JOURNAL OF AGRIBUSINESS MARKETING
e-ISSN: 2289-5671
Volume 10, Issue 1, January 2023
DOI: 10.56527/fama.jabm.10.1.3

JABM
Crossref

Open Access

Development of Smart Farming Technologies in Malaysia - Insights from Bibliometric Analysis

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ABSTRACT:
Smart Farming Technologies are instrumental in the agriculture industry with the ability to boost the production of farm crops and livestock, improve the quality, control resource usage, and ensure sustainability while maximizing profit and minimizing the cost of production. In this review, we pursue a bibliometric analysis of the development of Smart Farming Technologies in Malaysia. Using bibliometric data of 204 research articles from the Scopus database, this review sheds light on the leading authors, countries, institutions, outlets, articles, and themes of transfer pricing research over 50 years (1979–2022). Findings of this review suggest that there is a need for SFT research to connect the technologies and the collected data in order to automate decision-making strategies.

KEYWORDS: smart farming technology, technology development, bibliometric analysis

MANUSCRIPT TYPE:
Research Paper

PUBLICATION DETAILS:
Received: 14 Dec 2022
Revised: 3 Feb 2023
Accepted: 6 Feb 2023

INTRODUCTION, THEORETICAL BACKGROUND AND RESEARCH QUESTIONS

Smart Farming Technologies (SFT) refers to the use of technologies such as IoT, cloud storage, big data and mobile devices for collection of external environment data and monitoring of crop's growth for the purpose of risk management and timely interventions that can boost the quality and quantity of agriculture produces. The advantages of agriculture modernization through the application of SFT include the reduction of costs through the application of inputs (fertilizers and plant protection products for animals) according to the actual needs of the soil and of crops, thus reducing the environmental impact of the farm (Basso et al., 2016); attracting and retaining youths in agriculture (Som et al., 2018); broadening and strengthening the agriculture value chain (Klerkx, 2019); building resilience to climate change (Chandra et al., 2018); and promoting urban agriculture for sustainable city development (Azunre et al., 2018).

There is now a clear understanding of how SFT can be a solution to the climate, labour and production related problems by reducing human intervention through automation (Global Research Alliance, 2014). However, despite the availability of SFT in Malaysia and its significant influence on farm profitability, structure and environment impact, the adoption of SFT and development of agricultural production in Malaysia is lagging behind neighbouring countries.

Hence, this review argues that there is a need to pursue a bibliometric analysis of SFT researches in Malaysia. Numerous scholars have attempted but several limitations were observed. For example, Suebsombut et al. (2017)'s review of SFT was limited from the insights of climate change and farm management, and Pivoto et al. (2018)'s review was limited from the perspective of Brazilian farmers. Furthermore, a Scopus search of "smart farming technologies" and "review" between 2018 to 2022 showed no result. Thus, conducting this review is important and useful to help scholars, practitioners, and policymakers identify the leading authors, countries, institutions, outlets, articles, and topics of SFT, to gain a more comprehensive understanding of historical progression and current status, and future trend of smart farming technologies researches and applications in the agriculture industry in Malaysia.

Thus, the following research questions (RQs) are explored in this review:

RQ1. What is the publication trend (number of articles by year) of SFT?
RQ2. Where are the most influential publications (outlets, articles) of SFT?
RQ3. Who are the most prolific contributors (authors, countries, and institutions) of SFT?
RQ4. What does existing research (themes, topics) inform about SFT?
RQ5. Where can future research (avenues) explore to enrich the understanding of SFT?

METHODS

In this study, the knowledge on smart farming technology (SFT) in Malaysia is examined via systematic literature review. A systematic literature review can be carried out in a variety of methods (e.g., content analysis, bibliometric analysis, meta-analysis, thematic analysis) (Lim, Kumar & Ali 2022). This study adopts a bibliometric approach to review the literature. In essence, a bibliometric analysis relies on quantitative and statistical methods to analyse the literature (Donthu et al. 2021a). This method is chosen because (i) it can handle a large set of literature and (ii) it can mitigate bias as it relies on objective measures (statistics) to analyse the literature (Mukherjee et al. 2021). The review procedure of this study is guided by the considerations in existing review protocols using SPAR-4-SLR (Paul et al. 2021). The next sections explain the data collection and the data analysis for this systematic literature review using bibliometric analysis.

Data Analysis (Corpus Analysis)

The data collection was carried out in two stages: assembling and arranging.

In terms of assembling, this study used the search keywords that represented smart (i.e., smart, technology, devices, equipment, machine), farming (farm*, agriculture), and Malaysia (Malaysia). These keywords were identified based on a brainstorming session with experts in consultation with the literature (Paul et al. 2021). These keywords were searched in the Scopus database, which is one of the largest scientific database with bibliographic data, in the search field “article title, abstract, and keywords”, returning 580 documents.

In terms of arranging, this study’s search start date was left unspecified to include as many relevant articles as possible, but its end date was specified as up to 20 November 2022, which is the date the search was conducted (search period). The subject areas were limited to “Agriculture and Biological Science”, “Engineering”, “Environmental science”, “Earth and Planetary Science” as they were the most relevant areas for this study. The document type was limited to “article” to capture conceptual and empirical research in the field which are peer-reviewed for quality assurance. The publication stage selected was “final” to enable replicability as “in press” articles may be assigned to a later year. The source type was limited to “journal” due to (i) the existence of peer review, and (ii) represents full fledge research—others like “conferences” were not included because they represent research in progress while “book chapters” tend to be explanatory rather than exploratory. The language was limited to “English” due to the author(s) language proficiency. The results following this filtering led to the inclusion of 208 documents (and the exclusion of 372 documents). After filtering another 4 articles for duplicate errors, the final count stands at 204 articles.

Table 1. Search mechanism.

SPAR-4-SLR	Consideration	Decision
Assembling	Search focus	Smart farming technology
	Search keywords	(“farm*” OR "agriculture") AND (“smart” OR “technology” OR “devices” OR “equipment” OR “machine”) AND ("Malaysia")
	Search database	Scopus
	Search field	Article tittle, abstract, and keywords
	Search result	580 documents
Arranging	Search period	Up until 20 November 2022
	Subject area	“Agriculture and Biological Science”, “Engineering”, “Environmental science”, “Earth and Planetary Science”, and “Energy”
	Document Type	“Article”
	Publication	Final
	Source Type	Journal
	Language	English
	Search result	208 documents (before filtering for duplicate) 204 documents (after filtering for duplicate)
Assessing	Performance analysis/Corpus performance	Publication and citation trend Most impactful articles (citation) Most productive journals (publication) Most productive (publication) and impactful (citation) contributors (authors, institutions, countries)
	Science mapping/Intellectual structure	Co-citation analysis (historical major themes) Co-occurrence analysis (present major themes) Trend analysis (trending themes and topics)

Data Analysis (Corpus Analysis)

The data analysis was carried out in the last stage called assessing. Two types of bibliometric analysis were conducted: performance analysis and science mapping.

In terms of performance analysis, this study analysed the publication and citation trend to examine the productivity and impact of SFT. This study also unpacked the most impactful articles based on global and local citations, as well as the most productive journals based on the number of publications. In addition, this study sheds light on the most productive (publication) and impactful (citation) contributors consisting of authors, institutions, and countries. This coverage of performance evaluation is in line with past bibliometric reviews (citations).

In terms of science mapping, this study conducted a co-word analysis and a bibliographic coupling analysis. In essence, a co-word analysis unpacks the major themes in the literature based on the clustering of commonly occurring keywords, whereas a bibliographic coupling analysis reveals the major themes in the literature based on the clustering of articles that share common references (Donthu et al. 2021a). The use of these two analytical techniques provides a mean for triangulating the major themes in the literature (Lim, Kumar & Ali 2022). Finally, a trend analysis was conducted to map the evolution of the themes and topics in SFT.

The results of the bibliometric analyses are presented in the next sections.

Findings

Performance Analysis

Corpus Performance

The publication trend of SFT research is presented in Figure 1. The figure indicates that research in SFT has grown over the past 43 years (from 1979 to 2022). The very first article published in this corpus dated back to year 1979. From there on, until year 2016, there has been no significant volume of articles published on SFT, with none of the year recording more than 10 articles a year. This indicates that SFT had a very slow growth in its first few initial years, when the concept is rather novel and new to the world. This is a common norm for any form of research which is new. However, this period of slow growth rate of publication has extended over a span of about 37 years, which is a rather long spell of low research output. Year 2017 is the landmark where, for the very first time the number of articles published exceeded 10. The latest 6 years (2017-present) sees a constant volume of articles of more than 10 per year. In year 2020, a drop in article produced is observed. This could be due to the Covid-19 pandemic effect, where researchers are not able to carry out their research on field due to various restrictions imposed by majority of the countries. Figure 2 presents the citation trend in SFT. Similar to the trend observed in publication trend, majority of the citation numbers comes in only at the latest 6 years, starting from year 2017. This same trend has been observed in a research by (Chandra et al. 2022).

Figure 1. Publication (productivity) trend of SFT research

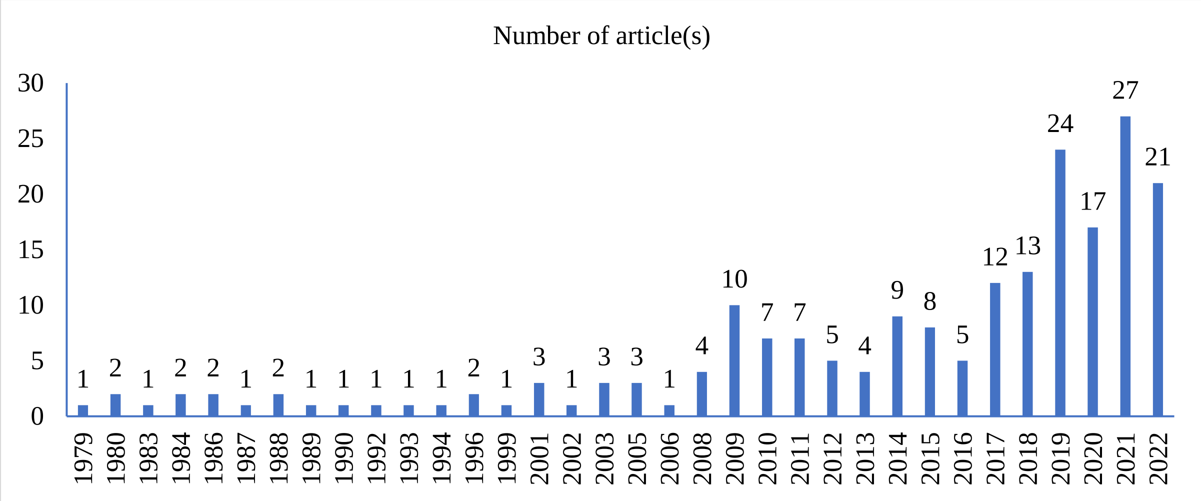
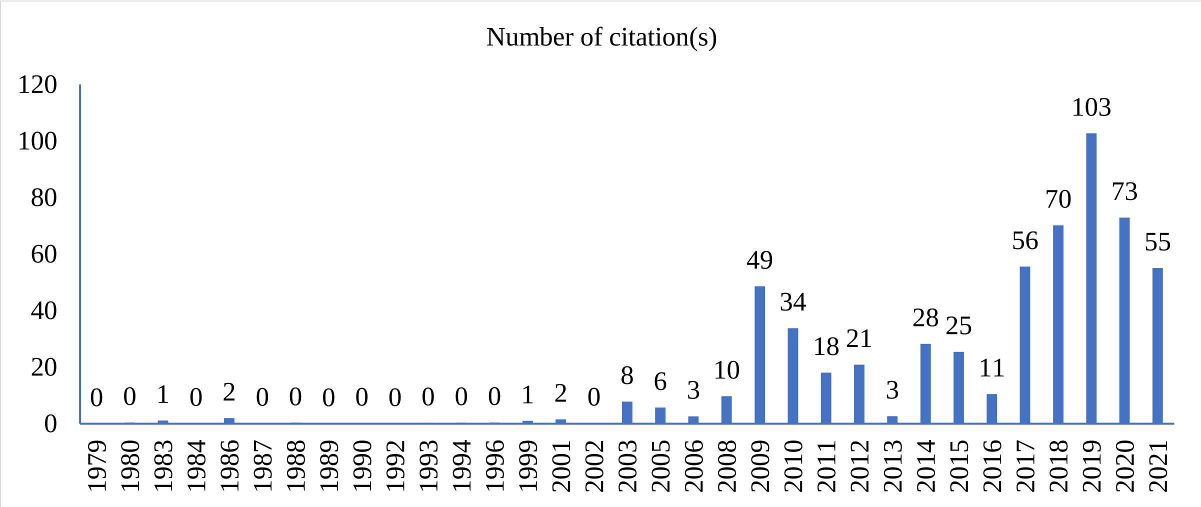


Figure 2. Citation (impact) trend of SFT research



Article Performance

The top articles for SFT research can be viewed from two perspectives: global citations versus local citations.

The number of citations received by an article indexed in Scopus from other Scopus-indexed articles is known as global citations (Donthu et al. 2021b). The top articles on SFT that received the highest number of global citations are presented in Table 2. The number one most globally cited article by Hameed, Krishni and Sata (2009) introduces a novel method of removing dye in aqueous solution using pineapple waste. Their work received a total of 292 citations. The second most-cited SFT article in this review corpus is (Goh et al. 2010). The paper describes the outlook and difficulties of producing bioethanol in Malaysia using lignocellulosic materials. Meanwhile, the third most-cited SFT article is by (Tripathi et al. 2012). This article contains research showing that soil pH, with the maximum diversity close to neutral pH values, was the strongest predictor of bacterial community composition and diversity across the various land use types.

Whereas, the number of citations received by an article in the corpus from other articles in the corpus is known as local citations (Donthu et al. 2021b). Local citations are determined using references from 204 papers on SFT research included in this corpus review. This citation count is more accurate since it shows how much study in one subject impacts research in related fields, in this case, the field of SFT. Table 3 shows the top ten locally cited SFT articles. Surprisingly, there are only 14 articles which are cited by other SFT articles in this review corpus. This shows that the articles in this review corpus cite very little from each other in the production of the research. This could mean that they mostly refer to global articles, suggesting that smart farming is a fairly new research agenda in Malaysia.

Table 2. Top 10 most globally cited articles on SFT

Rank	Author(s)	Title	Year	Total citations
1	Hameed, Krishni, Sata	A novel agricultural waste adsorbent for the removal of cationic dye from aqueous solutions	2009	292
2	Goh, Tan, Lee, Bhatia	Bio-ethanol from lignocellulose: Status, perspectives and challenges in Malaysia	2010	248
3	Tripathi, Kim, Singh, Lee-Cruz, Lai-Hoe, Ainuddin, Go, Rahim, Husni, Chun, Adams	Tropical soil bacterial communities in Malaysia: PH dominates in the equatorial tropics too	2012	188
4	Panichelli, Dauriat. Gnansounou	Life cycle assessment of soybean-based biodiesel in Argentina for export	2009	133
5	Ahmad, Tan. Shukor	Dimethoate and atrazine retention from aqueous solution by nanofiltration membranes	2008	125
6	De Souza, Pacca, De Ávila, Borges	Greenhouse gas emissions and energy balance of palm oil biofuel	2010	117
7	Rasul, Thapa	Shifting cultivation in the mountains of south and southeast Asia: Regional patterns and factors influencing the change	2003	113
8	Oliphant, Thenkabail, Teluguntla, Xiong, Gumma, Congalton, Yadav	Mapping cropland extent of southeast and northeast Asia using multi-year time-series landsat 30-m data using a random forest classifier on the google earth engine cloud	2019	93
9	Markom, Shakaff, Adom, Ahmad, Hidayat, Abdullah, Fikri	Intelligent electronic nose system for basal stem rot disease detection	2009	85
10	Hurtado, Gerung, Yasir, Critchley	Cultivation of tropical red seaweeds in the BIMP-EAGA region	2014	83

Table 3. 14 locally cited articles on SFT

Rank	Author(s)	Title	Year	Total citations
1	Adnan, Md Nordin, Rahman, Noor	Adoption of green fertilizer technology among paddy farmers: a possible solution for Malaysian food security	2017	4
2	Terano, Mohamed, Shamsudin, Latif	Factors influencing intention to adopt sustainable agriculture practices among paddy farmers in Kada, Malaysia	2015	3
=	Umar, Jennings, Urmee	Sustainable electricity generation from oil palm biomass wastes in Malaysia: An industry survey	2014	2
=	Mekhilef, Safari, Chandrasegaran	Feasibility study of off-shore wind farms in Malaysia	2012	2
=	Avtar, Suab, Syukur, Korom, Umarhadi, Yunus	Assessing the influence of UAV altitude on extracted biophysical parameters of young oil palm	2020	1
=	Dilipkumar, Chuah, Goh, Sahid	Weed management issues, challenges, and opportunities in Malaysia	2020	1
=	Sarkar, Begum, Pereira	Impacts of climate change on oil palm production in Malaysia	2020	1
=	Azmi, Mohammad, Pebrian	Evaluation of soil EC mapping driven by manual and autopilot-automated steering systems of tractor on oil palm plantation terrain	2020	1
=	Suboh, Baharudin, Basheer	Dispatch strategy for grid-connected micro-wind turbine generators with battery: case study in Malaysia	2019	1
=	Lim, Lee, Bong, Lim, Klemeš	Environmental and economic feasibility of an integrated community composting plant and organic farm in Malaysia	2019	1
=	Adnan, Nordin, Ali	A solution for the sunset industry: adoption of green fertiliser technology amongst Malaysian paddy farmers	2018	1
=	Vaughan, Riggio, Chen, Peng, Harris, Van Der Ent	Characterisation and hydrometallurgical processing of nickel from tropical agromined bio-ore	2017	1
=	Hassan, Hassan, Shaffril, D'Silva	Problems and obstacles in using information and communication technology (ICT) among Malaysian agro-based entrepreneurs	2009	1
=	Best	Change over time in a farming system based on shifting cultivation of hill rice in Sarawak, Malaysia	1988	1

Journal Performance

A total of 147 journals in Scopus have published 204 SFT articles. **Error! Reference source not found.** depicts the comparison between the top 10 publishing sources of SFT according to the number of articles production (productivity), total citations (impact) and the *h*-index (influence). 14 journals have published at least three SFT articles, which accounted for 25% (51 of 204) of articles in this SFT corpus. This shows that there is mass domination of any journals in this field of study. 27 journals have garnered at least 40 citations for their SFT articles and 21 journals have attained a minimum score of 2 in the *h*-index.

The top three most productive journals are Pertanika Journal of Science and Technology (6 articles), Journal of Cleaner Production (5 articles), and Jurnal Teknologi (5 articles). Journal of Hazardous Materials (417 citations), Bioresource Technology (269 citations), and Microbial Ecology (188 citations) are the top three most impactful journals according to the volume of citations. In regards to journals who have the most influence in this review corpus, the top two highest rank journals are Journal of Cleaner Production with score of 4, while Energy, Pertanika Journal of Science and Technology, Pertanika Journal of Tropical Agricultural Science, and Renewable Energy all recording the same *h*-index score of 3. Nonetheless, the most productive journal and the most cited journal does not necessarily mean that they are most influential when it comes to the impact on the field of study. As shown in **Error! Reference source not found.**, the most productive (number of articles published) journal which is Pertanika Journal of Science and Technology, and the most cited journal, Journal of Hazardous Materials, neither of them are ranked number one in the most influential in terms of *h*-index measure

Table 4. Top 10 publishing sources of SFT research

Ranking by articles			Ranking by total citations			Ranking by *h*-index		
Rank	Journal	Article(s)	Rank	Journal	Total citation(s)	Rank	Journal	*h*-index
1	*Pertanika Journal of Science and Technology*	6	1	*Journal of Hazardous Materials*	417	1	*Journal of Cleaner Production*	4
2	*Journal of Cleaner Production*	5	2	*Bioresource Technology*	269	2	*Energy*	3
=	*Jurnal Teknologi*	5	3	*Microbial Ecology*	188	=	*Pertanika Journal of Science and Technology*	3
3	*Food Research*	4	4	*Renewable Energy*	163	=	*Pertanika Journal of Tropical Agricultural Science*	3
=	*Indonesian Journal of Electrical Engineering and Computer Science*	4	5	*International Journal of Life Cycle Assessment*	133	=	*Renewable Energy*	3
4	*Renewable Energy*	3	6	*Computers and Electronics in Agriculture*	120	3	*Advances in Environmental Biology*	2
=	*Energy*	3	7	*Land Degradation and Development*	113	=	*Agriculture, Ecosystems and Environment*	2
=	*Aquaculture*	3	8	*Journal of Cleaner Production*	111	=	*Aquaculture*	2
=	*Sustainability (Switzerland)*	3	9	*Journal of Applied Phycology*	109	=	*Bioresource Technology*	2
=	*Pertanika Journal of Tropical Agricultural Science*	3	10	*International Journal of Applied Earth Observation and Geoinformation*	93	=	*Computers and Electronics in Agriculture*	2

Author performance

The SFT articles in this review paper were contributed by 666 authors. This shows that for every article produced, there are 3.3 authors working on the paper. Table 5 shows the top authors ranked based on the *h*-index and the total citations. According to the total citations for the top authors, SFT authors may have a considerable influence on the academic literature regardless of how frequently they produce SFT publications. This finding should encourage aspiring authors to conduct high-quality SFT research. While Adnan and Hashim appeared to be the most productive and influential, they do not appear as the top authors who are most impactful in this SFT research.

Table 5. Top authors in SFT research according to *h*-index and total citations.

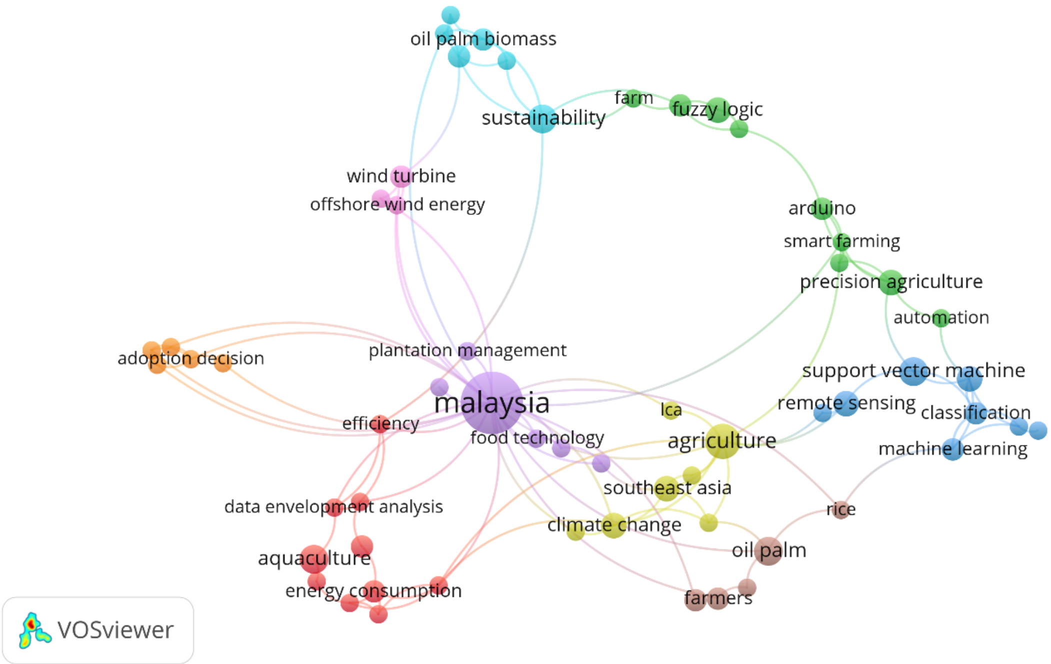
Ranking by *h*-index				Ranking by total citations			
Rank	Author	*h*-index	Article(s)	Rank	Author	Total citations	Article(s)
1	Adnan N	3	3	1	Hameed BH	292	1
=	Hashim H	3	3	=	Krishni RR	292	1
2	Ancrenaz M	2	2	=	Sata SA	292	1
=	Goossens B	2	2	2	Bhatia S	248	1
=	Shakaff AYM	2	2	=	Goh CS	248	1
=	Jennings P	2	2	=	Lee KT	248	1
=	Umar MS	2	2	=	Tan KT	248	1
=	Urmee T	2	2	3	Adams JM	188	1
=	Yu L	2	2	=	Ainuddin AN	188	1
=	Huang YF	2	2	=	Chun J	188	1
=	Koo CH	2	2	=	Go R	188	1
=	Mekhilef S	2	2	=	Husni MHA	188	1
=	Van Der Ent A	2	2	=	Kim M	188	1
=	Radzi Mam	2	2	=	Lai-Hoe A	188	1
=	Nordin SM	2	3	=	Lee-Cruz L	188	1
=	Amin MSM	2	2	=	Rahim RA	188	1
=	D'silva JL	2	2	=	Singh D	188	1
=	Hassan MA	2	2	=	Tripathi BM	188	1
=	Begum RA	2	2	4	Ancrenaz M	134	2
=	Pereira JJ	2	2	=	Goossens B	134	2

Science Mapping

Knowledge production clusters via co-occurrence of authors' keyword in SFT research

Authors select keywords to capture the spirit of their (Donthu et al. 2021a). Given that keywords stand in for the essential elements of a given research, this review uses a science mapping technology known as co-occurrence analysis to examine the relationships between the keywords used in the articles in the review corpus in order to understand the knowledge clusters in SFT research. This review creates a network visualisation map of keywords using VOSviewer, employing terms that appear at least twice in the review corpus (a deliberate choice required to provide a clear representation of keyword co-occurrences). The network visualisation map is presented in Figure 3. This figure is also supplemented with summary statistics in **Error! Reference source not found.** detailing the occurrences of each keyword and the total link strength of each keyword with other keywords. The intellectual framework of SFT research is supported by nine knowledge clusters in total, which are explored next utilising sensemaking, whereby keywords are arranged logically to represent the research core of each knowledge cluster.

Figure 3. Knowledge clusters in SFT research



Notes: Red (Cluster 1) = Smart farming in a sustainable manner, Green (Cluster 2) = Smart farming via automation, Dark blue (Cluster 3) = Smart farming via machine learning, Pink (Cluster 4) = Smart farming via wind-powered technology, Purple (Cluster 5) = Smart farming via bio-technology, Light blue (Cluster 6) = Smart farming via bio-energy, Orange (Cluster 7) = Smart farming involving decision making process, Brown (Cluster 8) = Smart farming via use of pesticides , Yellow (Cluster 9) = Smart farming in changing environment

Table 6. Keyword co-occurrence for knowledge clusters in SFT research

Keywords	OC	TLS	Keywords	OC	TLS
Cluster 1: Smart farming in a sustainable manner			*Cluster 5: Smart farming via biotechnology*		
Agriculture sector	2	4	Biotechnology	2	2
Aquaculture	5	2	Food technology	2	3
Co2 emissions	2	6	Indonesia	2	4
Data envelopment analysis	2	4	Intensification	2	3
Economic growth	2	4	Malaysia	27	33
Efficiency	2	4	Plantation management	2	1
Energy consumption	3	5	*Cluster 6: Smart farming via bioenergy*		
Paddy	2	4	Bioenergy	*2*	*4*
Production	2	2	Feed-in tariff	2	5
Sustainable agriculture	3	2	Oil palm biomass	3	8
Cluster 2: Smart farming via automation			Optimization	2	3
Arduino	3	4	Renewable energy	3	7
Automation	2	2	Sustainability	5	8
Farm	2	2	*Cluster 7: Smart farming involving decision-making process*		
Fuzzy logic	4	2			
Intelligent system	2	3	Adoption decision	2	5
Internet of things (IOT)	2	4	Food safety	2	2
Precision agriculture	4	5	Green fertilizer technology (GFT)	2	5
Smart farming	2	4	Paddy farmer	2	4
Urban farming	3	4	Theory of planned behaviour (TPB)	2	5
Cluster 3: Smart farming via machine learning			*Cluster 8: Smart farming via use of pesticides*		
Classification	3	6	Farmers	3	3
Classification algorithms	2	2	Oil palm	5	4
Deep learning	2	1	Pesticides	3	2
Image processing	4	6	Rice	2	3
Machine learning	3	5	Sarawak	2	2
Machine vision	2	4	*Cluster 9: Smart farming in changing environment*		
Remote sensing	4	3	Agriculture	8	11
Support vector machine	5	4	Climate change	4	8
Cluster 4: Smart farming via wind-powered technology			Food security	2	2
			Land-use change	2	4
Offshore wind energy	2	5	Life cycle assessment	2	2
Wind energy	2	3	Mitigation	2	2
Wind turbine	3	6	Southeast Asia	4	5

Note: OC= Occurrence, TLS = Total link strength for keyword co-occurrence among all keywords

- *Cluster 1: Smart farming in a sustainable manner*

The first cluster comprises of 10 keywords and centers upon various initiatives to conduct smart farming in a sustainable manner. The keyword co-occurrence in this cluster indicated that smart farming has been associated with sustainability in tandem with "sustainable agriculture" and "energy consumption". These are related to keywords such as "agriculture sector", "aquaculture", "CO2 emissions", "data envelopment analysis", "economic growth," "efficiency", "paddy", and "production".

- *Cluster 2: Smart farming via automation*

The second cluster contains 9 keywords and centers on the automation in smart farming technology. This cluster's work emphasis on mechanism to achieve automation via "arduino", "fuzzy logic", "intelligent system", "internet of things (IOT)", and "precision agriculture". Other keywords in this cluster are "farm", "smart farming", and "urban farming".

- *Cluster 3: Smart farming via machine learning*

The third cluster is made up of eight keywords, concentrated on the adoption of machine learning in smart farming. Machine learning is done through "classification algorithms", "deep learning", "image processing", "machine vision", "remote sensing", and "support vector machine".

- *Cluster 4: Smart farming via wind-powered technology*

The fourth cluster consist of three keywords emphasizing on how wind-powered technology can empower smart farming. The keywords related to this are "offshore wind energy", "wind energy", and "wind turbine".

- *Cluster 5: Smart farming via biotechnology*

The fifth cluster comprises of six keywords. The work in this cluster looks at bio-technology as a way to perform smart farming. Keywords in this cluster that point towards that are "food technology", "intensification" and "plantation management". Two more keywords "Indonesia" and "Malaysia" in this cluster suggest that these two countries have been practicing bio-technology in their farming processes.

- *Cluster 6: Smart farming via bioenergy*

The sixth cluster contains six keywords focusing on using bioenergy in the operation of smart farming. Keywords found in this cluster pertaining to bio-energy are "feed-in tariff", "oil palm biomass", "optimization", "renewable energy", and "sustainability".

- *Cluster 7: Smart farming involving decision-making process*

The seventh cluster has five keywords that looks at the type of decision-making process when it comes to deciding how smart farming will be conducted. The keywords on making decision decisions are "adoption decision" and "Theory of planned behaviour (TPB)". Such example of situations that need decision to be made upon are on "food safety", "Green Fertilizer Technology (GFT)", and "paddy farmer".

- *Cluster 8: Smart farming via use of pesticides*

The eighth cluster revolved around the usage of pesticides in smart farming as seen through five keywords i.e., "farmers", "oil palm", "pesticides", "rice", and "Sarawak".

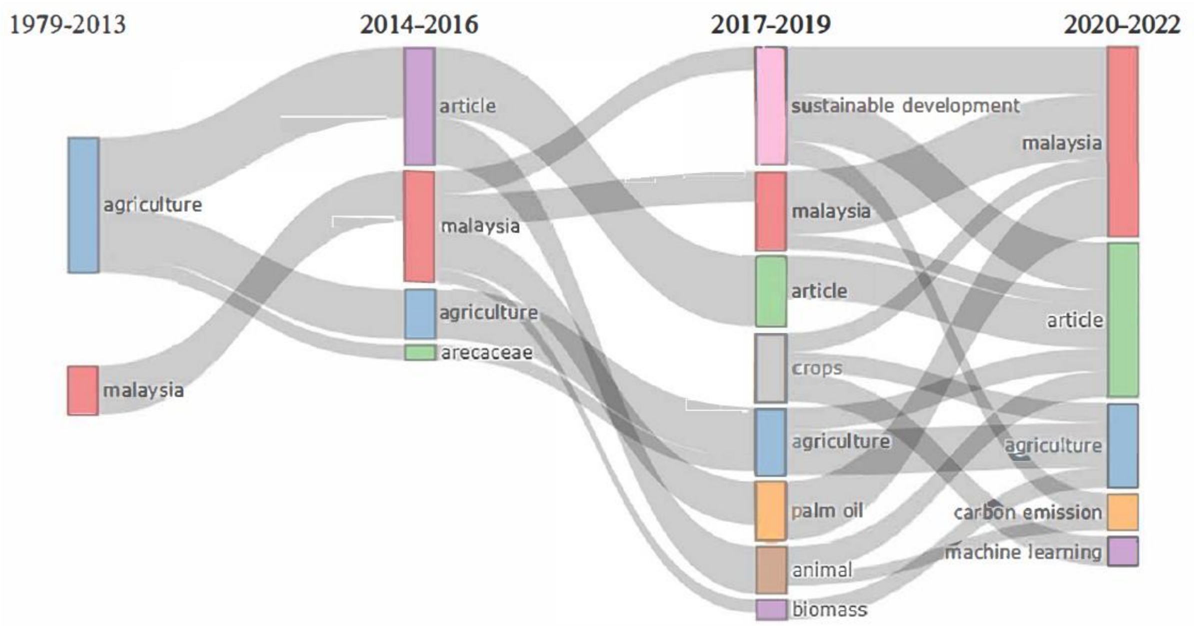
- *Cluster 9: Smart farming in changing environment*

The ninth cluster consists of seven keywords. The theme around this cluster is on how to manage smart farming in the ever-changing environment which is a key element in farming. Those keywords are "agriculture", "climate change", "food security", "land-use change", "life cycle assessment", "mitigation", and "Southeast Asia".

Evolution of SFT Research Over Time

Figure 4 shows the alluvial diagram on the evolution of SFT while **Error! Reference source not found.** depicts the evolution of themes in PO. The Biblioshiny programme has been used to analyse the development of themes. Three time slices were used to split the data period into four time zones. The first time zone runs from 1979 to 2013, while the next time zones have 3-year periods of 2014 to 2016, 2017 to 2019, and 2020 to 2022 (current). The time period was set at three years to give a clearer picture of the themes' evolution every three years.

Figure 4. Alluvial diagram of SFT research



DISCUSSIONS

The first publication related to SFT in Malaysia was related to precision farming along with publications studying soil properties and sustainable agriculture in 1979. Othman (2015) found that the research interest in SFT budded in 1999 with 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, 2015). Although 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 SFT in Malaysia started from precision farming in paddy cultivation with the focus of understanding the soil properties to achieve sustainable agriculture.

In 2004 when the research 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 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.

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). The concept of vertical farming emerged in 2018 to introduce urban farming techniques using hydrophobic green materials. Studies from 2018 to 2022 presented the application of automations such as UAV and AI.

IMPLICATIONS

Theoretical implications

The literatures related to the development of SFT in Malaysia were analysed to map the bibliometric attributes and the knowledge structure of the SFT domain. In general, the bibliometric analysis shed light on the leading authors, countries, institutions, outlets, articles, themes, and topics of SFT research from 1979 to 2022, which encompass a period of about 50 years. In particular, the co-authorship, citation, keyword co-occurrence, PageRank, publication, and social network analyses performed and reported in this research. This study identified gaps in the current body of research on smart farming technologies in Malaysia, which could inform future research efforts and guide the development of new technologies. This study also analysed the collaboration patterns among researchers, institutions, and industries involved in the development of smart farming technologies in Malaysia. This could provide insights into the strengths and weaknesses of the current research ecosystem and inform efforts to foster collaboration and knowledge-sharing. It also provide a benchmark for the performance of Malaysia in the development of smart farming technologies compared to other countries, regions or international standards. Lastly, this study highlighted the evolution of the research topics, the growth of the field, the emergence of new trends, and the impact of policy and funding decisions on the development of smart farming technologies in Malaysia.

Managerial implications

The first focus of the scientific literature was on the development of SFT. The second was on the management of these technologies and integration in supply chains and on farms. The third is on the impact of these technologies on the production system and the environment. The study could identify market opportunities for the development and commercialization of smart farming technologies in Malaysia. This could inform the strategic decision making of companies and organizations looking to invest in the field. The insights into the collaboration patterns among researchers, institutions, and industries involved in the development of smart farming technologies in Malaysia could inform the development of strategic partnerships between companies, research institutions, and government agencies to support the growth and commercialization of new technologies. As this study serve as a benchmark for the performance of Malaysia in the development of smart farming technologies compared to other countries, regions or international standards, this could inform the development of strategies to improve the competitiveness of the agricultural industry in Malaysia. Currently, scientific efforts have mainly been directed toward the development of SF hardware and software solutions. The application of these technologies at the farm level should intensify in the coming years. Therefore, it will be necessary to connect the technologies and the collected data in order to automate decision-making strategies. Before it becomes a techno-economic paradigm, a consistent scientific paradigm is needed to allow these innovations to emerge.

Recommendations

While the study of smart farming technologies has been broad, future research should focus on specific applications, such as precision irrigation, crop monitoring, and livestock management, to gain a deeper understanding of the benefits and challenges of these technologies in the Malaysian context. Research should investigate the barriers to adoption of smart farming technologies by farmers in Malaysia. This could include factors such as cost, lack of awareness, or lack of infrastructure. Future research should also study the economic and social impacts of smart farming technologies in Malaysia. This could include analysing the effect on farm productivity, income, and employment, as well as the impact on rural communities and the environment. In addition, collaboration between researchers, farmers, and industry stakeholders should be promoted to develop and implement smart farming technologies in Malaysia. This could include partnerships between universities, research institutions, and private companies, as well as collaborations between local and international researchers.

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