart Farming started in 1999 as a result of the introduction of the Third National Agricultural Policy (NAP3) from 1998 to 2010 by the Ministry of Agriculture to promote the adoption of sustainable management in the utilization of natural resources as the guiding principles to pursue agricultural development. The Government also pushed to increase the usage of Information Communication Technology (ICT) in all sectors to increase productivity (Othman, 2012). Rice is a staple food among Malaysian and even with the high production, Malaysia only produced eighty percent of self-sufficiency in 1998 (Lim et al., 2017). Hence, the development of Smart Farming technology in Malaysia started from precision farming in paddy cultivation with the focus of understanding the soil properties to achieve sustainable agriculture.

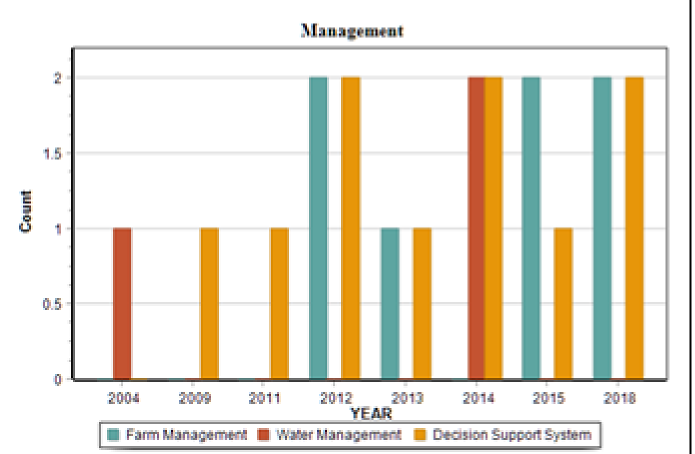

Fig. 4. Evolution of Smart Farming Management by Years.

In 2004 when the study on precision farming reached its peak, water management concept with irrigation system technology were introduced to develop a more comprehensive system across paddy fields. In 2009 when the studies on Internet of Things technologies emerged, studies on decision support system and farm management followed suit to discuss the concept of interconnected systems for decision making. Internet of Things open up new possibilities of managing farms with information technology, especially the possibilities of automation (Ibrahim et al., 2018). Hence, the studies on wireless sensor network, big data, cloud storage and mobile phone emerged from 2011 to 2019 as critical components that enable smart farming.

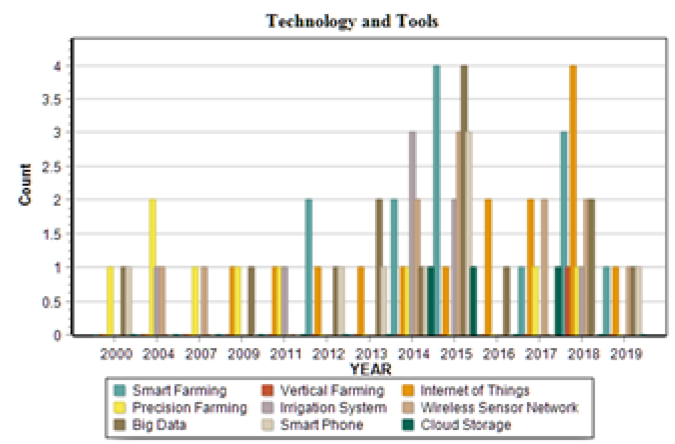

Fig. 5. Evolution of Smart Farming Technology and Tools by Years

Studies related to climate change appeared in 2012 and peaked along with the studies on sustainable agriculture in 2018. These studies highlighted the concerns towards the environmental issues as a result of agricultural activities and the emphasis of sustainable agriculture as the output of the development of smart farming technologies (Baharudin et al., 2018; Chuah et al., 2019). The concept of vertical farming emerged in 2018 to introduce urban farming techniques using hydropobic green materials.

4.2 The Evolution of Scientific Literature

The cluster analysis involves associating the terms in clusters based on the similarity index using a dendrogram based on Jaccard coefficient. Jaccard coefficient compares the similarity and diversity of sample sets, assuming values from 0 to 1, to determine which members are shared and which are distinct (Niwattanakul et al., 2013).

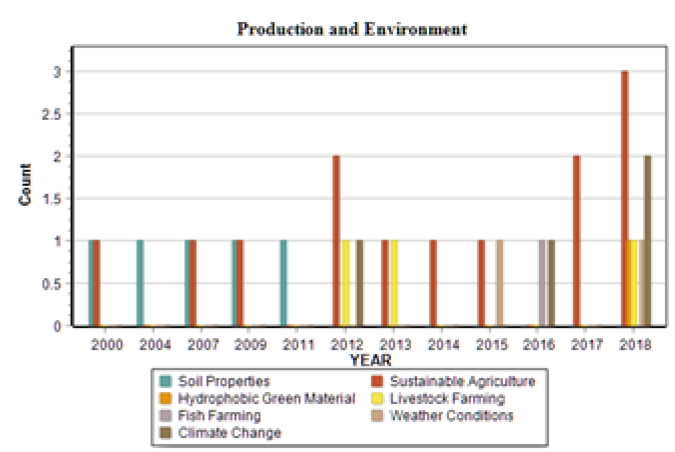

Fig. 6. Evolution of Smart Farming Production and Environment Factor by Years

The first cluster of terms has the highest similarity consisting of key terms related to management, technology and tools, and production and environment factors. The terms 'Big Data', 'Internet of Things', 'Smart Farming', 'Wireless Sensor Network', 'Decision Support System', 'Farm Management', 'Smart Phone', 'Precision Farming', 'Soil Properties' and 'Sustainable Agriculture' are closer, showing that these technologies are integrating production areas with the aim to achieve sustainable agriculture.

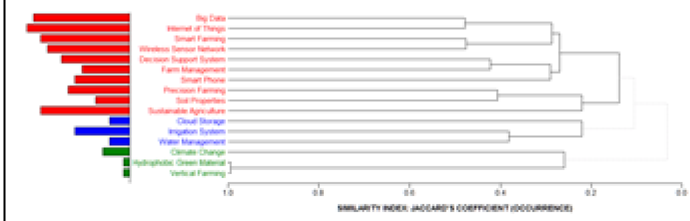

Fig. 7. Dendrogram showing cluster analysis of the most frequently used terms based on Jaccard's Coefficient

The second cluster illustrates how 'Cloud Storage' is critical to activate 'Irrigation System' in 'Water Management'. The third cluster shows how 'Climate Change' drives 'Vertical Farming' at urban areas using 'Hydrophonic Green Material'.

5 CONCLUSION

The first focus of the scientific literatures was on the development of Smart Farming technologies and tools in Malaysia. The second focus was on the management of the technologies and tools, and its integration in supply chains and in farms. The third focus was on the impact of the development of Smart Farming technologies on the production and the environment. The Malaysian market is in the initial development phase of Smart Farming technology adoption. Upon application of these technologies in Malaysia, the supply and development of Smart Farming tools are currently concentrated in Internet of Things, mainly for paddy fields. The application of these technologies at the farm level, or urban farming should intensify in the coming years. With its potential benefits, it is necessary for farmers of today and tomorrow to connect the technologies and the collected data in order to automate decision-making for the best output.

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