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Integration of Agri-Tech Tools Among Malaysian Women Agripreneurs in Sustainable Farming

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ABSTRACT

This study investigates how Malaysian women agripreneurs adopt agricultural technology (Agri-Tech) to support sustainable farming practices. Despite agriculture contributing 8.4% to Malaysia's GDP and employing 16% of its workforce, women agripreneurs face significant adoption challenges, with Agri-Tech investments representing only 2.10% of the sector's digital expenditures. Through semi-structured interviews with 14 women agripreneurs who participated in the Department of Agriculture's training course, the study identified various Agri-Tech applications, including digital farm management systems, precision agriculture, and digital marketing platforms. Benefits included improved market access, resource optimisation, cost reduction, and environmental sustainability. However, barriers persisted: financial constraints, knowledge gaps, poor infrastructure, inadequate technical support, and unfavourable policies. Recommendations include targeted financial assistance, expanded digital training, improved rural connectivity, better technical support, and policy reforms prioritizing small-scale women agripreneurs. This research uniquely contributes to understanding gender-specific dimensions of Agri-Tech adoption in Southeast Asian agriculture. Future research should examine longitudinal impacts and policy effectiveness in addressing identified barriers.

Keywords: *Agri-Tech tools, sustainable farming, women agripreneurs*

1.0 INTRODUCTION

The agricultural sector in Malaysia makes a significant contribution to economic growth, representing 8.4% of the country's Gross Domestic Product (GDP) and employing 16% of the population (MAFS, 2024). Agricultural technology (Agri-Tech) is revolutionising the sector, which had been largely based on conventional farming methods. Revolutionary concepts, including precision farming, automation, digital monitoring systems, and biotechnological processes, are the keys to enhancing productivity, sustainability, and resource optimisation (ASEAN, 2022). Increasing global food demand and inherent environmental issues create a need for every possible solution, including ensuring sustainable agricultural development while creating additional economic potential (FAO, 2021).

In this changing agricultural landscape, Malaysian women entrepreneurs have emerged as vital contributors to farming and agribusiness. Their integration of modern technologies has significantly enhanced operational efficiency and market competitiveness. Recognising their importance, the Malaysian government has developed several initiatives encouraging women to embrace agricultural technology as a pathway to success. The National Agrofood Policy emphasizes sustainability while incorporating strategies for women's empowerment through improved access to financing, training programs, and technological resources (Haque et al., 2019). Financial support mechanisms like the Women Entrepreneurs Financing Program (DanaNITA) by Majlis Amanah Rakyat provide crucial funding for women-owned agricultural businesses seeking to invest in modern farming technologies (MARA, 2023). The Malaysian Women's Development Action Plan focuses on bringing digital literacy to female farmers, fostering their inclusion in the increasingly digitized agricultural sector (ASEAN, 2022). Additionally, specialised Women in Agriculture Initiatives offer targeted training in agricultural technology and skill development to promote sustainable farming practices (MAFS, 2023).

Despite these governmental efforts, women agricultural entrepreneurs continue to face considerable obstacles in fully adopting technological tools. Financial limitations, insufficient digital literacy, and persistent gender-based barriers restrict their ability to leverage technology effectively (OECD, 2021). The agricultural sector in Malaysia has experienced slower digital transformation than other industries, with agricultural technology investments accounting for merely 2.10% of total digital expenditures (MDEC, 2022). Women farmers struggle with limited access to financial facilities and face heightened collateral requirements when seeking funding. Furthermore, societal norms sometimes discourage women from making independent business decisions, severely limiting their capacity for innovation and business expansion (Waqar et al., 2021).

This research examines how women agricultural entrepreneurs in Malaysia are adopting technological tools and evaluates their effectiveness in enhancing sustainable farming practices despite existing challenges. The study also identifies significant barriers limiting technology adoption and proposes recommendations for improving uptake. By embracing agricultural technology, the sector's potential to contribute to sustainability, food security, and economic resilience can be substantially enhanced, ensuring Malaysian women entrepreneurs play a central role in the ongoing modernization of agriculture.

2.0 LITERATURE REVIEW

2.1 Agri-Tech in Sustainable Farming

Agricultural technology (Agri-Tech) is the use of technology in agricultural practices to improve productivity, sustainability, and efficiency. Farmers can maximise net efficiency and tackle primary challenges within the agricultural system, such as climate change and food insecurity, using innovative tools and suitable data (Yechin et al., 2021). The shift from traditional farming methods to modern agricultural practices in Malaysia has been evident since the 1980s, with the nation placing importance on technological advancement to drive yield and accessibility to the market (Sharma et al., 2021).

A few assortments of Agri-Tech tools are being utilised in sustainable farming, such as precision farming, IoT applications, and AI-based arrangements. Precision agriculture utilises modern technology such as GPS and remote sensing to develop more field-specific farming management (Khanna & Kaur, 2019; Sharma et al., 2021). IoT applications enable real-time data collection and monitoring. When real-time data is available, farmers can make better decisions according to the current environment and crop health status. (Sadiku et al., 2021). AI-powered solutions help to analyse data and create predictive modelling for specific crops, thus integrating it into management practices (Khanna & Kaur, 2019; Sharma et al., 2021). For example, smart irrigation systems can play an important role in sustainable farming by using sensors to conserve water and reduce wastage (Sagheer et al. 2020). However, while the technical capabilities of these tools have been well-documented, their actual implementation in specific socio-cultural contexts, particularly by women farmers in developing economies, remains understudied.

2.2 Women Agripreneurs in Malaysian Agriculture

Women agripreneurs in Malaysia play a crucial role by actively participating in agricultural sectors and contributing to the food production supply chain, rural economic development, and sustainable initiatives (Mohd et al. 2018; Anderson et al. 2020). Their growing participation is largely driven by government policies, financial assistance, and increasing access to technology. Women entrepreneurs are a substantial force in the industry, making up nearly 20% of registered agripreneurs (Razak et al., 2024). These agripreneurs are improving productivity and fostering sustainability by employing modern agriculture practices and innovative technologies. Their participation in community-based agriculture programs also highlights their contribution to promoting empowerment and positive change in the sector (Azis et al., 2023). Despite their significant presence, there is a notable research gap regarding women agripreneurs' unique experiences with technology adoption, as most studies focus either on male farmers or treat farmers as a homogeneous group without gender-specific analysis.

2.3 Effectiveness of Agri-Tech for Sustainable Practices

Agri-Tech tools for women agripreneurs are proven efficient in sustainable farming by increasing efficiency, cost savings and significant environmental benefits. Precision agriculture tools promote optimal land use and healthy soil management, resulting in heightened productivity and diminished environmental impact (Bindurajashekar et al., 2023). Drones minimise the need for manpower to scout fields for pests and apply fertilisers in optimal locations (Cosby et al., 2024). Smart irrigation systems play a crucial role in water conservation by delivering precise amounts of water based on real-time soil moisture data (Saifuddin et al., 2021). Biotechnology advancements foster yield increase while achieving ecological balance by lowering dependency on chemical fertilisers (Hilaire et al., 2022). Such technological improvements offer women agripreneurs the means to make decisions, implement sustainable practices, and enhance livelihoods (Tribouillois et al., 2018). However, existing research broadly demonstrates these benefits in controlled environments or large-scale commercial operations, with limited evidence of their effectiveness when implemented by small-scale women agripreneurs in developing countries like Malaysia.

2.4 Barriers to Technology Adoption

Despite these advantages, women agripreneurs in Malaysia face challenges that prevent them from effectively adopting Agri-Tech technology. Financial constraints remain one of the biggest challenges, as equipment can be too expensive to invest (Dar & Ahmed, 2020). A digital divide exists among women, many of whom cannot gain the digital skills required in modern agriculture (Wahab et al., 2024). These challenges are exacerbated by infrastructure limitations in rural areas where access to critical data and online platforms is limited (Cao & Solangi, 2023). Cultural and gender norms can adversely affect women agripreneurs' acceptance of technology (Simkhada et al., 2014). Most agricultural technologies are designed for male users, making them less accessible and less user-friendly for women, with sophisticated operational characteristics and physical strength requirements further deterring adoption (Gebre et al., 2019). While these barriers have been identified separately in existing literature, there is insufficient research integrating these challenges into a comprehensive framework specific to women agripreneurs in the Southeast Asian context.

2.5 Research Gaps and Theoretical Framework

The literature review reveals several significant research gaps that this study aims to address. First, while extensive research exists on Agri-Tech adoption in general, studies specifically examining women agripreneurs' experiences with these technologies are limited, particularly in the Malaysian context. Second, most technology adoption studies focus on technical aspects or general adoption patterns without adequately considering gender-specific factors. Third, existing research rarely combines multiple theoretical perspectives to comprehensively understand both the technical and social dimensions of women's Agri-Tech adoption.

To address these gaps, this study employs a synthesised theoretical framework that encompasses the Diffusion of Innovation Theory (Rogers, 2003), the Technology Acceptance Model (Davis, 1989), and the Feminist Technology Studies (Wajcman, 2010). This integrated approach provides analytical tools to identify the types of Agri-Tech instruments adopted by the women agripreneurs through Rogers' characteristics of innovations and adoption categories (Objective 1). The perceived usefulness and actual system use dimensions of TAM serve as evaluative dimensions to assess the impact of these technologies on sustainable farming and evaluate their efficacy (Objective 2). Recent research on technology adoption in Malaysia has demonstrated that TAM is particularly effective in explaining how users accept and use new technologies based on perceived usefulness and ease of use (Chius et al., 2024). Focused on adoption-related barriers, TAM encompasses more gender-neutral rationales concerned with perceived ease of use and facilitating conditions. Meanwhile, Feminist Technology Studies postulates gendered barriers (such as design biases and socio-cultural constraints), which can help answer the research questions linked to women agripreneurs' obstacles (Research Objective 3).

By combining these theoretical perspectives, this study aims to provide a more nuanced understanding of women agripreneurs' Agri-Tech adoption experiences than possible using any single framework. This integrated approach addresses the current theoretical gap by examining how general technology adoption factors intersect with gender-specific considerations in the context of Malaysian agriculture.

3.0 METHODOLOGY

3.1 Design

This study employed a qualitative technique under the interpretive paradigm to examine how individuals in natural contexts experience and create meaning from ordinary experiences (Wimmer and Dominick, 2014). The qualitative method was used as it enables thorough data gathering, in-depth analysis, and complete conclusions (Anuar et al., 2022). Through in-depth case studies, qualitative research aims to provide a contextualised, in-depth understanding of human experience rather than generalisability (Lim, 2024). Purposive criterion sampling, a non-probability sampling strategy that finds people with pertinent, first-hand knowledge of the topic under study, was chosen to guarantee relevance (Patton, 2015). Criteria sampling is ideal since it guarantees that participants have first-hand knowledge (Creswell & Creswell, 2017). The sample comprises Malaysian female managers or owners of agribusiness who have participated in the Farmers and Entrepreneurs Training Course, a program provided by the Department of Agriculture. This selection process ensures the participants know how Agri-Tech is used in sustainable farming. Interviewees were selected from 14 individuals throughout 14 states in Malaysia.

3.2 Data Collection

The data collection took place from January 2024 until December 2024. Participants were in various geographical locations, and semi-structured interviews were conducted through video conferencing tools, such as *Google Meet* and *Microsoft Teams*. These interviews were digitally audio recorded with informed consent from the participants, and subsequently, fully transcribed verbatim to maintain authenticity and accuracy. The semi-structured framework allowed the responders the opportunity to freely discuss their experiences, as well as gave the interviewer the ability to probe deeper into the emerging theme.

3.3 Data Analysis

This study followed the six-phase reflexive thematic analysis approach described by Braun & Clarke (2006): (1) familiarisation with the data; (2) coding; (3) producing initial themes; (4) reviewing themes; (5) defining and naming themes; and (6) writing up. Thematic analysis was selected for this study due to its inherent flexibility and compatibility with diverse theoretical frameworks, making it particularly suitable for research employing multiple theoretical perspectives (Fuzi & Noor, 2024). The interviews were transcribed and then systematically coded to ensure that key insights were captured. Then, the research team categorises the data into relevant themes by developing and refining the codes using the iteration process.

The coding process was studied collectively to ensure agreement on the topic categorisation and enhance the coherence and validity of the findings. During the coding, particular attention was paid to how participants' responses mapped to theoretical constructs from the study's framework. For example, statements about ease of use or difficulties in operating technology were coded by referring to TAM's perceived ease of use construct. Meanwhile, adoption patterns were analysed using Rogers' adopter categories and innovation attributes. For instance, when participants discussed cost savings, these were coded as "relative advantage" within Rogers' framework, while statements about technology matching their farming practices were coded as "compatibility." Similarly, gender-specific barriers were examined through the lens of Feminist Technology Studies. This theoretically informed coding approach ensured that the analysis remained grounded in the study's conceptual framework while allowing for the emergence of new insights.

The qualitative analysis software NVivo assisted with data organisation, coding, and categorising the data set. An audit trail was maintained to ensure the study was conducted fairly and neutrally, noting key decisions made throughout different stages of data analysis. To guarantee that the themes were genuinely formed from the data and not preconceived ideas, frequent reflexive discussions about possible researcher biases were conducted.

4.0 RESULT AND DISCUSSION

4.1 Demographic and Business Profile

Tables 1a and 1b provide an overview of the demographic and business profiles of the 14 respondents, as well as key details about their origins, organisational designs, and involvement in the industry. Understanding these elements is essential to measuring their preparedness to adopt Agri-Tech and turn sustainable farming practices into a reality.

Table 1a: Demographic and Business Profile

Profile	Categories	Respondents						
		R1	R2	R3	R4	R5	R6	R7
Age	20-30			/				/
	31-39	/			/		/	
	40-49		/					
	50 above					/		
Education Level	Primary School							

	SPM/ SPMV		/					
	STPM/ Matriculation/Certificates				/	/		
	Diploma	/						
	Degree			/				/
	Master/ PhD						/	
Marital Status	Single							/
	Married	/	/	/	/	/	/	
Business Ownership	Individual							
	Group					/		/
	Family	/	/	/	/		/	
Business Experience	< 5 years			/				
	<10 years	/			/	/	/	/
	>10 years		/					
Membership in Association	Pertubuhan Peladang Kawasan	/				/		/
	Persatuan Kebangsaaan Pekebun Kecil Malaysia				/			
	Dewan Muda Perniagaan							/
	Lembaga Kemajuan Pertanian Kemubu		/					
	Persatuan Usahawan TKPM						/	
	Persatuan Fertigasi & Hidroponik Mukah			/				
	Dewan Perniagaan Melayu Malaysia							/

Table 1b: Demographic and Business Profile

Profile	Categories	Respondents						
		R8	R9	R10	R11	R12	R13	R14
Age	20-30		/					
	31-39			/		/		/
	40-49	/			/		/	
	50 above							
Education Level	Primary School							
	SPM/ SPMV	/					/	
	STPM/Matriculation/Certificates				/			
	Diploma		/					/
	Degree			/		/		
	Master/PhD							
Marital Status	Single		/					
	Married	/		/	/	/	/	/
Business Ownership	Individual		/		/	/		/
	Group			/			/	
	Family	/						
Business Experience	< 5 years	/	/		/	/		/
	<10 years			/			/	
	>10 years							
Membership in Association	Pertubuhan Peladang Kawasan		/	/		/	/	
	Persatuan Kebangsaan Pekebun Kecil Malaysia				/			
	Dewan Muda Pernigaan Melayu Malaysia							
	Lembaga Kemajuan Pertanian Kemubu							

	Persatuan Usahawan TKPM	/						/
	Persatuan Fertigasi & Hidroponik Mukah							
	Dewan Perniagaan Melayu Malaysia							

Most women agripreneurs are between 31 and 39 at 42.9%, followed by 28.6% of participants ages 40 to 49 and 21.4% for age 20 to 30. With less than 1/10 (7.1%) of respondents over 50, most women in this industry are in their peak working age. This demographic profile is well-balanced in terms of experience and adaptability to adopt new agricultural technologies. The younger participation suggests agribusiness is a possible career option for younger generations (Bouichou et al., 2021; Surainita et al., 2022). This age distribution aligns with Rogers' diffusion theory, where younger individuals often represent early adopters who are more willing to try innovations.

Tertiary education (having a degree) is the most common educational attainment (28.6%). In addition, 21.4% have diplomas, and 21.4% have equivalent certificates to STPM or Matriculation. An equal percentage had completed SPM/SPMV, while only one respondent had a postgraduate degree (7.1%). From a TAM perspective, education levels directly influence the perceived ease of use and usefulness of technology.

Regarding relationship status, the overwhelming majority (85.7%) are married. Many of these women juggle running businesses and servicing families, which affects decision-making, risk-taking, and business growth, especially regarding technology deployment that can improve processes and minimise labour needs (Kim et al., 2023). This observation connects directly to Feminist Technology Studies, emphasising how gendered responsibilities affect technology adoption patterns.

These agripreneurs have different ownership structures: family firms (42.9%), independent business owners (28.6%), and associations for agricultural ventures (28.6%). The prevalence of family-owned agribusinesses demonstrates the communal nature of Malaysian agriculture (Rensburg & Tjano, 2020). Half of the respondents (50.0%) have five to 10 years of experience, and 42.9% have less than five, suggesting an evolving and dynamic sector.

Membership in agricultural organisations provides valuable platforms for networking, mentoring, and training. Half of the respondents are members of Pertubuhan Peladang Kawasan, with others belonging to various agricultural associations. These organisational memberships reflect Rogers' diffusion theory of communication channels that facilitate technology adoption.

4.2 Types Of Agri-Tech Tools Utilised by Women Agripreneurs

Table 2: Agri-Tech tools

Code	Category	Theme
Artificial Intelligence (AI)	Digital Farm Management and Decision Support Systems	Categorisation of Agri-Tech Tools
Cloud Computing		
Internet of Things (IoT)	Precision Agriculture and Automation	
Drones		
Social media	Digital Marketing and Business Expansion	
Solar Energy	Sustainable Energy Solutions	

Automated Irrigation System	Water Management and Conservation	

Table 2 highlights types of Agri-Tech solutions, including Artificial Intelligence (AI), cloud computing, drones, the Internet of Things (IoT), social media, solar energy, and automated irrigation systems used by women agripreneurs. These technologies allow them to stay competitive by transforming farm management systems, optimising resources, and expanding markets in the rapidly evolving, tech-enabled agriculture ecosystem.

One key theme was adopting cloud computing technology and AI-enabled applications that automate farm operations. As one agripreneur (R4) explained, *"I use the Farm Byte application to gather market information and conduct transactions directly with customers."* It implies that women in agribusiness are reaping the benefits of AI-powered solutions through better market access (Sakapaji & Puthenkalam, 2023). The relative advantage and compatibility attributes from Rogers' theory are evident in this adoption pattern.

Similarly, cloud computing applications such as Smart Life have become important in automating essential agricultural processes, such as fertigation control. *"I use the Smart Life application on my phone to control the fertigation system, which runs automatically,"* one respondent (R9) stated. It illustrates that cloud computing technology enables remote farm management, thus helping agripreneurs to track and adapt to modern farming environments (Thar et al., 2020). This adoption relates directly to TAM's perceived usefulness construct.

Another key topic is precision farming through IoT and drone technologies, which have increased farming productivity. Using drones in agriculture has transformed the process of distributing seeds, applying fertiliser, and spraying pesticides. As R2 described, *"Drones are incredibly useful for seed harvesting, fertiliser application, and pesticide spraying"*. Similarly, R13 emphasised their convenience in large-scale farming, stating, *"I mainly use drones for spraying fertilisers and pesticides on my crops"*. These testimonies prove how drones are making labour-intensive tasks easier while improving the quality of farming practices.

Moreover, due to their real-time monitoring, many have utilised IoT-based automation systems for precise control of farming conditions. Several respondents detailed how they integrate IoT equipment into their farming practices. One agripreneur (R7) explained, *"I use a smart farming system equipped with automated irrigation, soil sensors, and smart fertilisation"*. Others claimed that IoT benefits fertigation management, as stated by R10, *"Our semi-fertigation system is operated through IoT technology"*. This result indicates that IoT solutions are essential for enhancing productivity, optimising resource use, and ensuring sustainable farming practices (Sood et al., 2021; Naman et al., 2024).

Social media for customer engagement and business growth was the next big theme. Several respondents also leveraged digital channels such as YouTube, TikTok, and Shopee to give more visibility to their offerings and reach more audiences. *"We actively use Shopee, TikTok, and YouTube to promote our products,"* R3 explained. Another respondent (R8) explained the role of social media in improving the company's presence by quoting, "*I use social media for marketing and customer engagement."* With more use of social media in agribusiness, digital platforms are helping women agripreneurs establish sustainable business models to connect with clients while bypassing artisans or middlemen directly. Research has shown that effective digital marketing strategies significantly contribute to brand development and customer engagement across various sectors in Malaysia (Erlinda & Ratnawati, 2022). In a highly digitalised industry, social media marketing helps agribusiness entrepreneurs sustain their competitive advantage and enhance their product awareness (Jamil et al., 2022). The observability attributed to Rogers' theory is particularly evident here, as social media success is evident to others.

Sustainability became a key theme, with the adoption of solar-powered equipment used in agricultural operations. Some respondents have started integrating solar energy into greenhouse management to reduce

their reliance on conventional electric sources and lower operating costs. *"I use a solar system in my greenhouse to minimise electricity expenses and promote sustainability,"* R7 added. This shift towards renewable energy sources showcases a commitment to environmentally friendly farming practices while ensuring long-term savings. These agribusiness owners adopt sustainable farming techniques that can reduce carbon footprints (Khan et al, 2019).

The other significant development mentioned was automated irrigation systems, which improve efficiency and reduce water wastage. Some agribusiness owners have installed timer-based watering systems to reduce manual work and ensure optimum soil moisture. R3 explained, *"I use a smart irrigation system with a timer installed in the water tank for automatic watering."* Similarly, R12 shared, *"I have set up an automated fertigation system controlled by a timer"*. Such irrigation technologies are key to climate-resilient farming as they help reduce waste, preserve water, and maintain an even moisture level for crops. The use of smart irrigation technology reflects a broader trend in contemporary agriculture whereby traditional, labour-intensive irrigation techniques are replaced by precision systems (Narzullaev, 2023).

4.3 Effectiveness of Agri-Tech's Contribution to Sustainable Agriculture

Table 3: Thematic Overview of Agri-Tech's Contribution to Sustainable Agriculture

Code	Category	Theme
Automation of farm operations	Improved Farm Efficiency	Effectiveness of Agri-Tech tools
Reduction of manual labour		
Faster completion task		
Water conservation	Optimised Resource Management	
Fertilizer efficiency		
Reduction in pesticide usage		
Lower operational costs	Cost Reduction	
Energy savings		
Reduction in input costs		
Expansion of customer base	Enhanced Market Access	
Direct engagement with consumers		
Increased sales and profitability		
Reduced chemical usage	Environmental Sustainability	
Real-time monitoring	Data-Driven Decision Making	
Precision farming technique		
Improved yield predictions		
Competitive advantage in agribusiness		

Improved Productivity	Business Growth and Competitiveness	
Expansion in digital agriculture		

Table 3 shows how Agri-Tech has transformed agricultural practices among women agripreneurs, enhancing farm productivity, resource management, cost reduction, market access, environmental sustainability, agribusiness expansion, and data-driven decision-making. Thematic analysis of respondents' interviews reveals how these technologies support sustainable farming through multiple mechanisms that align with TAM's perceived usefulness and Rogers' relative advantage concepts.

Improved Farm Efficiency: Integration of technology into farming has led to improved efficiency by speeding up operations and reducing physical labour (Moutaouakil & Falih, 2023). R1 noted, *"Automation helps speed up farm tasks and reduces the need for manual labour."* This benefit directly connects to TAM's perceived usefulness dimension.

Optimised Resource Management: Respondents emphasised how precision agriculture and smart irrigation reduce water waste and optimise fertiliser application. R4 stated, *"We only use what is required for the crops and save water with automated irrigation."* These technologies minimise adverse environmental impacts while ensuring crop health (Tsvetkova and Vakhovskaya, 2023).

Cost Reduction: Integration of Agri-Tech has reduced operational expenses and input expenditures. Adopting solar energy systems and precision agriculture techniques has helped farmers optimise financial resources. This economic benefit represents a key relative advantage in Rogers' innovation theory.

Access to Markets: Digital marketing platforms have expanded market reach for agripreneurs. Respondents have bypassed traditional distribution channels using platforms like YouTube, Shopee, and TikTok. This transformation of agricultural marketing demonstrates how digital tools enhance market access and profitability (Wang & Yu, 2023).

Environmental Sustainability: Automated systems and precision farming techniques have reduced the environmental footprint of agricultural operations by decreasing chemical usage and adopting renewable energy solutions. As R10 explained, *"We minimise environmental impact by reducing the use of pesticides and fertilisers."*

Data-Driven Decision-Making: Real-time monitoring has enabled better farming decisions through data analysis. R11 pointed out, *"We obtain real-time data on soil conditions using IoT-based monitoring."* This approach enhances sustainability and productivity through informed decision-making (Domingo-Palaoag, 2024).

These benefits align closely with Rogers' innovation attributes, particularly relative advantage, compatibility, and observability. The efficiency improvements represent clear relative advantages, while aligning with environmental sustainability goals and demonstrating compatibility with agripreneurs' values. The market access benefits showcase the observability of positive outcomes, further encouraging adoption.

4.4 Obstacles Faced by Women Agripreneurs in Implementing Agri-Tech Solutions

Table 4: Thematic Analysis of Challenges in Agri-Tech Adoption for Sustainable Farming

Code	Category	Theme
High cost of ICT tools	Financial Barrier	
High Cost of Maintenance		

Lack of financial assistance		Barriers to Agri-Tech Integration
Lack of Digital Skills	Knowledge and Training Barriers	
Lack of Awareness of Available Agri-Tech		
Unstable internet connectivity	Infrastructure Barriers	
Technical failures	Operational Barriers	
Technical Complexity of Tools		
Maintenance challenges	Technical Support Challenges	
Difficulty in Accessing Spare Parts		
Resistance to Technology Adoption	Cultural and Generational Barriers	
Limited Access to Training	Knowledge and Training Barriers	
Lack of Awareness on Available Agri-Tech		
Difficulties in Troubleshooting Issues	Technical Support Challenges	
Limited government support	Policy and Institutional Barriers	
Limited market access	Business and Marketing Barriers	
Inconsistent supply chain support		

Despite the benefits, women agripreneurs in Malaysia face significant challenges in adopting Agri-Tech solutions. Table 4 highlights eight major barriers: financial constraints, knowledge and training gaps, infrastructure limitations, operational challenges, insufficient technical support, inadequate policy frameworks, sustainability concerns, and business and marketing difficulties. These barriers can be understood through the lenses of TAM's facilitating conditions and Feminist Technology Studies' emphasis on gender-specific constraints.

Financial Constraints: The high cost of Agri-Tech tools remains one of the most significant barriers. R1 noted, "*One of the biggest struggles for me was the cost—not just acquiring the equipment but also maintaining it over time."* R13 added, *"I signed up because I wanted to use drones on my farm, but the price was too high, and there was no support from financial institutions."* Beyond initial purchase costs, ongoing maintenance expenses present additional financial burdens, with R9 observing that "Sometimes fixing broken equipment costs almost as much as buying a new one, which makes it difficult to justify repairs." These concerns align with research by Dhanya & Ashok (2022), emphasising that high investment and maintenance costs are major barriers to Agri-Tech adoption. From a TAM perspective, these financial constraints represent significant hindrances to facilitating conditions.

Knowledge and Training Gaps: Many respondents reported difficulties using modern technologies without professional instruction. R2 admitted, *"Honestly, I had no experience flying a drone. It took me a long time to figure out on my own,"* while R3 pointed out, *"The access is limited. I would like to see more training programs for women like me."* According to Manning et al. (2022), education and training are

critical to helping farmers adopt new technologies, but women often lack access to necessary training opportunities. This gender disparity in training access reflects the concerns raised by Feminist Technology Studies about systemic barriers to women's technological empowerment.

Infrastructure Limitations: Poor internet connectivity in rural areas significantly hampers technology adoption. R4 expressed frustration, saying, *"Where I am, the internet is proper crap,"* while R14 explained, *"I tried having an app to check on my crops, but the connectivity was so bad that it was frustratingly slow and often wouldn't work at all."* Limited internet access continues to hinder the use of online agricultural tools and digital markets for rural farmers (Michels et al., 2020).

Technical and Operational Challenges: Technical failures frequently disrupt farm activities, and many respondents lack the knowledge to address these issues. R6 complained, "*The systems are working one moment, and the next moment they are not, and I don't know how to fix it.".* R7 noted, *"Every automated system needs to be validated."* Repairs become expensive and time-consuming without reliable technical assistance. These challenges directly affect TAM's perceived ease of use construct.

Policy and Institutional Barriers: Government support for Agri-Tech adoption by women agripreneurs is often inadequate. R4 shared, *"I've tried applying for grants and loans to assist in purchasing Agri-Tech equipment, but either there's none available or the application process is just too convoluted. Government programs are focused on large farms."* The Asia Foundation (2024) reported that many micro, small, and female entrepreneurs in Malaysia struggle to understand loan application processes, further limiting their access to financial resources.

Sustainability Concerns: Some respondents expressed scepticism about the environmental implications of certain Agri-Tech solutions. R12 stated, *"Some technologies use a lot of water and energy, which makes me question whether or not they're truly sustainable over time,"* while R5 warned about the risk of becoming *"overly dependent on external fertilisers or pesticides, which potentially pose a negative danger to the environment."* These concerns highlight the need for technologies that balance productivity with ecological sustainability (Hart et al., 2022; Karyotaki & Drigas, 2022).

Marketing and Business Challenges: Despite technological advancements, many respondents still face difficulties in marketing their products. R2 noted, *"Although I utilise social media and digital platforms, I still have difficulty connecting with buyers."* Meanwhile, R11 explained, *"Not all farmers have access to established marketplaces, so selling online isn't always as straightforward as people think."* Market access and supply chain inconsistencies remain significant challenges, as highlighted by R10's observation about customer unpredictability. These findings align with research by Inegbedion et al. (2021) showing that while social media can enhance marketing efforts, it cannot completely resolve market access and distribution challenges.

The barriers identified through this research align with both TAM's constructs of perceived ease of use and facilitating conditions, and Feminist Technology Studies' emphasis on gendered design and access constraints. The financial, knowledge, and infrastructure barriers particularly affect facilitating conditions, while technical complexities influence perceived ease of use. The gendered aspects of these challenges, such as limited training opportunities and technologies designed primarily for male users, directly connect to Feminist Technology Studies frameworks.

5.0 CONCLUSION AND RECOMMENDATION

Agri-tech solutions have enabled Malaysian women agripreneurs to enhance farm yield, conserve resources, and expand their businesses. Many have adopted digital platforms, drones, IoT-based sensors, and automated irrigation systems to track crop conditions, reduce waste, and grow their customer base. However, significant challenges remain. Small-scale farmers often cannot afford these tools and lack training and connectivity to use them effectively. Technical difficulties are complex to resolve, while policies typically favour larger operations.

Our findings align with our theoretical framework. Through Rogers' Diffusion of Innovation theory, we observed that women agripreneurs evaluate Agri-Tech based on relative advantage, compatibility, complexity, trialability, and observability. From the Technology Acceptance Model perspective, perceived usefulness was evident, while perceived ease of use was negatively affected by training gaps. Feminist Technology Studies insights revealed how gendered design biases create unique barriers for women.

Recommendations to promote Agri-Tech adoption among women agripreneurs include:

1. **Financial Support**: Develop specialised financial instruments with flexible terms for women-led agribusinesses.
2. **Digital Training**: Implement gender-responsive programs focusing on digital literacy and Agri-Tech skills, scheduled with consideration for women's domestic responsibilities.
3. **Rural Infrastructure**: Enhance internet connectivity through expanded networks and community technology hubs.
4. **Technical Support**: Establish regional centres with experts who can troubleshoot issues and provide maintenance services.
5. **Policy Reforms**: Revise agricultural policies to consider small-scale women agripreneurs' needs through dedicated funding and simplified application processes.

For future research, we recommend longitudinal studies to track long-term impacts on sustainability and profitability, investigate policy intervention effectiveness, and comparative studies across Southeast Asian countries to identify transferable best practices.

This research contributes to understanding the intersection of gender, technology, and agriculture in Malaysia, providing a foundation for developing inclusive policies that strengthen women's roles in creating a sustainable agricultural sector.

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