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Factors Influencing the Acceptance and Use of the Internet of Things (IoT) by Thai Farmers

Supawadee Khunthongjan *

Puey Ungphakorn School of Development Studies, Thammasat University, Thailand

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Abstract

The capacity of agricultural production in Thailand can be significantly improved by strengthening farmers' skills. This article aims to present the factors influencing the acceptance and use of the Internet of Things (IoT) among 120 Thai farmers who voluntarily participated in workshops organized by the Community Organizations Development Institute (CODI) across 10 target areas. Primary data were collected through questionnaires and in-depth group interviews, and analyzed using descriptive statistics and multiple regression analysis. The results reveal that extreme weather conditions, rising production costs, and declining product quality have become major challenges in the development of IoT-driven smart farming models. As a result, many farmers are now shifting their mindsets and actively seeking new opportunities to overcome existing and emerging challenges. A promising solution is the context-specific adoption of IoT technologies, tailored to local socio-agricultural conditions. This approach not only addresses current issues but also enhances farmers' survival strategies and skill development. Two key groups have emerged in this process: farmers proficient in IoT and those using IoT-based systems. The study finds that the most influential factors driving IoT adoption among both groups include (1) efforts to raise plant-based production standards (2) reduction in production cost-related risks, and (3) supportive government policies promoting IoT use in agriculture-all with statistical significance at the 0.05 level.

Keywords

Internet of Things (IoT), acceptance of the Internet of Things, adoption of the Internet of Things (IoT), farmer models

* **Corresponding author:** Supawadee.k@psds.tu.ac.th **DOI:** 10.14456/tureview.2025.26

Trends in Global Agricultural Production

In line with the Sustainable Development Goals set by the United Nations Development Programme (UNDP), the global agricultural sector must transition to a new paradigm of production-one that is diversified, resilient, and rooted in sustainable agro-ecological systems. These systems aim to simultaneously achieve economic, environmental, social, and health outcomes. The UNDP is calling on all stakeholders to raise awareness about sustainable development, enhance competitiveness, adopt eco-friendly practices to reduce greenhouse gas emissions, and promote sustainable production systems. These emerging trends present significant challenges for Thailand's agricultural sector, as traditional farming methods are no longer effective in addressing them. Therefore, a shift in mindset and the pursuit of new opportunities-particularly through the adoption of innovation and technology-are essential. This includes practices such as precision farming, environmental monitoring of soil, humidity, water, and weather conditions, the use of GPS, soil testing, weather forecasting, groundwater mapping, and the integration of Internet of Things (IoT) technologies.

As aforementioned, innovations and technology significantly contribute to the improvement of effectiveness, productivity, product quality, and eco friendliness in agriculture (Office of Trade Policy and Strategy, 2023). Farmers from all over the world are witnessing unprecedented levels of adoption of technology in agriculture. There are many emerging technologies in agriculture that seem very promising for the future of farming, for example, crops field monitoring and more accessible marketing opportunities that generate stable income to farmers directly (Katz et al., 2014).

Current Agricultural Challenges Worldwide and in Thailand

Globally and in Thailand, agriculture is facing increasing pressure. Groundwater resources that support farms, households, and industries are being rapidly depleted-particularly in regions such as Central Asia, the South Caucasus, Turkey, and Kyrgyzstan. The sector is also grappling with soil degradation, declining soil fertility, and substandard agricultural products, among other challenges. To effectively overcome these agricultural challenges, it is essential to foster strong interconnections across various activities, economic sectors, societal stakeholders, and government regulations and policies. A relevant example can be found in Central Asian countries and Azerbaijan, where similarities in agricultural development highlight the benefits of a more established innovation ecosystem, a robust private sector, and responsive government support.

In Central Asian countries and Azerbaijan, smallholder farmers play a crucial role in producing large volumes of agricultural products. Enhancing agricultural competitiveness in similar contexts requires the integration of progressive and innovative technologies, alongside raising awareness among policymakers and farmers about the significant benefits that innovation can bring. The experience of Central Asian countries and Azerbaijan demonstrates how productive technologies can help overcome agricultural challenges. Critically, these technologies must be affordable, user-friendly, accessible, and free from irrelevant data-making them practical for smallholder farmers. With the right support, these farmers can capitalize on market opportunities and drive business growth (Katz et al., 2014).

Both the global and Thai agricultural sectors are facing similar challenges, particularly in terms of limited access to modern innovations and technologies among smallholder farmers due to high costs. Addressing these challenges requires strategic partnerships and collaborative efforts between farmers and relevant stakeholders across multiple sectors. In Thailand, several agencies are involved in agricultural development, but one key player is the Community Organizations Development Institute (CODI). Established under a Royal Decree in 2000, CODI aims to empower and strengthen communities to collaborate for shared benefits. Its objectives include promoting livelihoods, occupational and career development, increasing income, improving housing and the environment, and enhancing overall well-being.

In 2023, CODI launched the “Internet of Things (IoT)” Project in Pak Chong District, Nakhon Ratchasima Province. The project introduced IoT technology to local farmers, aiming to develop them into model farmers who, after training, could effectively adopt and demonstrate the use of IoT in agriculture. The initiative focused on technologies that are accessible, affordable, adaptable, and user-friendly.

These model farmers now act as knowledge disseminators, sharing their successful experiences and demonstrating the practical application of IoT to their peers. By doing so, they help spread awareness and encourage wider adoption of innovative agricultural practices.

Innovation and Technology in Agriculture

Expanding knowledge and adjusting agricultural practices is far from easy, particularly because many farmers have long been rooted in traditional ways of farming. They often hold strong beliefs in the effectiveness of their inherited methods, which have been passed down through generations. However, these practices may not necessarily qualify as formal skills or techniques that enhance agricultural capacity. Instead, they are better described as “intuition-based farming,” inherited from their ancestors (Patchimpet, personal communication, 2023). Nuthall (2010) asserts that skills, techniques, and good practices in innovation and technology are critical for farmers' success. Meijer et al. (2015) studied technological acceptance in agroforestry in Africa. The study revealed that knowledge, attitudes, perceptions, and comprehension are the main components affecting the acceptance of technology. Shifting farmers' mindsets and practices requires a structured learning process that helps them understand the root causes of the challenges they face. Once this awareness is established, they can begin exploring innovation and technology as viable solutions. Crucially, if a technology offers appealing, reliable, and relevant features, it can naturally attract farmers' interest. In such cases, farmers develop a genuine attachment to the technology, rather than feeling compelled to adopt it due to government promotion or pressure (Nuthall, 2010).

Interdependence between farmers and the government sector plays a key role in agricultural development, particularly through learning-by-doing approaches. Sharing success stories and practical outcomes from early adopters of technology and innovation can inspire and motivate traditionally minded farmers. This peer-driven influence is especially effective in shifting attitudes and building trust. Once mindsets begin to change, the willingness to acquire, accept, adopt, and eventually disseminate new innovations and technologies among other farmers increases significantly-leading to broader, more sustainable transformation in the sector.

The acceptance and adoption of Internet of Things (IoT) technologies among farmers require strong collaboration across all relevant sectors. This includes engagement with farmer counterparts, model farmers, and a thorough understanding of the factors influencing IoT adoption. Equally important is the design of an effective and appealing promotion and presentation strategy to introduce IoT technologies in a way that resonates with farmers.

Such efforts will significantly benefit the Community Organizations Development Institute (CODI) and other government agencies involved in agricultural development. By gaining practical insights and identifying appropriate approaches tailored to current agricultural trends, these organizations can better support farmers in embracing innovation.

As the project moderator, CODI will be well-positioned to enhance the competitiveness of Thai farmers-both in terms of quality and productivity-through secure, inclusive, and sustainable development strategies. This approach not only strengthens community resilience but also ensures that IoT implementation proceeds as planned. In essence, it is a win-win strategy: empowering communities while generating valuable data and insights for future agricultural advancement.

Objectives of the Article

This article aims to present the factors influencing the adoption of the Internet of Things (IoT) among 120 Thai farmers who voluntarily participated in a workshop entitled "Adoption of the Internet of Things (IoT)." The participants were drawn from 10 tambons (sub-districts) across three target provinces in Thailand: Phra Nakhon Si Ayutthaya, Nakhon Ratchasima, and Chumphon. Many expressed a willingness to learn and potentially adopt IoT technology for agricultural purposes-especially if they can witness successful outcomes firsthand. Exposure to real-world results and an open mindset are key to fostering understanding, which in turn encourages knowledge-sharing among fellow farmers within the same area and nearby communities.

While White and Raitzer (2017) noted that only about 10 out of 100 individuals may succeed in applying new knowledge based on empirical evidence alone, it is believed that knowledge management sessions, discussions, and workshops still offer meaningful value. Even if full adoption does not occur immediately, participants are likely to gain useful insights that contribute to gradual change and community learning.

Conceptual Framework

The action plan of the Community Organizations Development Institute (CODI), in line with the 13th National Economic and Social Development Plan and the 20-Year National Strategy, focuses on building strong communities throughout the country. One of the key strategies is to establish model areas for innovation and Internet of Things (IoT) technologies as alternative options for farmers in local communities. This is carried out through a process of developing appropriate models for applying innovation and technology, aiming to create cross-area learning networks that help strengthen the capacity of smallholder farmers in Thailand. Based on the literature review, several factors have been identified that influence farmers' acceptance and application of IoT technologies. These include the simplicity and ease of use of IoT systems, their ability to reduce production costs, their contribution to standardized crop production, and the presence of supportive government policies. The goal is to build strong agricultural communities that can respond to challenges and move toward stability, prosperity, and sustainability, thereby enhancing Thailand's competitiveness in the agricultural sector (Figure 1).

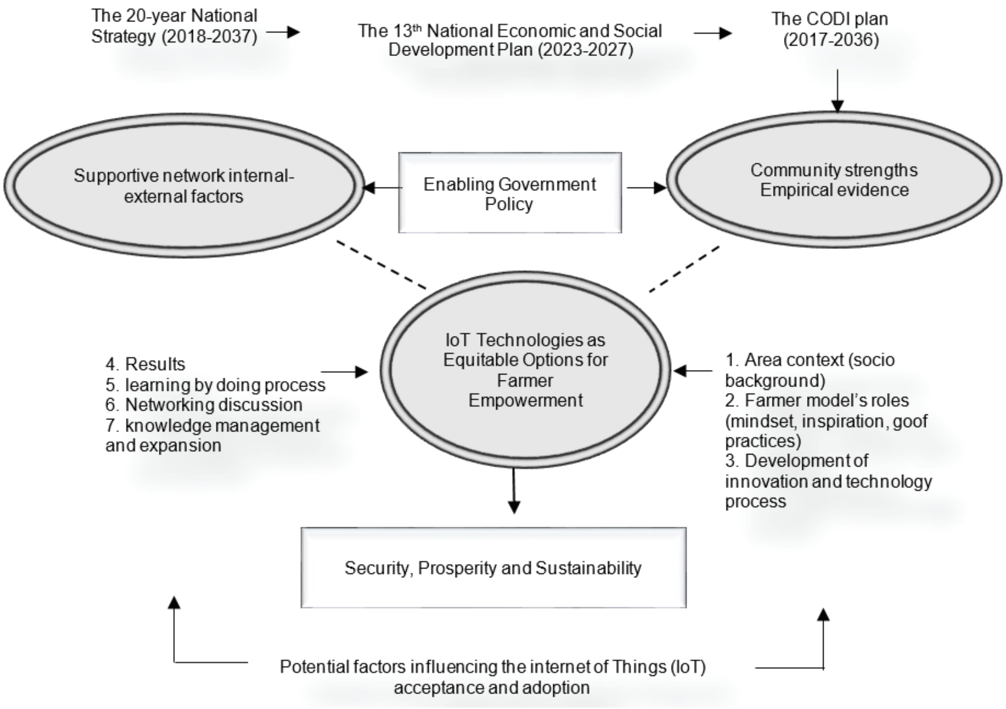

Figure 1 Conceptual Framework.

Literature Review

1. New Theory of Agriculture: Adaptation to Agricultural Development through the Sufficiency Economy

The New Theory of Agriculture is a distinctive and concrete application of the Sufficiency Economy Philosophy to the agricultural sector. His Majesty the late King Bhumibol Adulyadej introduced this theory to support Thai farmers affected by commodity price fluctuations, natural disasters, and unproductive environmental conditions such as dry spells and droughts. The New Theory aims to reduce the risks and vulnerabilities of agriculture to sudden changes, enhance financial stability and self-reliance, improve farmers' quality of life, increase income, and reduce expenses through the efficient use of inputs and resources.

If farmers carefully consider past fluctuations in agricultural commodity prices, they will understand the risks of concentrating all their resources on such commodities with the hope of high profits. By adopting the principle of self-immunity, farmers prioritize producing enough food for their own consumption before selling any surplus, thereby preparing for market price changes.

More tangibly, His Majesty developed the New Theory as a system of integrated and sustainable agriculture, reflecting his commitment to water resource development and conservation, soil rehabilitation, sustainable farming practices, and self-reliant community development. The ultimate goal is to optimize farmland use in a balanced and sustainable way.

As Bhumibol Adulyadej (1997) stated:

The favorable advantage of country development is that the agricultural sectors must be uplifted for better living conditions in order to form them to fundamentally live well and eat well. Having a good living starts by doing step with affordable tools and simple steps to use. It can be nature-based adapting tool for implementation depending on the context of area. Once all people have better living standard, peace and prosperity shall definitely follow.

As per King Bhumibol Aduluadej's speech, the New Theory provides a practical way to apply sufficiency thinking to the agricultural sector. It encourages farmers to develop a sufficiency mindset gradually and at various levels. Under the New Theory, farmers not only optimize land and water use in agriculture but also apply sufficiency principles more holistically in their daily lives. When farmers successfully implement the New Theory, they often become role models-known as smart farmers-whose land serves as a demonstration site for other farmers and the general public.

2. Motivation of Smart Farmer Models in Developing the Internet of Things (IoT)

As heirs to ancestral farming traditions, smart farmer models in Tambon Pakchong and 85 associated households rely on farming as their primary livelihood to build a stable household foundation. However, challenges such as limited farmland, low living standards, and poverty persist due to adherence to traditional farming methods.

In 2014, during the era of the Thai coup d'état, the nation was governed by the National Council for Peace and Order (NCPO). At that time, agricultural land unlawfully acquired by a Chinese investor was confiscated by the government. Subsequently, farmers and community members agreed to register for the use of this confiscated land for agricultural purposes. Official permission was granted to utilize 1,024 rai (approximately 405 acres) of land.

Having been abandoned for some time, the soil on this land had become severely degraded. Soil degradation manifested in forms such as water and wind erosion, salinity, loss of organic matter, declining fertility, changes in pH (acidity or alkalinity), and contamination. This situation prompted the smart farmer models to rethink and redefine their approach, seeking new agricultural development theories to avoid repeating past mistakes.

They recognized that sustainability and progress could be achieved by integrating the development of Internet of Things (IoT) technologies, producing tangible results to strengthen community confidence. This development aligns with the principles of the Sufficiency Economy Philosophy, as initiated by His Majesty the late King Bhumibol Adulyadej.

As leaders, farmer role models contribute to soil enrichment by rotating crops and plants in different areas each year. This practice helps prevent nutrient depletion and breaks the cycles of pests and diseases, ensuring the garden soil remains healthy over time. By integrating local wisdom with innovative Internet of Things (IoT) technology, these farmers effectively manage water, soil enrichment, and fertilization in their agricultural production. Their key practices include:

1. **Fertilizer Application:** Using chemical fertilizers or compost-based irrigation systems by adding plants or manure into water tanks-an approach well-suited for organic farming.
2. **Water System - Venturi Valve:** The Venturi system uses a physical phenomenon to inject liquids into the main water flow without additional pumps. It is commonly used to inject soluble or liquid fertilizers in greenhouse and landscape watering systems.
3. **Installation of Automatic Irrigation Controllers:** These devices operate irrigation systems such as lawn sprinklers and drip irrigation. Most controllers allow users to set irrigation frequency, start times, and watering durations based on plant types.

All these features are fully connected to the internet via software that can be controlled remotely through smartphones or other devices. This system enables users to manage irrigation schedules, measure soil moisture, and even control animal feeding remotely (see Figure 2). Materials and spare parts are readily available online through platforms like Shopee, Lazada, or at local community stores.

This approach saves costs, time, and labor by allowing farmers to attend to other tasks, such as running errands downtown, without worrying about watering crops constantly. Ultimately, it helps reduce risks, limitations, and problems associated with agricultural production.

Figure 2 Adoption of innovation and technology IoT in a farmer's farm

3. Diffusion of Innovation Theory

Rogers (2003) states that the process of adopting new innovations involves four prior conditions: (1) previous practice, (2) felt needs or problems, (3) innovativeness, and (4) norms of the social system. The innovation-decision process itself consists of five stages:

1. **Knowledge Stage:** The process begins with the knowledge stage, where an individual becomes aware of the innovation and seeks information about it. This stage involves three key characteristics of the decision-making unit: socioeconomic status, personality variables, and communication behavior. Even if an individual has all the necessary knowledge, adoption is not guaranteed, as their attitude toward the innovation also plays a crucial role.
2. **Persuasion Stage:** After gaining knowledge, the individual forms an attitude toward the innovation. This stage is influenced by the degree of uncertainty about how the innovation functions and by social reinforcement from others, which shape opinions and beliefs about the innovation.
3. **Decision Stage:** At this stage, the individual decides whether to adopt or reject the innovation. Rejection means choosing not to adopt it.
4. **Implementation Stage:** The innovation is put into practice during this stage. However, some uncertainty about the outcomes of the innovation may persist, which can pose challenges during diffusion. This stage concludes once the innovation loses its novelty and becomes integrated into regular use.
5. **Confirmation Stage:** Although the decision to adopt has been made, the individual seeks reinforcement for their choice. This decision can be reversed if the individual encounters conflicting information about the innovation.

Rogers (2003) defined adopter categories as classifications of members within a social system based on their level of innovativeness. These categories include:

1. **Innovators:** Innovators are willing to try new ideas and act as gatekeepers who bring innovations into the system from outside. They make up the first 2.5% of individuals to adopt an innovation.
2. **Early Adopters:** Representing 13.5% of the population, early adopters are more socially integrated within the system compared to innovators. Often holding leadership roles, they are trusted sources of advice and information about innovations. Their early adoption helps reduce uncertainty and encourages others to follow.

3. **Early Majority:** Comprising 34% of the population, the early majority interacts well with other members but typically lacks leadership roles. They adopt innovations deliberately and tend to be neither the first nor the last to adopt.
4. **Late Majority:** Also making up about 34% of the population, the late majority adopts innovations only after most peers have done so. They tend to be skeptical but are often influenced by economic necessity and peer pressure.
5. **Laggards:** Laggards hold traditional views and are the most skeptical about innovations. Due to limited resources and low awareness or knowledge of new ideas, they wait until an innovation is proven effective before adopting it.

An innovation is perceived as being better than the idea it supersedes. It may be measured in economic terms, but social prestige, convenience, and satisfaction are also important factors. Innovations offering more relative advantages, compatibility, simplicity, trialability, and observability will be adopted faster than other innovations. But getting a new idea adopted, even when it has obvious advantages, is difficult. The presence of these factors helps accelerate the innovation-diffusion process. Building on this, Venkatesh and Bala (2008) developed an extension of the Technology Acceptance Model (TAM2), which explains perceived usefulness and usage intentions through social influence and cognitive instrumental processes (see Figure 3).

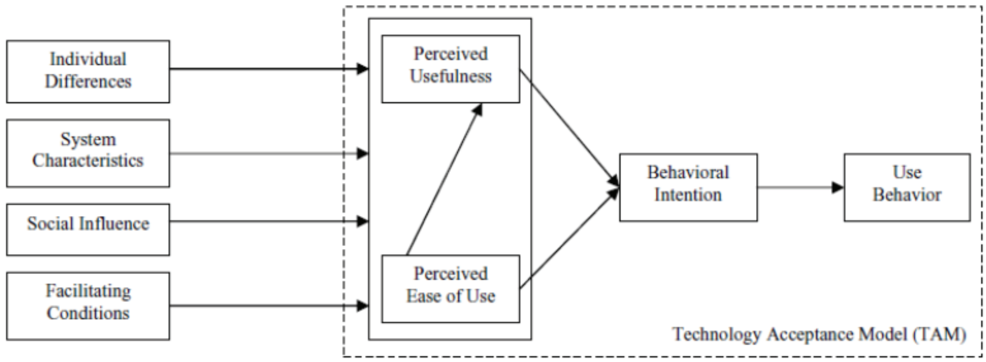

Figure 3 Technology Acceptance Model

Source: Venkatesh & Bala, 2008

According to Rogers' (2003) Diffusion of Innovations Theory and Venkatesh and Bala's (2008) Technology Acceptance Model, individuals progress through stages during which their understanding of an innovation evolves, ultimately leading them to accept or reject it. The characteristics of Thai farmers can be described and analyzed using these theories and models.

4. Innovation and Technology Acceptance: Thai Farmer Context

While Rogers' (2003) Diffusion of Innovations theory provides clear methodologies, the acceptance of innovation and technology among Thai farmers involves both internal and external variables. According to Khunthongjan et al. (2021), the internal factors include:

1. Ecological diversity in agriculture,
2. Production systems, such as monoculture, polyculture, new theory agriculture, organic farming, or livestock farming,
3. Farm size, classified as small, medium, or large,
4. Cluster farming versus non-cluster farming,
5. Individual farmer characteristics, including knowledge, skills, socio-economic perceptions, communication and networking, attitudes toward risk management, and acceptance of innovation and technology,

Social capital, or the level of trust and dependability among farmers.

External factors include:

1. The government sectors responsible for promoting, facilitating access to, and encouraging the adoption of innovation and technology by farmers, and
2. Characteristics of the innovation and technology itself, such as its strengths, complexity, and the consequences of its acceptance.

In summary, the literature review highlights that key factors influencing the acceptance and adoption of innovation and technology include knowledge, attitudes, perceptions, limitations of existing technologies, demand for new solutions, social norms, ease of use, the influence of reference persons, and ecological differences. Additionally, personal characteristics and supportive government policies play crucial roles. Despite Thailand's strong agricultural foundation and rich agrarian tradition, many farmers-especially smallholders within communities-still require innovation and technology to improve production skills, effective management of resources, holistic knowledge management, agricultural risk mitigation, disaster preparedness, and strategies to cope with price volatility in agricultural commodities and markets.

Innovation and technology in the context of Thai farmers may not represent the latest trends, but they are considered resilient innovations. Resilient technology must be accessible, adaptable, agile, scalable, flexible, recoverable, and interoperable. Moreover, resilience should extend beyond plant- and animal-based production to include the characteristics and capacities of the farmers themselves. The independent variables examined in this study include personal factors (gender, age, and level of education), as well as characteristics of innovation and technology-specifically, whether the technology enables standardized crop production, is simple and user-friendly, helps reduce production costs, and is supported by enabling government policies. These variables were selected based on their relevance to the characteristics of farmers, their alignment with local socio-ecological contexts, and their potential to respond to the complex challenges currently faced by smallholder farmers.

Research Methodology

This study adhered strictly to ethical research standards throughout all stages. It employed a mixed-methods approach, integrating both quantitative and qualitative methodologies. Data were collected between May and September 2023 from 120 farmers who participated in a hands-on IoT innovation and technology training program. These farmers were drawn from 10 subdistricts across three provinces in Thailand. All participants had previously experienced challenges in agricultural production due to a lack of suitable innovations and technologies. They voluntarily joined the program-many were encouraged by fellow farmers or had learned about IoT through online platforms such as YouTube-in an effort to seek alternative solutions to their existing problems.

The quantitative component employed a structured questionnaire designed to gather general demographic data, perceived production risks, and farming practices over the past five years (2019-2023). Closed-ended statements were used for most sections, while factors influencing IoT acceptance were measured using a 5-point Likert scale.

For the qualitative component, ten key informants were selected from among the quantitative participants based on specific criteria: they had active vegetable or fruit farms, were currently cultivating or producing, and faced labor shortages within their households. Data were collected through both individual and group interviews, focusing on attitudes toward IoT innovations, desirable features of contextually appropriate technologies, and farmers' processes of technology acceptance. The qualitative data were used to complement and enhance the interpretation of the quantitative findings.

The quantitative analysis provides a descriptive overview of farmers and risks in agricultural management, using statistical methods to calculate percentages and means. The rating scales and criteria are outlined in Table 1.

Table 1 Rating scale and criteria of overall information of farmers and risks

Rating scale	Rating criteria	$\bar{x}$	Interpretation
5	maximum	4.21 - 5.00	maximum
4	much	3.41 - 4.20	much
3	medium	2.61 - 3.40	medium
2	low	1.81 - 2.60	low
1	lowest	1.00 - 1.80	lowest

Note: Memon et al., 2020

The final section presents the factors influencing the acceptance and use of the Internet of Things (IoT) through a Multiple Regression Analysis. The independent variables include gender (Male = 0, Female = 1), age (in years), education level (number of years), IoT's role in uplifting plant-based production standards (No = 0, Yes = 1), ease of using IoT (No = 0, Yes = 1), cost risk (rated on a scale from 1 to 5), and government policy risk (rated on a scale from 1 to 5). The dependent variable is the acceptance of the Internet of Things (IoT).

This analysis is complemented by responses to open-ended questions from farmers, exploring how they anticipate and solve risks in the production process through the acceptance and adaptation of innovation and technology like IoT. It also investigates the conditions and reasons behind their acceptance or rejection. The insights gained will help enhance and expand promotion plans for IoT use in agriculture, building on its productive implementation in ten pilot areas to support security, prosperity, and sustainability in Thailand's agricultural sector.

Results and Supporting Details

1. Background Information of the Project and Participants in the "Adoption of Internet of Things Workshop"

This project was implemented under the area-based community strengthening program of the Community Organizations Development Institute (CODI). It focuses on promoting the application of low-cost Internet of Things (IoT) innovations and technologies as an alternative solution to reduce production costs and labor in response to the pressing challenges faced by farmers. The initiative targeted smallholder farmers in operational areas who are often constrained by limited access to expensive technologies. These farmers were introduced to the key functions and practical applications of IoT through a process of experiential learning that included conceptual understanding, hands-on modification and assembly, and field installation. The learning process was supported by peer-to-peer knowledge exchanges between model farmers-who served as trainers-and fellow participants who shared common goals. A monitoring and evaluation mechanism was also embedded to track progress and identify limitations and challenges during the implementation phase. The iterative exchange and continuous improvement process contributed to the development of a farmer-led innovation network across regions. This strategy enhanced agricultural efficiency and equity in access to appropriate technologies, thereby fostering the development and dissemination of innovation knowledge among smallholder farmers.

Out of 120 participants, 50.8% were female, with an average age of 51.53 years. Most had completed junior high school (Grade 9). The average household size was five members, with two working on the farm. The average farmland size per family was 12.62 rai (4.98 acres), with rice as the primary crop. The median annual wage was 83,300 Thai baht.

Regarding loans, 53.3% of participants had an average crop loan of 97,773.97 Thai baht from banks, 97,050.00 Thai baht from agricultural cooperatives, and 23,094.20 Thai baht from community funds (as of 2022). The median income from agriculture and the average loan debt indicate a significant risk, as loan amounts exceed income. Therefore, exploring new agricultural theories-particularly the acceptance and adaptation of innovation and technology aimed at reducing costs-is being carefully considered to improve product quality and ensure survival.

2. Risk Scale of Participants in the “Adoption of Internet of Things Workshop”

The overall risk faced by all 120 farmers was assessed at a medium level as follows: economic risk ($\bar{x}$= 3.40), investment risk ($\bar{x}$= 2.94), and agricultural production and price risk ($\bar{x}$= 2.60). Agricultural-related policies were perceived as very important by the farmers, who strongly agreed that these policies should focus on enhancing agricultural production skills, developing smart farmer capabilities, promoting Good Agricultural Practices (GAP), supporting organic farming, and encouraging agricultural market development.

Given the medium level of risk, these policies are expected to effectively support risk management. Timely implementation of government policies-especially those promoting various forms of innovation and technology-will enable farmers to respond more effectively to future risks.

On the contrary, infrastructure remains a critical support factor in Thailand’s agricultural sector, drawing attention due to significant challenges. Notably, 85% of farmers lack access to farm irrigation systems on their land, and issues such as water scarcity and soil degradation persist. However, all farmers (100%) have access to high-speed internet, which serves as an important supportive component.

For agricultural innovation and technology to thrive, a stable internet connection is essential. Internet-enabled technologies help farmers address challenges like water scarcity, soil degradation, and irrigation problems. For example, drip or trickle irrigation systems-where water is delivered slowly through small-diameter plastic pipes with outlets or drippers-can be operated remotely via smartphone, optimizing water use and improving efficiency.

3. Use of Agricultural Innovation and Technology Over a Five-year Period (2018-2022)

Between 2018 and 2022, 100% of farmers enhanced their knowledge of new agricultural theories, innovations, and technologies through various communication channels such as district agricultural offices, Tambon agricultural offices, and independently surfing the internet via smartphones, laptops, and PCs. On average, farmers use about 2.92 agricultural-related applications, as well as social media platforms that provide access to information on production factors and agricultural commodities directly on their smartphones. Line and YouTube are the primary channels they use to research and deepen their knowledge.

This demonstrates that farmers are actively adapting innovations and technology within their agricultural practices to keep up with current trends in products and markets. They rely heavily on the concept of self-reliance, remaining open to new innovations and Internet of Things (IoT) technologies by continuously learning and updating their skills.

The findings revealed that the innovations and technologies farmers have used or been aware of over the past five years include weather forecast applications, the LDD Soil Guide by the Land Development Department, agro-economic news and information applications from the Office of Agricultural Economics (Ag-Info), the Brown Planthopper (BPH) count or Insect Shot application, and water situation updates from the Water Management System Center (WMSC) application. The acceptance and adaptation of these existing applications benefit farmers regardless of whether they are government-operated or voluntarily adopted.

The innovation and technology features that attract farmers the most are low complexity, affordability, easy accessibility, minimal unnecessary data entry, and eco-friendliness. Those who share these views tend to be forward-thinking individuals with leadership qualities who are open and willing to try new things. This aligns with the characteristics of innovation adopters described by Rogers (2003).

4. Effective Strategies for Expanding Knowledge Regarding IoT in Agriculture

Between 2018 and 2022, farmers adopted innovation and technology in agriculture through several effective strategies, including the power of word-of-mouth, free online media channels like YouTube, and workshops organized by the Community Organizations Development

Institute (CODI). The innovations that attract farmers' attention are those that save time, are easy to access, and reduce costs-especially technologies related to automated irrigation systems and soil degradation prevention. Additionally, agricultural extension and networking play a pivotal role in the sector. By connecting with like-minded individuals, potential buyers, suppliers, and partners, farmers stay informed about the latest trends, innovations, and market opportunities. As one farmer expressed:

> "With or without government support, innovation and technology will continue to be accepted and adapted in agriculture. However, some technologies remain out of reach because they are too complicated or expensive. We farmers are willing to adopt and share experiences with innovations that are affordable, easy to access, and cost-saving" (Karntaharn, personal communication, 2023).

It is also noticeable that a certain group of farmers holds traditional views and is more skeptical about innovations and change agents. They typically lack leadership roles and have limited resources and awareness of new technologies. This group prefers to wait and see proof that an innovation works before adopting it. According to Rogers (2003), these individuals tend to adopt only after most of their peers have done so. Though skeptical, economic necessity and peer pressure often lead them to accept innovations eventually.

Socioeconomic status, personality traits, and communication behaviors are generally positively related to innovativeness. Innovativeness refers to the degree to which an individual adopts new ideas earlier than others in their social system.

Based on these characteristics, participants can be classified into two main groups:

1. **Adopters**: These individuals are willing to experiment with new ideas and accept some level of uncertainty and risk associated with innovations. Their interest in new ideas often extends their social networks beyond local peers to more cosmopolitan relationships. Innovators commonly communicate and share knowledge despite geographical distances. As one farmer said:

> *"No matter how global food security trends change, we as food producers must continually improve product quality. Acceptance and adaptation of the Internet of Things (IoT) is unavoidable because it helps reduce costs and minimize input risks" (Patchimpet, personal communication, 2023).*

Adopters typically have sufficient financial resources to absorb potential losses from unsuccessful innovations and the ability to understand and apply complex technical knowledge. They play a critical role in introducing innovations into the social system, acting as gatekeepers for new ideas.

2. **Intuition-based agriculture users**: This group relies heavily on past experience when making decisions. Their resistance to innovations is often rational due to limited resources and a strong need to avoid failure. For example, some have installed adapted devices developed by the adopter group to monitor soil quality and control automated irrigation systems. As one interviewee explained:

> *"Having friends knowledgeable in innovation and technology, capable of adapting and setting up affordable automated devices priced at 2,500 THB (compared to 20,000 THB on the market), has been a crucial factor for adopting these technologies, even though we can't make the devices ourselves." (Hongnak, personal communication, 2023).*

Another farmer shared:

> *"It's just my wife and me working on the farm. Watering vegetables takes about 60 minutes per bed, and when I'm away running errands, my wife manages all the farm work. It would be great to have an automated irrigation system controlled via smartphone. Innovation and technology help us live more conveniently and improve our quality of life." (Thanisan, personal communication, 2023).*

Consequently, innovation and technology reduce agricultural costs-market-ready devices are often ten times more expensive-save time, and mitigate labor shortages by allowing farmers to control irrigation systems remotely through smartphone apps. This gives them more time for other activities and makes decision-making easier regarding adoption in agriculture.

Table 2 Comparison of innovation and technology adaptation by farmers participating in the workshop

List	Tradition-Based	Innovation and Technology-Based
Cost of innovation and technology	Controlled devices in the market for the selling cost of 20,000 baht	Some parts can be purchased from local stores or online platforms like Shopee or Lazada and assembled at home, costing only about 2,500 baht.
Time period of irrigation	60 mins per bed, so it takes 3 hours for 3 beds	The irrigation runtime is controlled via an online application, allowing the automated irrigation system to be scheduled for turn-on and turn-off directly from a smartphone.
Area of irrigated land	3 hrs for 3 beds (more work for fewer products)	On-off mode operated on an automated device within 60 secs for 3 beds
Direct monetary compensation per kilogram	60 baht per kilogram	60 baht per kilogram, with some extra time left to engage in other activities such as working, running a food truck at a flea market, and more.
Family relationships	Two work and rest together during watering time. If one is unavailable, the other takes full responsibility for watering all the farm beds.	This allows them to enjoy their free time, have pleasurable moments, and strengthen family bonds.
Learning process	Traditional existing knowledge employed repeatedly	Take action, adopt, adapt, and implement new innovation and technology for further productive results
Risk management	Variable inputs caused by extreme weather	Variables like water, fertilizers, and soil are managed effectively, regardless of climate change

Note: Interviews, 2023

5. Factors Influencing the Acceptance and Use of Internet of Things (IoT) by Thai Farmers

Multiple regression analysis (MRA) was employed to analyze the independent variables (Table 3), as per the following model:

Y = β_0+β_1 (gender) + β_2 (age)+ β_3 (educational background)+ β_4 (IoT to standardize products) + β_5 (IoT to allow for easier access and reduce complications) +β_6 (production costs) + β_7 (government policies)

Table 3 Basic statistics of independent variables

Variables	Min.	Max.	$\bar{x}$	S.D.
Number of innovations and technology that farmers know	2	6	2.92	1.274
Gender	0	1	0.51	0.502
Age (year)	25	80	51.53	11.785
Educational background (year)	6	16	9.53	2.054
IoT to standardize products	0	1	0.43	0.498
IoT to allow for easier access and reduce complications	0	1	0.85	0.359
Production costs	0	5	2.94	2.035
Government policies	0	5	0.44	1.262

Note: Calculation, 2024

Y = 3.509 + 0.161*gender - 0.017*age + 0.029*educational background
(3.425) (0.701) (-1.611) (0.516)
+ 0.472*IoT to standardize products
(2.083)*
- 0.050*IoT to allow for easier access and reduce complications
(-0.146)
- 0.121*production costs + 0.216*government policies
(-2.126)* (2.406)*

According to the MRA, the results revealed an F-value of 2.716 and a significance level (Sig. F) of 0.012. This indicates that at least one of the independent variables is significantly related to and predictive of the dependent variable. The Multiple Coefficient of Determination (R^2) was 0.145, meaning that the model explains 14.5% of the variance in the dependent variable. Three independent variables were found to be significantly correlated with the dependent variable, as shown in Table 4 and explained below:

1. **Innovation and Technology in Promoting Agricultural Product Standardization:** Farmers showed a higher level of acceptance toward innovations and technologies that aim to improve the quality standards of agricultural products, with statistical significance at the 0.05 level. This indicates that technologies contributing to standardized and market-ready products are more readily adopted than those targeting other agricultural improvements. The distribution of substandard products often fails to meet market demand. At the same time, growing concerns around health security, sustainable consumption, and eco-friendly practices increase the demand for reliable production methods. The Internet of Things (IoT) offers a promising solution for achieving standardization, thereby increasing income through the distribution of high-quality agricultural products.
2. **Risk Cost Management:**
   The analysis showed that risk costs were rated at a high level, which negatively affected the acceptance and adaptation of innovation and technology, also with statistical significance at the 0.05 level. In other words, farmers are less likely to adopt expensive technologies-especially those requiring additional investment-because such costs can disrupt budget plans. In the current economic climate, where financial uncertainty is prevalent, farmers are cautious about unexpected expenses. Moreover, increasing loan debt reduces their capacity for effective debt management, further limiting their willingness to take financial risks on new technologies.
3. **Supportive Public Policies:**
   Government policies that support agricultural development significantly increased farmers' acceptance and adaptation of innovation and technology ($p < 0.05$). Examples of these policies include the establishment of agricultural learning centers, promotion of traditional farmers to smart farmers, development of Good Agricultural Practices (GAP), support for organic agriculture, and efforts to expand agricultural markets. Public policies play a critical role in encouraging

innovation adoption by promoting farm clustering, providing funding opportunities, and offering training courses to strengthen farmer competencies. These policies are most effective when they directly respond to farmers' needs and priorities.

Table 4 Multiple regression analysis: Factors influencing the acceptance and use of Internet of Things (IoT) by farmers participating in the IoT Workshop

Variables	Regression coefficient	t	Sig.
Constant	3.509	3.425	0.001
Gender	0.161	0.701	0.485
Age (year)	-0.017	-1.611	0.110
Educational background (year)	0.029	0.516	0.607
IoT to standardize products	0.472	2.083	0.040*
IoT to allow for easier access and reduce complications	-0.050	-0.146	0.884
Production costs	-0.121	-2.126	0.036*
Government policies	0.216	2.406	0.018*
R = 0.381 R^2= 0.145 SEE = 1.214 F = 2.716 Sig. of F = 0.012			

Note: * Significance level at 0.05

Conclusion

The majority of farmers participating in the project were women, with an upward trend in average age. Household labor availability was found to be declining, and income from agriculture alone was insufficient for subsistence. These farmers faced significant barriers in accessing modern technologies due to high costs, prompting them to seek more accessible and equitable alternatives. In this context, low-cost Internet of Things (IoT) innovations were perceived as viable solutions to support their agricultural production systems. Statistically significant factors influencing farmers' acceptance of IoT technology included its potential to enhance product standards, its capacity to reduce production costs, and supportive government policies.

The study found that the IoT innovations adopted by Thai farmers in the study areas were not necessarily high-tech or expensive. Rather, they were localized innovations developed by repurposing readily available materials-either from the community or local markets-through a hybrid approach combining traditional knowledge with global technological understanding. These farmer-driven adaptations produced context-specific, low-cost IoT solutions tailored to address pressing agricultural challenges. Such innovations were culturally appropriate, economically feasible, and well-aligned with the lived realities of Thai smallholder farmers.

Nonetheless, this study was conducted with a specific group of 120 smallholder farmers in 10 pilot areas and may not fully represent the broader population of Thai small-scale farmers. However, it reflects common challenges faced by many such farmers across the country-particularly the limited access to expensive modern technologies or state-supported innovations that often require collective organization, which may not be feasible for all. Some advanced technologies also fail to align with local farming practices. Therefore, the promotion of affordable, locally adapted innovations-developed collaboratively based on the real needs and challenges of farmers themselves-offers a promising model for equitable, accessible, and sustainable agricultural development. This approach may contribute to the emergence of a localized IoT innovation model grounded in Thailand's socio-ecological contexts.

Suggestions

The key components that significantly influence the acceptance of innovation and IoT technology among farmers are: (1) the ability of IoT to support standardized crop production, (2) the potential to reduce production costs, and (3) supportive government policies.

To effectively promote the use of IoT in agriculture, Group 1 farmers (adapters)-those with the potential to apply the technology, who play an important role in the community, and who hold a positive attitude toward innovation and view IoT as a suitable and worthwhile alternative-should be encouraged to become partners with the Community Organizations Development Institute. They can serve as models for scaling up by opening their farms as learning spaces and taking roles as facilitators within and across communities. Their role is not only to transfer technical knowledge but also to foster critical thinking, enhance problem-solving skills, and lead innovation development based on real agricultural challenges.

At the same time, to strengthen Group 2 farmers (users)-those who apply IoT but are not yet innovators-the Institute should collaborate with local administrative organizations to create mechanisms that encourage farmers to communicate the problems and limitations they face in their farming contexts. These insights can be passed on to Group 1 farmers to further develop and refine innovations that respond to diverse socio-geographic contexts. Special attention should be given to how innovations improve key production factors such as soil and water. Moreover, experienced Group 2 farmers should be supported in progressing to Group 1, thereby enhancing both the quantity and quality of agricultural innovators.

Besides Groups 1 and 2, there are still other farmers in the area who belong to Group 3-traditional farmers who are less open to change, have not participated in the training program, and tend to rely on intuition and personal beliefs. For this group, interventions may begin with family members, such as children or returning migrants, who are more receptive to new ideas. Local organizations can promote activities to encourage these younger household members to learn about innovation and IoT technologies. This approach can be framed as “Group 1 + Group 2 to attract Group 3.”

Regarding policy, government support for agricultural innovation must be flexible and responsive to local ecosystems, farming behaviors, and cultural norms. Policy goals and performance indicators should be designed to allow contextual adaptation. A practical and immediate policy recommendation is to promote the development of area-based IoT innovations by integrating local wisdom with global knowledge to address agricultural challenges and support sustainable development. Such policies will promote fairness and equity in access to innovation, particularly for smallholder farmers across diverse regions. They will also enable farmers to overcome localized challenges, enhance their livelihoods, and strengthen the overall competitiveness of the country’s agricultural sector.

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