Smart Farming Adoption – A Scoping Review

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Abstract. Smart farming, one of the most rapidly growing technologies in the agriculture sector in the midst of the Industrial Revolution 4.0 era, signifies the integration of technologies into the industry. Numerous challenges in the agriculture sector were able to be decoded and formulated efficiently. Over the past few years, research on smart farming has grown expeditiously, observing every different cornerstone of the sector. This scoping review investigates the adoption of smart farming technologies, addressing the critical issue of enhancing agricultural productivity and sustainability. The main objective of this study is to investigate the adoption of exogenous factors in smart farming technology through the lens of a scoping review, identifying the challenges faced by stakeholders. Selections of articles from several different sources published between 2010 and 2024 with specific keywords were thoroughly observed. Valuable information was identified and discussed, particularly the positive and negative factors influencing the adoption of smart farming. This study found that while smart farming technologies hold promises for the transformation of the agriculture field, widespread adoption is obstructed by technological, economic, and social barriers. The study contributes to the understanding of smart farming adoption and serves as a bedrock for an upcoming study in technology adoption, promoting efficient and sustainable agricultural practices.

Keywords: smart farming; technology adoption; IR 4.0; sustainable development goals

1. Introduction

The term "smart" is compatible across various domains, namely education, manufacturing, and healthcare [1-5]. Smart farming technology emerged as the essence of a transformative technology in agriculture. Driven by the Fourth Industrial Revolution (IR 4.0), smart farming signifies the integration of cutting-edge technologies into conventional farming practices, promising a significantly efficient, sustainable, and productive agricultural environment. With the rapid advancement of the world today, the agriculture sector is set to witness a prominent transformation and pledge to address the challenges that arise [6].

Amidst this dynamic transformation, research and innovation on smart farming has seen an upward trend, comprising different areas and disciplines of agriculture and technology [7-10]. Stakeholders of all levels are actively exploring the potential of the technology. Therefore, understanding the factors influencing technology adoption is important as it sheds valuable insights, including both positive drivers and negative barriers.

The significance of adopting the technology extends beyond the business point of view. The study focuses on the broader landscape of societal prosperity. Aligned with the 2030 Agenda for Sustainable Development propelled by the United Nations, particularly the Sustainable Development Goal 2: Zero Hunger, the adoption of smart farming technologies has become a crucial solution worldwide [11]. Collaborative initiatives between researchers, policymakers, and other stakeholders are essential to the adoption of technology and the improvement of issues regarding food security in rural, suburban, and urban areas.

This scoping review aims to provide a comprehensive overview of the factors influencing the smart farming technology adoption. By analyzing the literature from a diverse source published between 2010 and 2024, this study seeks to identify the critical exogenous factors influencing the adoption process. Through a systematic analysis of the literature, this review serves as a bedrock, laying the groundwork for future research in this domain. The study is organized as follows. Section 2 describes the methodology completely. Then, the analysis and discussion are in Section 3. Finally, Section 4 concludes the study.

2. Methodology

The study was performed through the scoping review lens. A scoping review is a method that renders an overview, revealing the foundations of a research topic [12]. As proposed, a scoping review should include the key phases which will govern the methodology section.

2.1 Formulation of research questions

The following research questions were developed within the key context of the study, which directed the scoping review: (1) What are the main drivers of smart farming adoption? (2) What hinders the adoption of smart farming technology? These questions were determined to be consistent with the primary objective of the study, which was to observe the adoption of smart farming technology.

2.2 Inclusion and exclusion criteria

The study thoroughly examined literature from several different sources published between 2010 and 2024. The fourteen-year period was selected due to the subject's maturity, which is in line with the increased interest in the topic and practical technological progress [13]. The nature of the review is on smart farming; therefore, additional terms related to the topic are included. Literature written in languages other than English and Malaysian was excluded to avoid any misunderstanding and mistranslation on the topic. Table 1 illustrates the inclusion and exclusion criteria in detail.

Table 1. Inclusion and Exclusion Criteria.

Inclusion	Exclusion
Articles on the subject matter "Smart Urban Farming", "Urban Farming", "Digital Transformation", "Agriculture"	Articles written in other than English and Bahasa Malaysia language
Indexed journal articles	Indexed journal articles not accessible online
Smart farming specifically in the IT domain	Articles published before 2010

2.3 Search strategy

The databases used for the literature selection process were Scopus and Web of Science (WOS). A thorough search was conducted with specific keywords "smart urban farming", "urban farming", "digital transformation" and "agriculture". Figure 1 depicts the search results in Scopus and WOS.
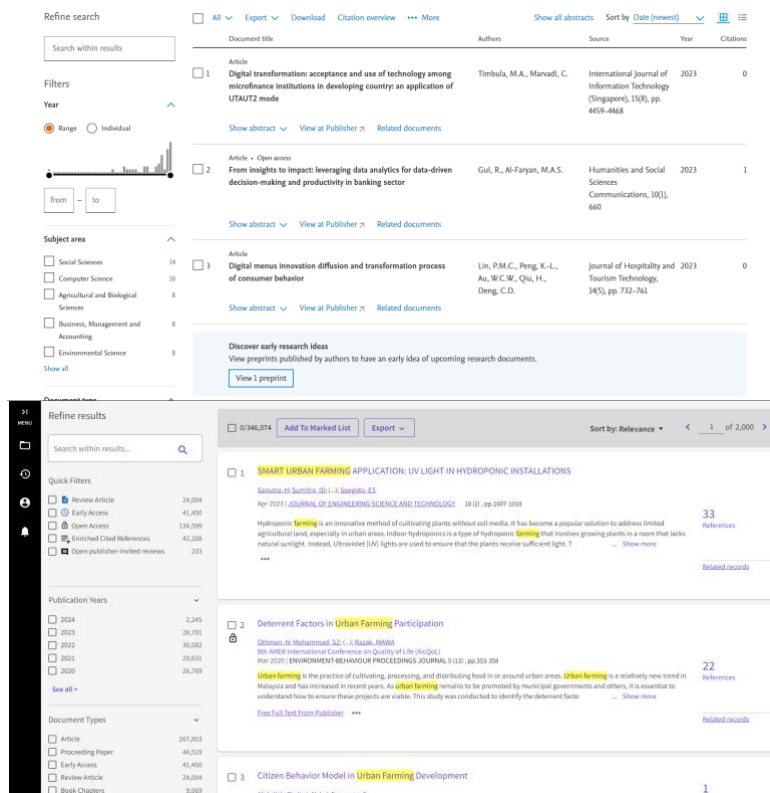

Figure 1. Search Results

2.4 Screening and selection

Screening and selection of literature were conducted to ensure the quality of the review. In the first stage, 756 articles were identified. The process of elimination began, with 320 articles being discarded due to duplication. The remaining articles were further examined by inclusion and exclusion criteria, discarding 59 articles. Further elimination process determined that 14 articles were eliminated due to the themes of the research. The remaining articles were prepared for quality appraisal by experts in the field of smart farming technology adoption. Seventeen articles adhering to the quality standard were deemed the most suitable for the scoping review. Figure 2 illustrates the article selection process.
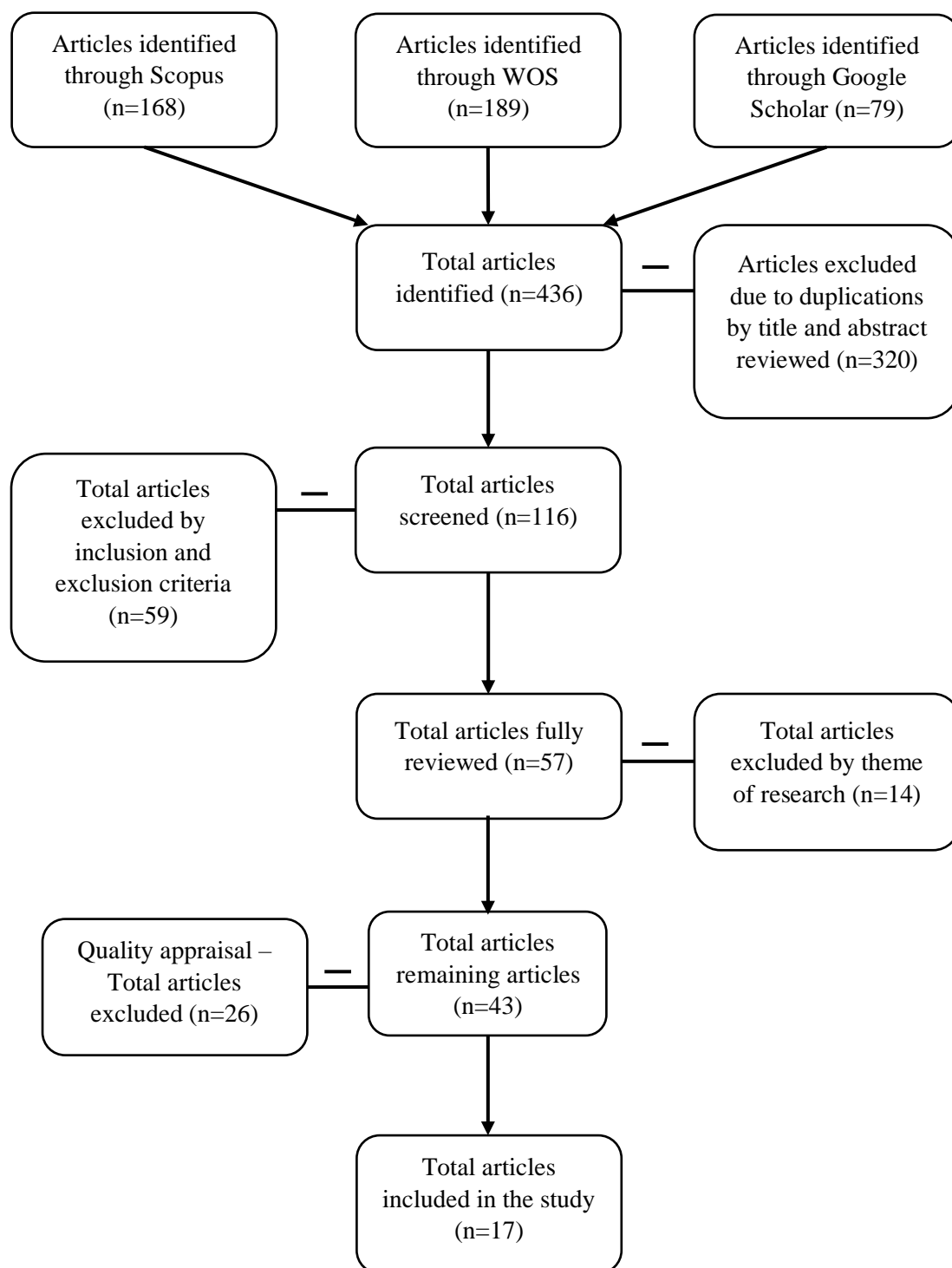
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┌─────────────────┐    ┌─────────────────┐    ┌─────────────────┐
│ Articles        │    │ Articles        │    │ Articles        │
│ identified      │    │ identified      │    │ identified      │
│ through Scopus  │    │ through WOS     │    │ through Google  │
│ (n=168)         │    │ (n=189)         │    │ Scholar (n=79)  │
└─────────────────┘    └─────────────────┘    └─────────────────┘
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Total articles identified (n=436) — Articles excluded due to duplications by title and abstract reviewed (n=320)

Total articles excluded by inclusion and exclusion criteria (n=59) — Total articles screened (n=116)

Total articles fully reviewed (n=57) — Total articles excluded by theme of research (n=14)

Quality appraisal – Total articles excluded (n=26) — Total articles remaining articles (n=43)

Total articles included in the study (n=17)

Figure 2. Article Selection Process

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2.5 Data extraction and analysis

The 17 pieces of finalized literature that fit the research questions formulated were analyzed. Appropriate and relevant data were extracted procedurally through a thorough observation of the literature. Firstly, appropriate information was scanned using the title and abstract of the literature. Afterward, the conclusion section was examined, followed by the body of the literature. Appropriate and relevant data that coincide with the theme of the study were identified and drawn into a table in Microsoft Word software. The factors weighed in the finalized literature were clustered (see Figure 3). Further analysis is discussed in section 3.
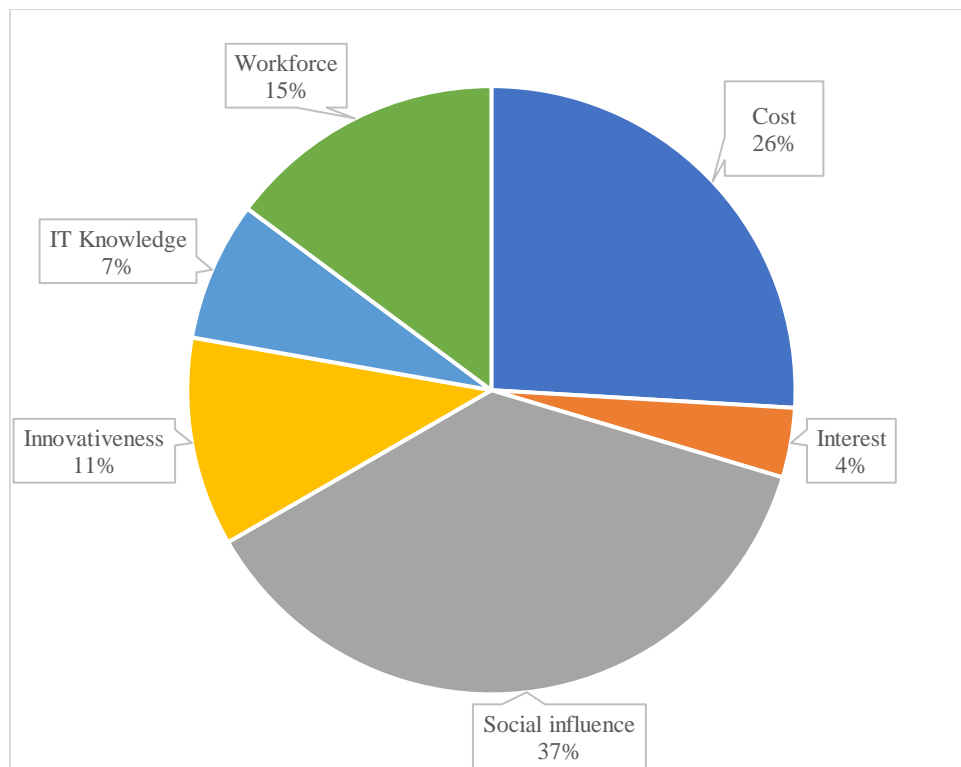

Figure 3. Factor Clusters from Previous Studies

3. Analysis and Discussion

Identified themes from the literature were discussed in this section. As illustrated in Figure 3, the main factors that affect the adoption of the smart farming technology were grouped into five clusters, that are cost (26%), social influence (37%), interest (4%), innovativeness (11%), IT knowledge (7%) and workforce (15%). Other factors from these studies were ruled out based on the theme of the scoping review. Table 2 lists the factors determined.

Table 2. Factors Determined from Previous Studies.

No.	Source	Factors					
		Cost	Social Influence	Interest	Innovativeness	IT Knowledge	Workforce
1.	Yoon, et al. [14]				*	*	
2.	Jaroenwanit, et al. [15]	*	*	*			
3.	Yokamo [16]		*				
4.	McDonald, et al. [17]						*
5.	Fox, et al. [18]	*	*				
6.	Li, et al. [19]		*				
7.	von Veltheim and Heise [20]		*				*
8.	Zhou and Abdullah [21]	*					
9.	Michels, et al. [22]						*
10.	Salimi, et al. [23]		*				
11.	Verma and Sinha [24]		*				
12.	Okoroji, et al. [25]	*	*			*	
13.	Fox, et al. [26]	*	*				
14.	Mohr and Kühl [27]				*		
15.	Bagheri and Emami [28]				*		
16.	Dai and Cheng [29]	*	*				
17.	Caffaro, et al. [30]	*					*

Social influence has been so often interpreted differently. It can be defined as the behavior of individuals towards something that meets the demands of the surrounding community. In a study, social influence is described as "sociopolitical pressure" [20]. Social influence is considered one of the strongest factors in technology adoption [18]. In another study, the factor significantly influenced the adoption of smart farming technology [15]. Farmers are driven by the norms of their surroundings, and if the technology is integrated, it would be considered a standard that will positively influence adoption. In a study, imitation was mentioned, as well as peer effects and norm-based diffusion in social-cultural factors, which could be interpreted as the same as social influence factors [16]. It was argued that cultural differences could both positively and negatively affect the perspectives of locals in certain areas. However, these views could be greatly influenced by participating in social groups, equipping participants with better information about the technology, hence amplifying the adoption of the technology. In some cases, social influence may have a negative influence on the technology adoption, depending on the practicality of the technology [25]. All agreed that social influence has an impact on technology adoption [20, 24-26, 29]. However, in a slightly different study conducted, particularly in precision agriculture technology, it was found that social influence negatively influenced the adoption of the technology [19]. This may be caused by the intricate and hefty farming management system. Similarly, in a study conducted which described in the proposed model, social influence had no impact on the adoption of smart farming [23].

The workforce is the backbone of any organization. Several studies supported the positive impact of the factor towards the adoption [17, 22, 30]. However, they all described the factors in different contexts. It was described that the entirety of all levels in an organization, from top to bottom, is taken in the context of the workforce [17]. In another study, it was discussed that the job relevance of drones by individuals is taken in the context of the workforce [22]. In another one, it was described that work should be done more quickly and workloads should be reduced, taken into account in the context of the workforce [30]. Although the positive impact of the factor is supported, it was pointed out that in some cases, workforce concerns include not having enough laborers for physically demanding roles, lack of numbers of skilled laborers, and roles displaced by autonomous robots which would potentially lead to a social problem [20]. This could definitely influence the adoption rate of smart farming.

Innovativeness is a tendency to be engaged in and adopt an idea. This factor implies that individuals or organizations that display higher levels of innovativeness are more likely to embrace new technologies. This was supported by the fact that innovativeness has a positive influence on technology adoption [28]. Another study defined the innovativeness factor into the CEO's role in an organization [14]. It was determined that the factors do not influence the adoption of the technology. This suggests that external factors other than the innovativeness of the head of the organization might play a crucial role in the adoption of technology. In a different context, another study defined the innovativeness factor in the farmers [27]. Similarly, it was concluded that the factor does not have an influence on supporting the adoption of the technology. However, it is important to note that this may be caused by the small sample size of their study, which could limit the outcome [27].

IT knowledge is the awareness, familiarity, and practical ability of a technology. This factor encompasses the IT skills possessed, including basic computing concepts and the capability to roam around the tools to solve technical problems. Considering the rapid changes of the modern digital world, IT knowledge enables individuals or organizations to effectively leverage technology effectively. A study conducted supported the IT knowledge factor positively, especially in developing countries [25]. In this particular case, technological advancements play a crucial role in economic and social development in developing countries. Enhancing IT knowledge literacy and training to the masses in these regions could aid in greater technology adoption, thereby contributing to the growth of the local economy and social life. On the contrary, in a different study, it was found that the factor does not have any influence on the adoption of the technology, which may be caused by the factor definition in a different context [14]. These strikingly different findings indicate that the impact may vary based on the context defined and measured.

Interest can be defined as the attention and curiosity of a person engaged in something. In the smart farming context, interest plays a crucial role in the acceptance of innovation. This significantly influences the acceptance of the innovation made in conventional agricultural practice [15]. Interest by individuals in smart farming technology would positively impact others around. This can be manifested in various ways, such as seeking more information about smart farming, participating in lectures or sharing sessions, or even experimenting with a new agricultural practice oneself. More often than not, these kinds of initiatives could influence others around to do the same thing, creating a ripple effect among peers.

4. Conclusion

Technology adoption is known as an inevitable challenge at all levels of society, depending on the nature of the technology. Integrating technologies into a conventional practice is a great idea on paper. However, adopting that wholistically may invite convictions from all levels of parties. Such innovations will definitely reshape the way any given field operates, including the users, consumers, businesses, industries, and policymakers.

In agriculture, the integration of "smart" is not an alien term. Smart farming has been around for quite some time. However, the adoption of smart farming itself has been rather low, especially in other parts of the world where conventional farming is still a major practice. As this study reviewed, the adoption

of the technology is rather demanding. Within the mounted methodology of the scoping review, several main factors are determined in the scope of smart farming adoption. Social influence, workforce, cost, innovativeness, interest, and IT knowledge. These factors, both positively and negatively, influence the adoption of the technology.

In this day and age, within the realm of the 2030 Agenda for Sustainable Development, proposed by the United Nations, governments play a vital role in assuring the prosperity of the nations for Sustainable Development Goal 2: Zero hunger, especially the developing nations. Governments should collaborate with researchers, experts, and other stakeholders, such as both SMEs and large corporations, to successfully execute the bills. The efforts should also extend to individuals and households, creating awareness and nurturing the culture of a self-sufficient home at all levels of society in rural, suburban, and urban areas.

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References
[1] K. A. Demir, "Smart education framework," *Smart Learning Environments,* vol. 8, no. 1, p. 29, 2021/11/06 2021, doi: 10.1186/s40561-021-00170-x.

[2] C. A. C. Flórez, J. M. Rosário, and D. A. Hurtado, "Application of Automation and Manufacture techniques oriented to a service-based business using the Internet of Things (IoT) and Industry 4.0 concepts. Case study: Smart Hospital," *Gestão & Produção,* vol. 27, 2020.

[3] M. Humayun, A. Alsirhani, F. Alserhani, M. Shaheen, and G. Alwakid, "Transformative synergy: SSEHCET—bridging mobile edge computing and AI for enhanced eHealth security and efficiency," *Journal of Cloud Computing,* vol. 13, no. 1, p. 37, 2024/02/08 2024, doi: 10.1186/s13677-024-00602-2.

[4] M. I. Nashiruddin and S. Winalisa, "Designing LoRaWAN Internet of Things Network for Smart Manufacture in Batam Island," in *2020 8th International Conference on Information and Communication Technology (ICoICT)*, 24-26 June 2020 2020, pp. 1-6, doi: 10.1109/ICoICT49345.2020.9166426.

[5] G. Yusufu and N. Nathan, "A Novel Model Of Smart Education For The Development Of Smart University System," in *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*, 18-21 March 2020 2020, pp. 1-5, doi: 10.1109/ICMCECS47690.2020.240912.

[6] M. Shahbandeh. "Smart agriculture - statistics & facts." Statista. https://www.statista.com/topics/4134/smart-agriculture/#topicOverview (accessed 21/2/2024, 2024).

[7] R. M. Ambong and M. Paulino, "Analyzing Rice Farmers' Intention to Adopt Modern Rice Technologies Using Technology Acceptance Model (TAM)," *Asian Research Journal of Agriculture,* pp. 21-30, 06/06 2020, doi: 10.9734/arja/2020/v13i130094.

[8] H. Dong, H. Wang, and J. Han, "Understanding Ecological Agricultural Technology Adoption in China Using an Integrated Technology Acceptance Model—Theory of Planned Behavior Model," (in English), *Frontiers in Environmental Science,* Hypothesis and Theory vol. 10, 2022-June-30 2022, doi: 10.3389/fenvs.2022.927668.

[9] P. Jain and Rekha, "Impact of Demographic Factors: Technology Adoption in Agriculure," *SCMS Journal of Indian Management,* Article vol. 14, no. 3, pp. 93-102, 2017. [Online]. Available: https://eresourcesptsl.ukm.remotexs.co/login?url=https://search-ebscohost-com.eresourcesptsl.ukm.remotexs.co/login.aspx?direct=true&db=bth&AN=125470371&site=eds-live.

[10]   S. Duang-Ek-Anong, S. Pibulcharoensit, and T. Phongsatha, "Technology Readiness for Internet of Things (IoT) Adoption in Smart Farming in Thailand," *International journal of simulation: systems, science & technology,* 2019.

[11]   United Nations. "Goal 2: Zero Hunger." United Nations. https://www.un.org/sustainabledevelopment/hunger/ (accessed March 22, 2024).

[12]   M. D. J. Peters *et al.*, "Updated methodological guidance for the conduct of scoping reviews," *JBI Evidence Synthesis,* vol. 18, no. 10, 2020, doi: https://doi.org/10.11124/JBIES-20-00167.

[13]   S. Kraus, M. Breier, and S. Dasí-Rodríguez, "The art of crafting a systematic literature review in entrepreneurship research," *International Entrepreneurship and Management Journal,* vol. 16, no. 3, pp. 1023-1042, 2020/09/01 2020, doi: 10.1007/s11365-020-00635-4.

[14]   C. Yoon, D. Lim, and C. Park, "Factors affecting adoption of smart farms: The case of Korea," *Computers in Human Behavior,* vol. 108, p. 106309, 2020/07/01/ 2020, doi: https://doi.org/10.1016/j.chb.2020.106309.

[15]   P. Jaroenwanit, P. Phuensane, A. Sekhari, and C. Gay, "Risk management in the adoption of smart farming technologies by rural farmers," *Uncertain Supply Chain Management,* vol. 11, pp. 533-546, 01/01 2023, doi: 10.5267/j.uscm.2023.2.011.

[16]   S. Yokamo, "Adoption of Improved Agricultural Technologies in Developing Countries: Literature Review," *International Journal of Food Science and Agriculture,* vol. 4, pp. 183-190, 06/01 2020, doi: 10.26855/ijfsa.2020.06.010.

[17]   N. McDonald, E. S. Fogarty, A. Cosby, and P. McIlveen, "Technology Acceptance, Adoption and Workforce on Australian Cotton Farms," *Agriculture*, vol. 12, no. 8, doi: 10.3390/agriculture12081180.

[18]   G. Fox, J. Mooney, P. Rosati, V. Paulsson, and T. Lynn, *Towards an Understanding of Farmers' Mobile Technology Adoption: A Comparison of Adoption and Continuance Intentions*. 2018.

[19]   W. Li *et al.*, "A hybrid modelling approach to understanding adoption of precision agriculture technologies in Chinese cropping systems," *Computers and Electronics in Agriculture,* vol. 172, p. 105305, 2020.

[20]   F. R. von Veltheim and H. Heise, "The AgTech Startup Perspective to Farmers Ex Ante Acceptance Process of Autonomous Field Robots," *Sustainability*, vol. 12, no. 24, doi: 10.3390/su122410570.

[21]   D. Zhou and Abdullah, "The acceptance of solar water pump technology among rural farmers of northern Pakistan: A structural equation model," *Cogent Food & Agriculture,* vol. 3, no. 1, p. 1280882, 2017/01/01 2017, doi: 10.1080/23311932.2017.1280882.

[22]   M. Michels, C.-F. von Hobe, P. J. Weller von Ahlefeld, and O. Musshoff, "The adoption of drones in German agriculture: a structural equation model," *Precision Agriculture,* vol. 22, no. 6, pp. 1728-1748, 2021/12/01 2021, doi: 10.1007/s11119-021-09809-8.

[23]   M. Salimi, R. Pourdarbani, and B. A. Nouri, "Factors Affecting the Adoption of Agricultural Automation Using Davis's Acceptance Model (Case Study: Ardabil)," *Acta Technologica Agriculturae,* vol. 23, no. 1, pp. 30-39, 2020, doi: doi:10.2478/ata-2020-0006.

[24]   P. Verma and N. Sinha, "Integrating perceived economic wellbeing to technology acceptance model: The case of mobile based agricultural extension service," *Technological Forecasting and Social Change,* vol. 126, pp. 207-216, 2018/01/01/ 2018, doi: https://doi.org/10.1016/j.techfore.2017.08.013.

[25]   V. Okoroji, N. Lees, and L. Xiaomeng, "Factors affecting the adoption of mobile applications by farmers: An empirical investigation," *African Journal of Agricultural Research,* vol. 17, pp. 19-29, 01/31 2021, doi: 10.5897/AJAR2020.14909.

[26]   G. Fox, J. Mooney, P. Rosati, and T. Lynn, "AgriTech Innovators: A Study of Initial Adoption and Continued Use of a Mobile Digital Platform by Family-Operated Farming Enterprises," *Agriculture*, vol. 11, no. 12, doi: 10.3390/agriculture11121283.

[27] S. Mohr and R. Kühl, "Acceptance of artificial intelligence in German agriculture: an application of the technology acceptance model and the theory of planned behavior," *Precision Agriculture,* vol. 22, no. 6, pp. 1816-1844, 2021/12/01 2021, doi: 10.1007/s11119-021-09814-x.

[28] A. Bagheri and N. Emami, "Farmers' intention to use precision farming technologies, application of the 3 extended technology acceptance model: A case in Ardabil province," *Journal of Agricultural Science and Technology,* 2024.

[29] Q. Dai and K. Cheng, "What Drives the Adoption of Agricultural Green Production Technologies? An Extension of TAM in Agriculture," *Sustainability*, vol. 14, no. 21, doi: 10.3390/su142114457.

[30] F. Caffaro, M. Micheletti Cremasco, M. Roccato, and E. Cavallo, "Drivers of farmers' intention to adopt technological innovations in Italy: The role of information sources, perceived usefulness, and perceived ease of use," *Journal of Rural Studies,* vol. 76, pp. 264-271, 2020/05/01/ 2020, doi: https://doi.org/10.1016/j.jrurstud.2020.04.028.