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Charting the Path: A Framework for Embracing Smart Agriculture in Malaysia

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ABSTRACT

The emergence of "smart agriculture" stands out as a notable trend driving growth within the agricultural sector. This trend has sparked a global surge in campaigns urging farmers to adopt sustainable agricultural practices. However, there remains a scarcity of published research addressing comprehensive factors that influence smart agriculture adoption, particularly in Malaysia. This study combines qualitative and quantitative insights from 12 industry experts specializing in rice-based smart agriculture technology. Its objective is to formulate an innovative framework for smart agriculture adoption in Malaysia, utilizing the Fuzzy Delphi Method. The framework, rooted in the perspectives and consensus of agricultural experts, comprises four key factors: individual, organizational, technical, and environmental. Drawing from prior empirical research, the framework encompasses 31 elements across these factors. Notably, six elements were deemed unsuitable by fewer than 75% of the experts surveyed. These study findings serve as valuable guidance for navigating pivotal decision-making junctures concerning the successful implementation of smart agriculture in Malaysia.

1. Introduction

Agricultural systems require leveraging innovation and technology to improve the efficiency, quality, and output of agricultural processes and products. Amidst the recent global challenges, including the threat of a food shortage due to COVID-19-related trade disruptions, there's a pressing need to strengthen food production capacity. This necessitates making agricultural systems more

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sustainable through the adoption of new technologies, catering to increasing food demand and emerging market opportunities.

Digital innovations in smart agriculture are pivotal for enhancing productivity, competitiveness, and profitability. National-level evaluations of digital agricultural systems are crucial for comprehending their intricate dynamics. By investigating the engagement and adaptation of these systems by diverse actors, a clearer understanding of their complexities can be attained. Throughout the innovation process, actors' roles may evolve, necessitating a nuanced understanding of how innovations cater to diverse needs and contexts [1].

Malaysia is determined to revitalize its agricultural industry, emphasizing modernization and smart agriculture, highlighting the importance of this agenda to propel the country's agro-food sector sustainably and technologically forward [2]. While current participation of young people in agriculture remains limited, there's a growing interest among them to embrace contemporary farming practices, potentially reshaping the sector soon. Some are even willing to forgo secure jobs for the lucrative opportunities offered by agriculture [3].

The adoption of modern agriculture faces multifaceted challenges in Malaysia and globally as depicted in Table 1. All shortcomings were taken into consideration when developing the framework with experts. These challenges underscore the need for comprehensive strategies to address barriers to modern agricultural practices and ensure the sector's sustainable development.

Table 1
Related research by others on digital agriculture

Reference	Category	Findings
Dr. Kanwar B. *et al.*, [4]	Concerns about Agriculture and Food Security	Issues include increasing productivity, ensuring food quality, sustainable practices, and environmental preservation.
Mohd Rozaimy Ridzuan, [5]	Natural Disasters	Floods and droughts threaten farmers' livelihoods and hinder agricultural sustainability.
Mohd Rozaimy Ridzuan, [5]; Jia-Qi Cheong, [6]	Lack of Technological Adoption	Limited research and resources constrain the adoption of modern technologies in agriculture.
Alexandr Sakal, [7]	Land Restrictions	Farmers hesitate to adopt modern agriculture due to land limitations and acquisition challenges.
Shiva Pujan Jaiswal *et al.*, [8]	High Costs	High financial investments and inadequate farmer knowledge hinder modernization and technology adoption.
Alexandr Sakal, [7]	Ageing Farmer Population	Age demographics skew towards older farmers, creating challenges for adopting modern technologies.
Alexandr Sakal, [7]; Pathma Subramaniam, [9]	Telecommunications Infrastructure	Limited rural internet connectivity impedes the implementation of agricultural technologies.
X. Yang *et al.*, [10]	Security Concerns	Smart agriculture introduces risks to agricultural production and IT, requiring robust security measures.
Ahmad *et al.*, [11]	Limited Coverage of Small-scale Farmers	Significant barriers in adopting smart farming technologies due to limited resources and technical knowledge.
Zaman *et al.*, [12]		Rice farmers struggle with high initial investment costs.
Jamalut *et al.*, [13]		Digital divide between large-scale commercial farms and smallholder farmers.
Ibrahim *et al.*, [14]	Technology Infrastructure Gaps	Challenges in maintaining consistent internet connectivity for IoT systems.
Jamalut *et al.*, [13]		Lack of necessary telecommunications infrastructure in rural areas.

Despite the importance of smart agriculture, there is a lack of comprehensive research on its potential and adoption challenges in Malaysia. Identifying overlooked concerns is imperative to ensure accurate decision-making.

The agricultural sector worldwide is under pressure to adopt sustainable practices to meet escalating food demands and seize emerging market opportunities through innovation and technology [15]. Understanding a country's specific context, including barriers to innovation, policy roles, and governance structures, is crucial [16,17].

In Malaysia, there is a notable gap in comprehensive research analyzing the factors influencing the success of smart agricultural knowledge and innovation systems. This study aims to address this gap by proposing a novel framework tailored to empower Malaysia's smart agricultural knowledge and innovation systems. Hence, this study employs the Fuzzy Delphi Method to devise a novel framework for smart agriculture adoption in Malaysia, drawing insights from 12 experts in rice-based smart agriculture technology. The research encompasses both qualitative and quantitative data and aims to provide a comprehensive framework to guide critical decision-making in Malaysia's smart agriculture deployment. The adoption of smart agriculture hinges on four key factors: individual, organizational, technological, and environmental. A robust framework will not only aid in current adoption efforts but also pave the way for future advancements such as automated systems, robotics, and artificial intelligence within the realm of smart agriculture.

2. Materials and Methods

The research methodology comprises two main parts: firstly, the overall approach adopted, and secondly, the application of the Fuzzy Delphi method in developing the framework.

2.1 Research Design

The study employs design research, aiming to gather reliable and pertinent insights into smart agriculture. It involves data collection from expert interviews, creation of instruments based on initial interviews, and iterative interpretation to shape the framework. Specifically, the Fuzzy Delphi method guides the design process, drawing on expert opinions and consensus.

Primary and secondary data sources are utilized, with primary data obtained from expert interviews. Respondents are meticulously selected to ensure accuracy and relevance, with 12 managers representing farmers, public agro-authorities, and information technology specialists. Expert questionnaires are designed using various methods, and responses are collected using the Likert Scale.

2.2 Fuzzy Delphi Method (FDM)

The Smart Agriculture Adoption Framework is developed using the Fuzzy Delphi Method (FDM), derived from the traditional Delphi technique. The process involves several steps as shown in Table 2 below:

Table 2
Steps involved in developing Smart Agriculture Adoption Framework using the Fuzzy Delphi Method (FDM)

Step	Description
1	Experts are carefully chosen to provide relevant insights, with 12 managers from various sectors participating.
2	Expert questionnaires are conducted via interviews and literature review, with responses measured on the Likert Scale.
3	Data collection methods include expert meetings and distribution of questionnaires via Google Survey.
4	Linguistic variables are transformed into triangular fuzzy numbers to represent uncertainty in expert responses.
5	Data analysis is based on triangular fuzzy numbers to obtain a threshold value and ensure expert agreement.
6	Expert agreement percentage is determined, with a threshold of 75.0%.
7	Analysis involves obtaining fuzzy scores through defuzzification, ensuring acceptance of elements based on expert agreement.

This comprehensive methodology ensures a systematic approach to developing the Smart Agriculture Adoption Framework, incorporating expert insights and addressing uncertainties in the adoption process.

3. Proposed Framework

This study aimed to present a novel framework for smart agriculture adoption in Malaysia, incorporating insights and consensus from agricultural experts through qualitative and quantitative research methods. The Fuzzy Delphi Method guided the framework's development as proposed in Figure 1. A detailed explanation of the factors and elements chosen are given in the next part of the paper.

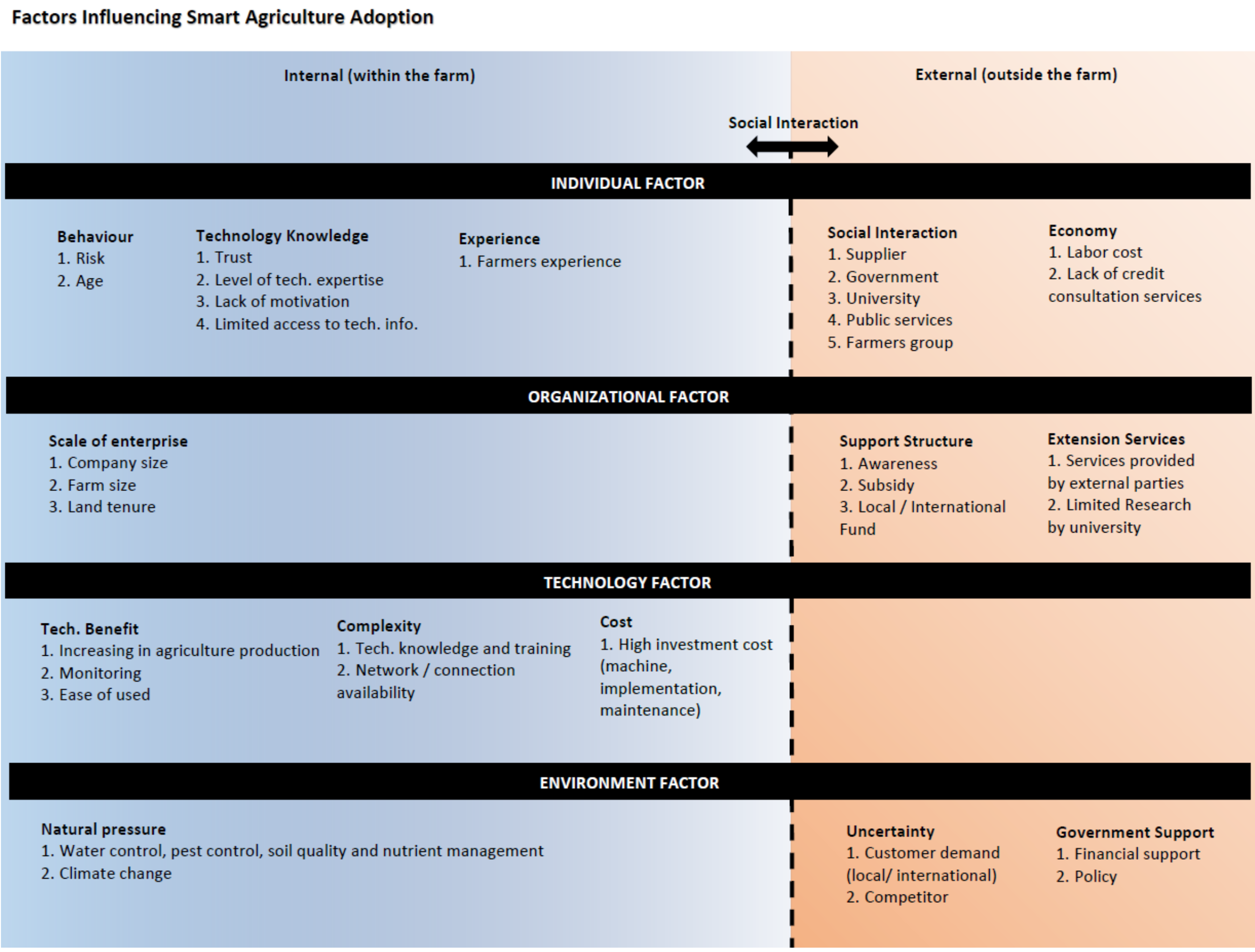

Fig. 1. A proposed framework for smart agriculture adoption in Malaysia

4. Results and Discussions

Based on prior research findings, four primary factors were identified, leading to an in-depth exploration that revealed 31 elements. These factors were discerned through the Fuzzy Delphi Method involving 12 experts and Likert scales. The adoption of smart agriculture is influenced by both internal and external factors, categorized into individual, organizational, environmental, and technological factors, as below:

4.1 Individual Factor

The individual factor encompasses 11 components (Table 3). Notably, training in technological competence emerged as the most pivotal aspect, with unanimous agreement among experts. Other influential elements include the degree of expertise, social interaction, motivation, adoption risk perception, economic factors, and technical expertise. However, elements such as farmer's age and experience were rejected by 50% of experts' consensus, suggesting negligible impact on technology adoption.

Table 3
Individual factor and 11 elements influencing smart agriculture adoption in Malaysia by using Fuzzy Delphi Method

No	Item/Element	Condition of Triangular Fuzzy Numbers		Condition of Fuzzy Evaluation Process				Expert Consensus Decision	ACCEPTED Element	Ranking
		Threshold Value (d)	Percentage of Expert Consensus (%)	m1	m2	m3	Fuzzy Score (A)			
1	Individual - Behavior (Risk)	0.233	75.00%	0.417	0.617	0.817	0.617	ACCEPT	0.617	22
2	Individual - Behavior (Age)	0.275	50.00%	0.383	0.567	0.767	0.572	REJECT	0.572	27
3	Individual - Technology Knowledge (Training)	0.085	100.00%	0.567	0.767	0.967	0.767	ACCEPT	0.767	1
4	Individual - Technology Knowledge (Level of Expertise)	0.115	100.00%	0.550	0.750	0.950	0.750	ACCEPT	0.750	4
5	Individual - Technology Knowledge (Motivation)	0.178	91.67%	0.483	0.683	0.883	0.683	ACCEPT	0.683	15
6	Individual - Technology Knowledge (Limited access to Technology Info.)	0.199	83.33%	0.283	0.483	0.683	0.483	ACCEPT	0.483	31
7	Individual - Experience	0.153	50.00%	0.400	0.600	0.800	0.600	REJECT	0.600	25
8	Individual - Social Interaction (Supplier, government, university, public services)	0.153	100.00%	0.500	0.700	0.900	0.700	ACCEPT	0.700	12
9	Individual - Social Interaction (Farmer's group)	0.178	91.67%	0.500	0.700	0.900	0.700	ACCEPT	0.700	12
10	Individual - Economy (Cost of labor)	0.187	75.00%	0.417	0.617	0.817	0.617	ACCEPT	0.617	23
11	Individual - Economy (Credit	0.170	91.67%	0.517	0.717	0.917	0.717	ACCEPT	0.717	8

consultant services)

4.2 Organizational Factor

The organizational factor comprises eight elements (Table 4). Key factors contributing to smart agriculture adoption include a robust support system for technology adoption, subsidy support, extension services, and technological awareness. While factors like firm size and insufficient university research showed minimal impact, elements such as scale of enterprise and land tenure received 75% expert consensus.

Table 4
Organizational factor and 8 elements influencing smart agriculture adoption in Malaysia by using Fuzzy Delphi Method

No	Item/Element	Condition of Triangular Fuzzy Numbers		Condition of Fuzzy Evaluation Process				Expert Consensus Decision	ACCEPTED Element	Ranking
		Threshold Value (d)	Percentage of Expert Consensus (%)	m1	m2	m3	Fuzzy Score (A)			
12	Organizational - Scale of enterprise (Company size)	0.191	66.67	0.383	0.583	0.783	0.583	REJECT	0.583	26
13	Organizational - Scale of enterprise (Farm size)	0.353	8.33%	0.417	0.600	0.800	0.606	REJECT	0.606	24
14	Organizational - Scale of enterprise (Land tenure)	0.215	75.00%	0.350	0.533	0.733	0.539	ACCEPT	0.539	30
15	Organizational - Support structure (Technology awareness)	0.170	91.67%	0.517	0.717	0.917	0.717	ACCEPT	0.717	8
16	Organizational - Support structure (Subsidy)	0.115	100.00%	0.550	0.750	0.950	0.750	ACCEPT	0.750	4
17	Organizational - Support structure (Local and international funding)	0.085	100.00%	0.567	0.767	0.967	0.767	ACCEPT	0.767	1
18	Organizational - Extension Services (Services by external parties/visit	0.136	100.00%	0.533	0.733	0.933	0.733	ACCEPT	0.733	7

19	by agriculture officer) Organizational - Extension Services (Limited technology research by university)	0.340	41.67%	0.367	0.550	0.750	0.556	REJECT	0.556	28

4.3 Technology Factor

The technology factor consists of six elements (Table 5). Ease of use emerged as the primary driver for adopting smart agriculture, backed by unanimous expert consensus. Other significant factors include technology's advantage in monitoring weather, boosting farm productivity, and complexity of usage. Despite concerns over network connectivity in rural areas, technology's overall ease of use remains paramount. This factor is in line with other researches, namely Zaman *et al.*, [12], and Khanil *et al.*, [18].

Table 5
Technology factor and 6 elements influencing smart agriculture adoption in Malaysia by using Fuzzy Delphi Method

No	Item/Element	Condition of Triangular Fuzzy Numbers		Condition of Fuzzy Evaluation Process				Expert Consensus Decision	ACCEPTED Element	Ranking
		Threshold Value (d)	Percentage of Expert Consensus (%)	m1	m2	m3	Fuzzy Score (A)			
20	Technology - Technology benefit (Increasing in agriculture production)	0.170	91.67%	0.467	0.667	0.867	0.667	ACCEPT	0.667	17
21	Technology - Technology benefit (Monitoring)	0.208	91.67%	0.483	0.683	0.883	0.683	ACCEPT	0.683	15
22	Technology - Technology benefit (Ease of used)	0.085	100.00%	0.567	0.767	0.967	0.767	ACCEPT	0.767	1
23	Technology - Complexity (Technology knowledge and training)	0.204	91.67%	0.467	0.667	0.867	0.667	ACCEPT	0.667	17
24	Technology – Complexity (Network connection/ connection availability)	0.170	83.33%	0.433	0.633	0.833	0.633	ACCEPT	0.633	21

25	Technology - Cost (High investment cost on machine/ implementation / maintenance)	0.319	50.00%	0.350	0.533	0.733	0.539	REJECT	0.539	29

4.4 Environment Factor

The environment factor includes six elements (Table 6). Natural pressures from climate change, water and insect control, and government financial assistance are deemed critical for smart agriculture adoption, receiving unanimous expert consensus. Additionally, government support policies, competition unpredictability, and client demand also play substantial roles. Notably, no elements were eliminated due to insufficient consensus, highlighting the collective acknowledgment of environmental factors' significance.

Table 6
Environment factor and 6 elements influencing smart agriculture adoption in Malaysia by using Fuzzy Delphi Method

No	Item/Element	Condition of Triangular Fuzzy Numbers		Condition of Fuzzy Evaluation Process				Expert Consensus Decision	ACCEPTED Element	Ranking
		Threshold Value (d)	Percentage of Expert Consensus (%)	m1	m2	m3	Fuzzy Score (A)			
26	Environment - Natural pressure (Water control, pest control, soil quality and nutrient management)	0.149	100.00%	0.517	0.717	0.917	0.717	ACCEPT	0.717	8
27	Environment - Natural pressure (Climate change)	0.115	100.00%	0.550	0.750	0.950	0.750	ACCEPT	0.750	6
28	Environment - Uncertainty (Customer demand from local/ international)	0.301	75.00%	0.467	0.650	0.850	0.656	ACCEPT	0.656	19
29	Environment - Uncertainty (Competitor)	0.212	83.33%	0.433	0.633	0.833	0.633	ACCEPT	0.633	20
30	Environment - Government Support (Financial support)	0.149	100.00%	0.517	0.717	0.917	0.717	ACCEPT	0.717	8

31	Environment - Government Support Policy)	0.178	91.67%	0.500	0.700	0.900	0.700	ACCEPT	0.700	12

These findings provide a comprehensive understanding of the multifaceted determinants shaping the adoption of smart agriculture in Malaysia, essential for developing targeted strategies and policies to facilitate its advancement.

The outcomes of this study are poised to offer substantial insights to the Ministry of Agriculture and Food Industries, illuminating prevailing challenges and effective strategies to navigate the current landscape. It highlights the pivotal roles of all stakeholders - farmers, public authority officers, and IT experts in driving the successful adoption of smart agriculture in Malaysia, underscoring their respective contributions and significance. This research lays a robust foundation for policy formulation and strategy development, facilitating the accelerated application of current technology in agriculture.

5. Conclusion and Future Recommendation

The study's findings reveal that variables related to smart agricultural practices adoption can be categorized into a four-factor dimension consisting of 31 elements. These factors encompass individual, organizational, technological, and environmental considerations. However, the expert consensus identified six elements that were rejected by less than 75% of the experts.

The adoption of smart agriculture is influenced by a multitude of elements. Despite the extensive research documented in the past, this study highlights a gap in the literature regarding factors influencing the adoption of smart agricultural technology.

The study acknowledges several methodological limitations that could impact the generalizability of its findings. Firstly, the use of a self-report questionnaire scale introduces the potential of limitations inherent in subjective reporting. Additionally, the cross-sectional nature of the data limits the study's ability to draw causal conclusions or assess changes over time accurately. Furthermore, the data were exclusively obtained from 12 specialists focused on rice-based smart agricultural technology in Malaysia, potentially restricting the framework's relevance to other locations or nations and other agricultural technologies.

To address these limitations and broaden the scope of future research, it is recommended to conduct studies in various locations and with different agricultural technologies. Additionally, future studies may explore alternative dependent variables beyond rice-based smart agricultural technology adoption metrics to provide a more comprehensive understanding of agricultural technology adoption. This could involve examining various technology-based agriculture techniques such as agriculture robotics, sensor systems, and other emerging technologies. By diversifying the focus of research and methodologies, future studies can contribute to a more nuanced understanding of the factors influencing smart agriculture adoption across different contexts and technologies.

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