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Adoption Intentions and Functional Requirements of Big Data–Driven Smart Farming Systems: An Empirical Study in Taiwan

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Abstract: With the rapid development of artificial intelligence (AI), smart agriculture has become a key direction for agricultural transformation. However, in Taiwan, the adoption rate of smart farming management systems among agricultural practitioners remains relatively low. This study aims to identify the key factors influencing adoption intentions and to analyze the functional requirements of big data-driven smart farming applications (APPs). By extending the Technology Acceptance Model (TAM) [1], this research incorporates perceived privacy and perceived security as external variables [2]. A qualitative approach was adopted through semi-structured in-depth interviews with farmers, production and marketing group leaders, cooperative managers, and agricultural association representatives. Government open data were also utilized to supplement the APP design analysis. The findings reveal that perceived usefulness and perceived ease of use remain the primary determinants of adoption, while privacy and security concerns significantly affect users' trust and their intention to adopt the system. Interviewees emphasized that an effective smart farming management system should include core functions such as farmland and crop management, pest and pesticide monitoring, inventory control, cost management, and real-time alerts. In addition, privacy and security dimensions should be given due consideration. Therefore, this study integrates privacy and security constructs into the proposed framework, thereby addressing an important research gap in smart agriculture adoption. Practically, the results provide empirical insights for system developers and policymakers to design user-centered smart farming applications and to promote agricultural digital transformation. Overall, this study not only enhances academic understanding of adoption mechanisms in smart agriculture but also offers valuable implications for policy formulation and system development.

Keywords: smart agriculture technology, big data analytics, Technology Acceptance Model (TAM), perceived usefulness, perceived ease of use

1 Introduction

1.1 Research Background

In Taiwan, despite the government's active efforts to promote agricultural digital transformation, the adoption rate of smart farming management systems among agricultural practitioners remains relatively low. Smart agriculture leverages data analytics and automation technologies to enhance management efficiency, reduce production costs, and improve the quality of agricultural products. According to the Executive Yuan's 2024 National Science and Technology Conference, smart agriculture has been designated as one of the nation's strategic priorities for technological development [3]. Its primary objectives include:

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1. Enhancing agricultural productivity: Utilizing data analytics and intelligent decision-making to increase yields and optimize resource utilization.
2. Ensuring food security: Implementing precision agriculture technologies to mitigate the effects of climate change and pest infestations on food supply.
3. Promoting agricultural sustainability: Reducing the excessive use of pesticides, fertilizers, and water resources to minimize environmental impact.

1.2 Research Motivation

Although the Taiwanese government has designated smart agriculture as a national development priority, farmers' acceptance and utilization of digital tools remain limited in practice. The main barriers include high technological thresholds, concerns over data privacy and security, and the lack of user-oriented functional design and educational promotion. These challenges indicate that current smart farming management systems have not been sufficiently developed from a user-centered perspective; their functional designs often fail to meet farmers' practical operational needs [3]. Based on this perspective, this study investigates the key factors influencing farmers' adoption of smart farming management systems and proposes functional design recommendations that better align with practical requirements, thereby narrowing the gap between academic research and agricultural application.

1.3 Research Objectives

This study aims to address the low adoption rate of smart farming management systems during Taiwan's agricultural digital transformation by identifying the key influencing factors and proposing user-centered system design recommendations. Based on the aforementioned research motivation, the specific objectives of this study are as follows:

To examine the effects of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) on agricultural practitioners' intentions to adopt smart farming management systems.

To analyze how Perceived Privacy (PP) and Perceived Security (PS) influence users' behavioral intentions.

To identify the functional requirements of agricultural practitioners for smart farming management systems and to categorize key functional modules through qualitative interviews.

To integrate empirical findings and requirement analyses to propose practical design guidelines for smart farming applications that enhance both farmers' adoption intentions and the overall value of system implementation.

2 Literature Review

This study conducts a comprehensive review of the relevant literature from five key perspectives: (1) smart agricultural technology, (2) big data analytics, (3) the Technology Acceptance Model (TAM), (4) perceived usefulness and perceived ease of use, and (5) perceived privacy and perceived security. These theoretical foundations serve to clarify the conceptual structure of this research and to establish the analytical framework for exploring the adoption intentions and functional requirements of big data-driven smart farming management systems.

2.1 Smart Agricultural Technology

Modern agriculture increasingly relies on smart agricultural systems to meet the growing demands of crop production. Through the integration of the Internet of Things (IoT), cultivation management technologies, and online operation interfaces, smart agriculture enables farmers and agricultural experts to edit and manage crop-specific programs, monitor growth conditions, and analyze data as physiological indicators for crop health. Such systems facilitate the establishment of intelligent farms that enhance precision, efficiency, and sustainability in agricultural production [4].

Agricultural communication is a comprehensive and interdisciplinary process of human interaction that encompasses agriculture, food systems, natural resources, and rural well-being. Effective agricultural communication not only facilitates knowledge exchange and accelerates the diffusion of technological innovations but also strengthens collaborative relationships among stakeholders, thereby playing a crucial role in advancing the sustainable development of smart agriculture [5].

2.2 Big Data Analytics

With the continuous development of the Internet of Things (IoT), cloud computing, artificial intelligence (AI), and machine learning (ML), big data has become a fundamental driver of digital transformation across multiple industries [6]. In the agricultural domain, big data analytics has been widely applied—particularly in precision agriculture (PA).Beyond crop production, big data analytics also supports smart farming management, optimizing farm operations through real-time data-driven decision-making [7]. By integrating environmental and operational data, big data systems help farmers assess soil health, forecast yields, and provide evidence-based recommendations for improving farm productivity and profitability [8].

However, the application of big data in agriculture still faces several challenges, such as data standardization, privacy protection, and farmers' acceptance of digital technologies [9].

2.3 Technology Acceptance Model (TAM)

Davis (1989) proposed the so-called Technology Acceptance Model (TAM). Based on the Theory of Reasoned Action (TRA) [10] and the Theory of Planned Behavior (TPB) [11], Davis modified and developed the model to evaluate users' acceptance and intention to use information technology. The Technology Acceptance Model suggests that if users increase their willingness to use information technology, their intention to use it will also increase. Therefore, Davis proposed two major constructs in the model: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Please refer to Fig. 1.

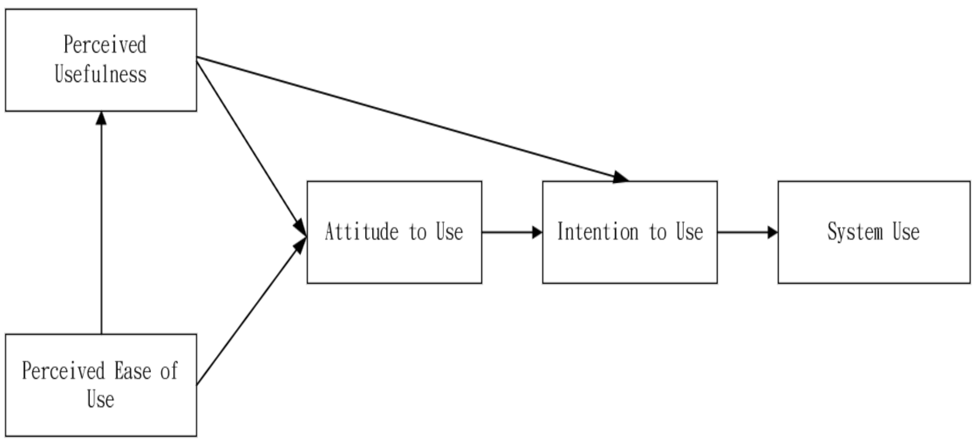


Fig. 1. Technology acceptance model (Reference: Davis, 1989)

2.4 Perceived Usefulness and Perceived Ease of Use

According to Burton-Jones and Hubona, the Technology Acceptance Model (TAM) has been widely applied by researchers and practitioners to predict and explain users' acceptance of information technology [12]. Warshaw stated that the TAM was developed to understand the causal relationship linking external variables with users' acceptance and actual usage behavior [13]. Cano Giner, Fernandez, and Díaz Boladeras pointed out that behavioral intention depends on an individual's attitude toward the use of an object [14]. Venkatesh and Davis further explained that this attitude is determined by perceived usefulness and perceived ease of use [2]. Davis (1989) and Pranidana (2011) summarized several indicators of perceived ease of use in information technology research [1, 15], including:

1. Information technology is easy to learn.
2. Information technology helps users accomplish tasks easily and achieve their goals.
3. Users' skills will improve through the use of information technology.
4. Information technology is very easy to operate.

Subagio, Mugiono, and Hadiwidjojo defined perceived ease of use as the condition in which a person believes that using a particular system or application does not require much time for analysis—in other words, the technology can be easily understood by users [16]. Davis pointed out that when users perceive an application as flexible, easy to understand, and simple to operate, these characteristics represent ease of use [1]. The frequency and intensity of users' interaction with the application can also indicate perceived ease of use. Adams et al. noted that the more frequently an application is used, the more it suggests that the system is well-known, easy to operate, and user-friendly [17].

2.5 Perceived Privacy and Perceived Security

Smart agriculture services establish a comprehensive service system through technologies such as ICT (Information and Communication Technology), AI (Artificial Intelligence), and the IoT (Internet of Things). However, the frequent transmission and exchange of data have significant implications for personal privacy and information security. Users' concerns regarding privacy and security are important determinants of technology adoption. When users perceive problems related to privacy or security, their trust in the system decreases, thereby reducing their willingness to adopt smart agricultural technologies [18].

From a theoretical perspective, information privacy and security are generally regarded as important factors influencing technology adoption. However, perceived privacy and perceived security may not directly determine users' behavioral intentions. Instead, they are more likely to influence adoption intention indirectly by shaping users' trust in the system. Based on these differing empirical findings, this study comprehensively examines both the direct and indirect effects of perceived privacy and perceived security on the adoption intention of smart agriculture technologies.

3 Research Methodology

This chapter presents the overall research design, encompassing the key components of the study, including the establishment of the research framework, formulation of hypotheses, identification of research subjects, data collection and analytical methods, and a discussion of research limitations. Through a systematic design and execution of these procedures, this study aims to ensure the validity and reliability of the research findings, thereby providing a solid foundation for subsequent discussion and practical recommendations.

3.1 Research Framework and Hypotheses

This study is grounded in the Technology Acceptance Model (TAM) proposed by Davis (1989) to investigate agricultural practitioners' acceptance of smart farming applications (Smart Farming Apps). The model examines the interrelationships among Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude Toward Use (ATT), and Behavioral Intention (BI).

In the initial stage of this study, a series of in-depth interviews were conducted with farmers, agricultural association representatives, and domain experts to collect insights regarding users' perceptions and needs related to smart agricultural applications. During these interviews, several participants expressed significant concerns about data privacy and system security. In response to these findings, the research framework was extended by incorporating two additional constructs—Perceived Privacy (PP) and Perceived Security (PS)—to enhance the explanatory power of the traditional TAM.

By integrating these two constructs, this study aims to provide a more comprehensive understanding of the factors influencing agricultural practitioners' adoption intentions toward smart farming applications. The proposed research framework is illustrated in Fig. 2, which depicts the hypothesized relationships among the six major constructs.

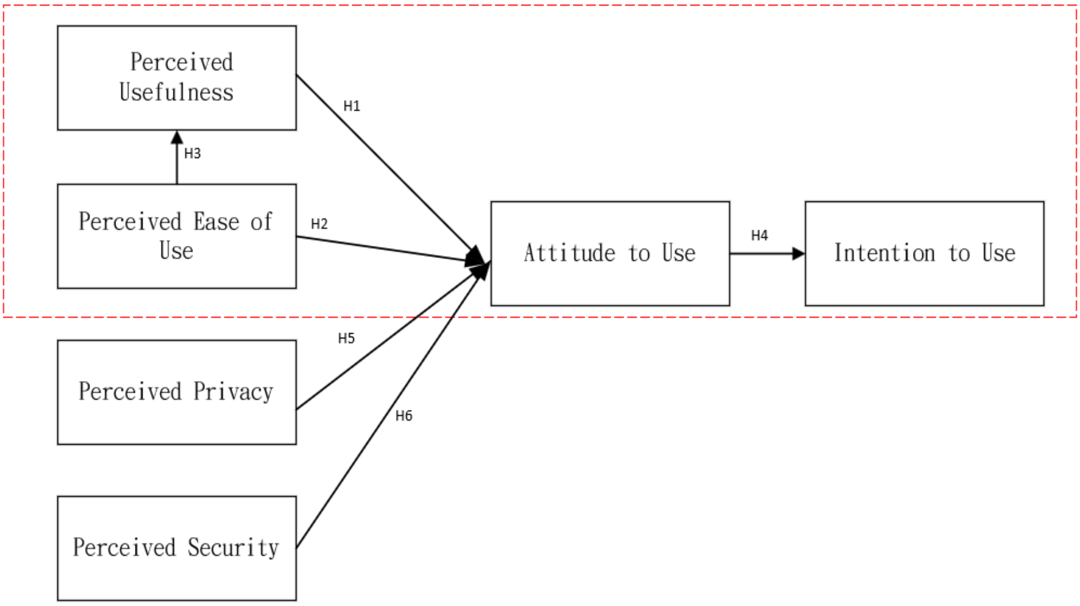


Fig. 2. Research framework (Compiled by this study)

Based on the literature review, this study proposes the following hypotheses:

H1: The *Perceived Usefulness* (*PU*) of smart farming applications has a positive effect on *Attitude Toward Use* (*ATT*).

H2: The *Perceived Ease of Use* (*PEOU*) of smart farming applications has a positive effect on *Attitude Toward Use* (*ATT*).

H3: The *Perceived Ease of Use* (*PEOU*) of smart farming applications has a positive effect on *Perceived Usefulness* (*PU*).

H4: The *Attitude Toward Use* (*ATT*) of smart farming applications has a positive effect on *Behavioral Intention* (*BI*).

H5: The *Perceived Privacy* (*PP*) of smart farming applications has a positive effect on *Attitude Toward Use* (*ATT*).

H6: The *Perceived Security* (*PS*) of smart farming applications has a positive effect on *Attitude Toward Use* (*ATT*).

These hypotheses extend the original Technology Acceptance Model (TAM) by incorporating Perceived Privacy and Perceived Security as external variables, thereby providing a more comprehensive understanding of the behavioral mechanisms influencing agricultural practitioners' adoption intentions toward smart farming applications.

3.2 Research Participants

The selection criteria for the interview participants were as follows: respondents were required to have practical experience in agricultural production or management and possess a certain level of awareness or potential interest in smart farming–related applications to ensure the reliability and relevance of their feedback. The participants primarily comprised vegetable farmers and agribusiness managers in Yunlin County, Taiwan. To capture sample diversity, the interviewees represented different age groups, educational levels, and occupational backgrounds, with a minimum of five years of work experience in agriculture. The participants' years of experience ranged from 7 to 30 years, and included both users and non-users of smart farming management systems (see Table 1).

In terms of gender distribution, the majority of respondents were male (n = 9), with only one female participant, who served as a staff member at an agricultural association. This distribution reflects the reality that men continue to constitute the primary labor force in Taiwan's agricultural sector. Regarding age, most participants were between 40 and 60 years old, representing a middle-aged group with substantial farming experience. In terms of education, the participants held qualifications ranging from vocational high school to master's degrees, with the majority holding junior college or undergraduate degrees, indicating a relatively strong professional background.

Occupationally, the respondents included not only general farmworkers but also section chiefs of agricultural associations, leaders of vegetable production and marketing groups, and cooperative chairpersons, providing perspectives from multiple managerial and operational levels. Concerning experience with smart farming systems, eight respondents reported prior use of such technologies, indicating a relatively high level of interest and adoption intention among younger farmers (young agripreneurs).

However, the sample primarily consisted of younger farmers, who tend to exhibit greater openness to digital technologies, while older farmers remain less inclined to adopt or engage with such systems. Therefore, although this study captures diverse perspectives from Yunlin County's vegetable farming operators, caution should be exercised when generalizing the findings to other agricultural sectors or scales of operation.

To gain an in-depth understanding of users' adoption intentions and influencing factors regarding smart farming management applications, this study employed a semi-structured interview approach. The detailed profile of interview participants is presented in Table 1.

This study employed a semi-structured interview method to gain an in-depth understanding of users' intention to use smart agricultural management apps and the influencing factors. The interviewees are listed in Table 1:

Table 1. In-depth interview participants (Compiled by this study)

Code	Age	Education	Job title	Professional experience (Years)	Cultivation or purchase category	Used smart agricultural related systems?
F1	45	University	Self-employed farmer	12	Vegetables, leafy greens. Cruciferous small leafy greens (organic)	Yes
F2	50	Junior college	Self-employed farmer	20	Vegetables	No
F3	42	University	Vegetable cooperative manager, self-employed farmer	15	Leafy greens, wax gourd, pumpkin	Yes
F4	57	Senior vocational agriculture school	Production and sales team leader	30	Leafy greens, cruciferous vegetables. Flowers, fruit trees, vegetables, rice, etc.	No
F5	41	Master's	Agricultural association production and sales department head	7	Flowers, fruit trees, vegetables, rice, etc.	Yes
F6	55	University	Pesticide shop owner	21	-	Yes
F7	45	Junior college	Farm worker	12	Vegetables, leafy vegetables	Yes
F8	51	Junior college	Farm worker	21	Organic leafy vegetables	Yes
F9	65	Vocational high school	Chairman of vegetable cooperative	25	Leafy vegetables, cruciferous vegetables, etc.	Yes
F10	56	Vocational high school	Farm worker	15	Leafy vegetables, cruciferous vegetables, etc.	Yes

In addition to conducting interviews and collecting qualitative data, this study also utilized government open data platforms—including the Agricultural and Food Agency's Crop Statistics Database, Pest and Disease Information System, and Pesticide Usage Management Platform—as supplementary sources of knowledge. For example, when interviewees emphasized the urgent need for a pest and disease early warning system, the research team referred to official data on pesticide usage and climate conditions to provide a more comprehensive contextual understanding. Such integration of open government data not only enhanced the depth and credibility of the study but also contributed to transforming academic research findings into practically beneficial knowledge resources for farmers and agricultural stakeholders.

3.3 Data Analysis Methods

This study adopted qualitative research methods to explore agricultural practitioners' perceptions of big data–driven smart farming management systems. Data were collected through semi-structured in-depth interviews and systematically analyzed to identify the key factors influencing user adoption intentions and functional requirements.

Interview Data Analysis. The collected interview data were analyzed using the Thematic Analysis approach proposed by Braun and Clarke (2006) [20], which consists of six systematic steps for processing and interpreting qualitative data:

1. **Familiarization with data:** All interview recordings were transcribed verbatim, followed by repeated readings to ensure a comprehensive understanding of the content.
2. **Initial coding:** Open coding was applied to the transcripts to label core concepts related to adoption intentions and functional requirements.
3. **Theme identification:** Codes with similar meanings were clustered and synthesized into initial themes.
4. **Theme review:** Data from different interviewees were cross-checked to confirm the stability and consistency of the identified themes.
5. **Theme definition and reporting:** The finalized thematic structure was organized and integrated into the research report to present the main findings and insights.

Supplementary Data and Knowledge Expansion. To enhance the practical relevance and completeness of participants' perspectives, the study further incorporated open government data as supplementary knowledge sources:

1. **Interview data:** Included a diverse group of participants such as farmers, leaders of production and marketing groups, cooperative managers, and representatives from agricultural associations, providing multiple layers of qualitative insights.
2. **Government open data:** Incorporated information from publicly accessible databases such as the *Agricultural and Food Agency's Crop Statistics*, the *Taiwan Agricultural Research Institute's Pest and Disease Database*, and the *Pesticide Usage Management System*. These datasets were used as background knowledge and as a foundation for conceptualizing potential smart farming APP databases.

This approach was not intended to verify the interview results but rather to complement and enrich the knowledge base required for smart farming application development. By integrating open data with user insights, the study provides more applicable and context-aware findings, thereby supporting farmers with comprehensive information for practical agricultural management.

3.4 Research Limitations

This study is subject to the following limitations:

First, regional differences: Since this study primarily focused on leafy vegetable cultivation, most participants were located in Yunlin County, Taiwan's largest vegetable-producing region. Therefore, the findings may not be fully generalizable to other agricultural contexts or regions across Taiwan.

Second, technological barriers: Some elderly farmers exhibit lower acceptance of digital tools and technologies. Because this study mainly targeted young farmers (young agripreneurs), the results may have limited applicability to older farming populations, potentially affecting the broader promotion and implementation of smart farming systems among senior agricultural practitioners.

3.5 APP System Architecture

Based on the findings from the literature review and in-depth interviews, this study preliminarily constructed the overall architecture of the smart farming management system (see Fig. 3). The operational flow of the system begins with user registration and login, followed by access to the main interface, which is divided into three core functional modules according to user needs:

1. Shared Data Maintenance,
2. Cultivation Data Maintenance, and
3. Inventory and Sales Management.

These three modules are interconnected, forming an integrated and real-time agricultural information management platform. The modules are introduced as follows:

1. Shared Data Maintenance
This module provides fundamental yet essential data support, encompassing:

- Crop Management: Establishes and maintains basic attributes and growth information for various crops to support cultivation planning and farm operations.
- Pest and Disease Management: Integrates open government databases (e.g., pest and disease inquiry systems) to provide real-time updates on prevention and control knowledge, enabling farmers to access timely pest-related information.
- Pesticide Management: Connects to the *Pesticide Usage Management Database* to ensure compliant and safe pesticide use, allowing users to query regulations and alternative agents instantly.
- Labor Management: Builds an agricultural human resource platform where farmers can search for and hire skilled laborers by region or expertise, enhancing workforce allocation efficiency.

The core value of this module lies in its automatic synchronization with open government data, which ensures data accuracy and timeliness while reducing users' maintenance workload.

2. Cultivation Data Maintenance
This module focuses on managing users' actual farmlands and agricultural processes, including:

- Field Management: Records information about farmers' land parcels, including boundaries, locations, and key attributes, allowing comprehensive monitoring of resource allocation.
- Cultivation Management: Tracks the cultivation status of each plot, including crop growth progress, cultivation plans, and operation logs, thereby enhancing transparency and efficiency in farm operations.
- Notification and Reminder System: Provides automated push notifications regarding agricultural plans, pesticide usage regulations, and pest or disease control schedules to help users manage critical tasks in real time.

Through this module, farmers can effectively plan agricultural activities, minimize information gaps, and reduce potential losses caused by delayed or missed operations.

3. Inventory and Sales Management
This module focuses on business and operational analytics, covering:

- Inventory Management: Monitors real-time inflows and outflows of agricultural materials and products to prevent shortages and minimize resource waste.
- Revenue and Expense Tracking: Records all income and expenditures in agricultural operations, generating financial reports to help farmers understand their profitability and cost structure.
- Cost Control: Tracks input-output efficiency to perform cost analyses, thereby providing data-driven insights for decision-making and farm management optimization.

The value of this module lies in the digitalization of operational and financial data, helping farmers achieve precision agriculture and long-term sustainability.

Overall Features and Advantages

- Real-Time Functionality: Ensures up-to-date information through dynamic data integration and open-data synchronization.
- Integration: Consolidates agricultural management, resource allocation, and financial operations into a single unified platform, reducing system fragmentation.
- Intelligence: Incorporates notification alerts, data analytics, and decision-support functions to enhance management efficiency and scientific precision.
- User-Friendliness: Designed around farmers' actual needs, with a clear interface guiding users from registration and login to operating the three major modules.

This system is not merely an information platform but a comprehensive smart agriculture solution. It assists farmers in improving operational efficiency, reducing management costs, and increasing profitability, thereby facilitating digital transformation and smart agricultural advancement.

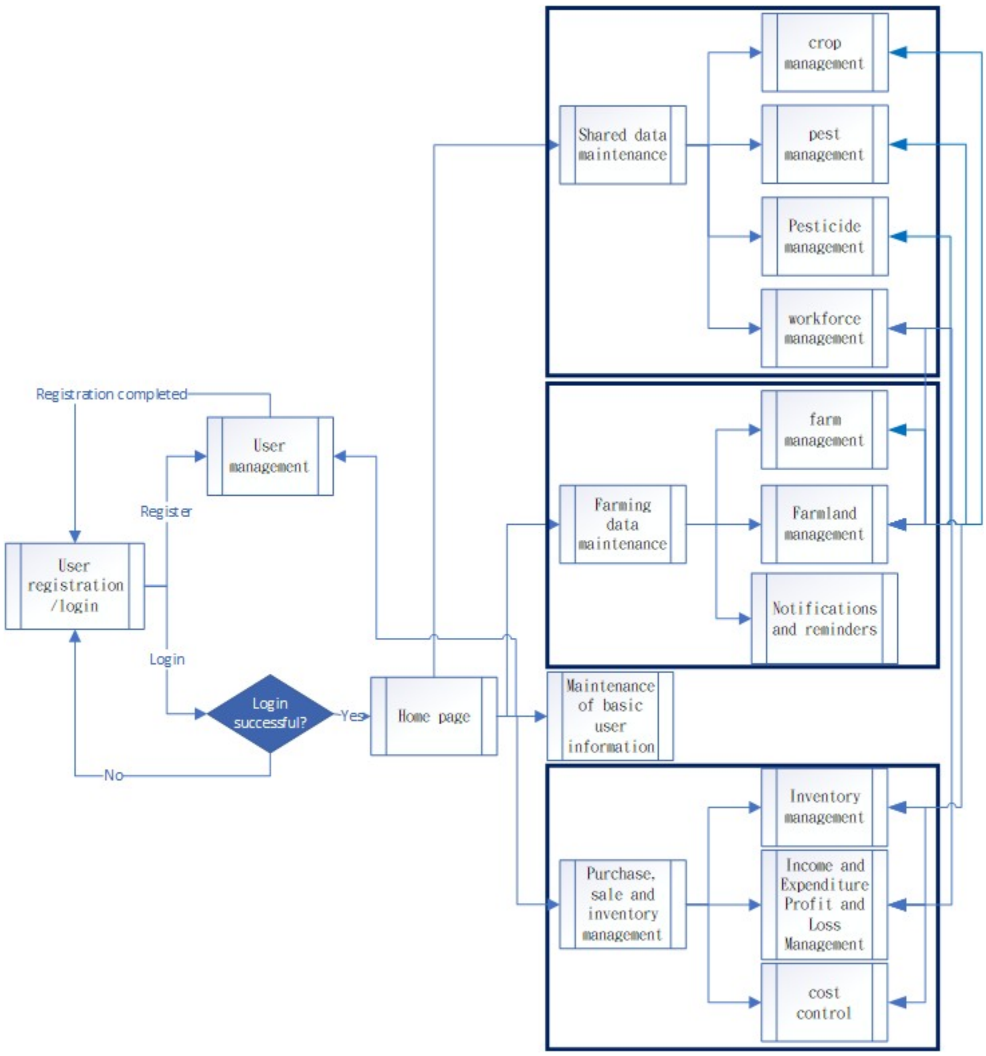


Fig. 3. Smart farming APP system architecture diagram

3.6 Related Studies and Research Gap

Previous studies on the adoption of smart agricultural technologies have primarily focused on the core constructs of the Technology Acceptance Model (TAM)—namely, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)—with relatively few studies incorporating Perceived Privacy (PP) and Perceived Security (PS) into an integrated analytical framework.

Table 2. The comparison between existing studies and the contributions of this research is summarized in Table 2

Research aspect	Characteristics of existing studies	Contributions of this study
Model framework	Adoption of the traditional TAM (PU, PEOU, BI)	Extension of TAM by incorporating perceived privacy and perceived security
Methodology	Primarily quantitative; lacking in-depth qualitative exploration	Qualitative research with in-depth interviews to identify user needs precisely
Practical application	Limited provision of concrete design or functional suggestions	Development of a complete functional module and APP architecture diagram

Compared with most studies that focus solely on Perceived Usefulness and Perceived Ease of Use [2], this research offers two significant advancements.

First, it explicitly integrates privacy and security into the analytical framework, addressing a theoretical dimension that has rarely been explored in smart agriculture adoption research [19].

Second, unlike the majority of prior studies that rely heavily on quantitative survey-based methods, this study employs a qualitative in-depth interview approach, supplemented by government open data validation, to capture farmers' authentic experiences and needs more accurately.

Therefore, this study contributes to the field by not only extending the theoretical scope of the TAM but also offering actionable, practice-oriented design recommendations for the development of user-centered smart farming management systems.

4 Research Analysis and Results

This study gathered insights from agricultural practitioners regarding the functional requirements and user expectations of a Smart Farming Management System (Smart Farming App) through in-depth interviews. The qualitative data were systematically organized and analyzed to extract key themes and patterns, providing a holistic understanding of farmers' practical needs and perceptions concerning the adoption and implementation of smart farming technologies.

4.1 In-Depth Interview Analysis

This section presents the analytical results obtained from the in-depth interviews, which form the foundation for subsequent system design. Table 3 summarizes the key findings, highlighting the main functional requirements and user expectations identified by agricultural practitioners.

Table 3. Summary of key findings from in-depth interviews

Interface / Module	Key conclusions on overall requirements
Real-Time Query and Record Management	(1) Simplify data-entry procedures to enable rapid on-site recording and ensure cross-module access to historical data. (2) Provide a user-friendly interface that minimizes repetitive operations and reduces input time.
Farmland and Crop Management	(1) Support plot-based management with complete recording of land and crop conditions. (2) If multiple farmers share the same plot, the system should issue duplicate-entry alerts instead of restricting data input. (3) Allow flexible field identification using nicknames or geotags in addition to cadastral numbers.

Interface / Module	Key conclusions on overall requirements
Pest and Disease Management	(1) Provide early-warning capabilities by integrating historical data with climatic information. (2) Establish a pest-and-disease database containing prevention guidelines and corresponding pesticide information.
Pesticide Management	(1) Record pesticide usage details—type, dosage, and effectiveness—and remind users of pre-harvest safety intervals. (2) Include a searchable database offering compatibility recommendations to prevent pesticide resistance.
Labor Management	(1) Record detailed worker information, including wages, working hours, and contact data. (2) Integrate with the cost module to automatically calculate labor costs.
Inventory Management	(1) Track stock levels and expiration dates of pesticides, fertilizers, and other inputs. (2) Support flexible data entry and querying to accommodate farms of different scales.
Revenue and Profit/Loss Management	(1) Automatically calculate production costs (pesticides, fertilizers, labor, etc.) and generate profit-and-loss statements. (2) Generate monthly, quarterly, and annual financial analyses to support long-term planning.
Cost Control	(1) Record and analyze production inputs (seeds, fertilizers, pesticides, irrigation, labor, etc.) to optimize resource allocation. (2) Use data analytics to reduce waste and minimize production costs.
Notification and Reminder Function	(1) Deliver alerts related to pest control, pesticide safety intervals, and irrigation schedules. (2) Support personalized notification settings to avoid excessive interruptions. (3) Present notifications concisely and effectively to serve as essential management aids.
System Design and Usability	(1) Provide a simple, intuitive, and icon-based interface accessible to users with diverse educational backgrounds. (2) Present clearly structured features with minimal visual clutter to improve user experience. (3) Design primarily for young farmers while ensuring accessibility for older users through training sessions and user workshops.
Promotion and Adoption	(1) Conduct pilot trials and promotional campaigns targeting young farmers to gradually foster adoption among older farmers. (2) Organize training programs and information sessions to demonstrate the system's practical value.

Note: This table summarizes the major functional requirements identified through the in-depth interviews conducted in this study.

4.2 Summary of Findings and Recommendations

Based on the in-depth interview results, this study concludes that the Smart Farming App should prioritize simplicity, efficiency, and practicality as its core design principles while offering flexible functional modules tailored to the diverse needs of different farming contexts. Such an approach can effectively address key challenges in agricultural management, thereby enhancing operational efficiency and economic performance.

According to the interview participants (F1–F10), pest and disease management, pesticide management, and cost management were identified as the system's core functions, whereas notification and reminder services were considered supportive features. A user-friendly interface was regarded as essential for increasing user acceptance. Regarding promotion strategies, young farmers were identified as the primary target group for initial implementation, with gradual expansion to older farmers through training programs and demonstration activities to raise overall adoption levels.

For pest and disease management, the App should incorporate an early-warning function that integrates historical data with local climatic conditions, enabling farmers to respond proactively to potential outbreaks. A comprehensive pest and disease database should also be developed, containing corresponding pesticide information and preventive recommendations to reduce the risks associated with pesticide resistance and residues.

In terms of pesticide management, the system should facilitate detailed recording of pesticide types, dosages, and efficacy while providing compatibility recommendations and pre-harvest safety reminders to ensure accuracy and safety in pesticide application.

The farmland and crop management module should emphasize simplicity and practicality by supporting multiple-plot records and crop rotation planning to promote efficient land use. While inventory management may be less critical for small-scale farms, it remains essential for larger farms or those operating multiple production batches, as it enables inventory tracking and expiration alerts.

For cost and profit management, the system should automatically integrate data on pesticide, fertilizer, and labor costs to generate multidimensional financial reports, allowing farmers to better evaluate business performance and financial outcomes.

From a design and usability perspective, the interface should remain simple and intuitive to accommodate users across different age groups, while training sessions and workshops should be conducted to facilitate adoption. The notification system should deliver timely alerts for pest control, irrigation, and pesticide safety intervals and allow personalized settings to balance practicality and convenience.

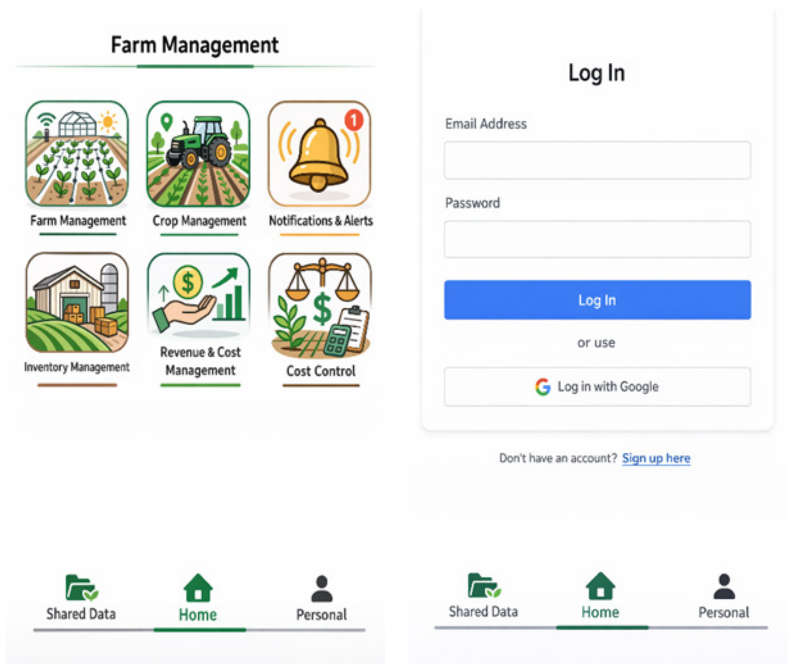
Promotion and adoption strategies should initially focus on young farmers, who generally possess higher digital literacy and technology acceptance. Older farmers may require longer-term guidance and adaptation. Demonstration projects, free trials, and phased promotional strategies can gradually improve system penetration within the agricultural community, fostering the broader adoption of smart farming technologies.

In summary, the success of smart farming applications depends on user-centered design that balances functionality and usability while employing tiered promotion and training strategies. By meeting the diverse needs of farmers, the system can effectively contribute to the sustainable development and digital transformation of agriculture.

4.3 Current Development of the Smart Farming Management System (Smart Agricultural Information Management System) App (“Farm Boss”)

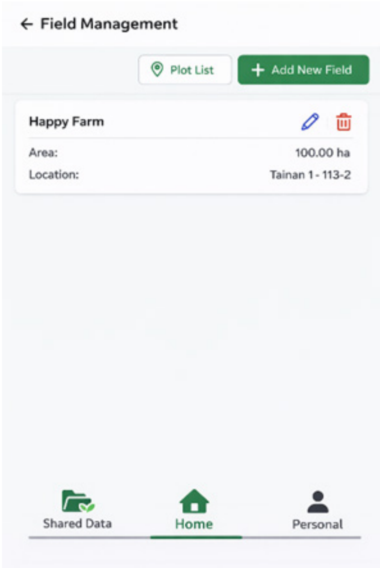
The Smart Agricultural Information Management System was implemented as a mobile application to demonstrate the feasibility and usability of the proposed design. The app focuses on facilitating digital transformation in agricultural management by integrating essential farming data and operational processes within a unified platform. The development process emphasized user experience, modular design, and compatibility with open data sources to ensure both scalability and real-time data accessibility.

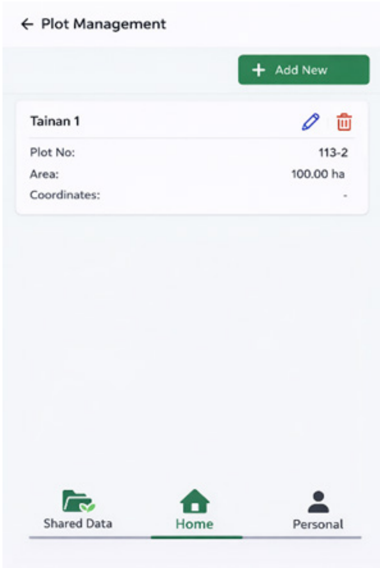
Table 4. Current results and description of the APP

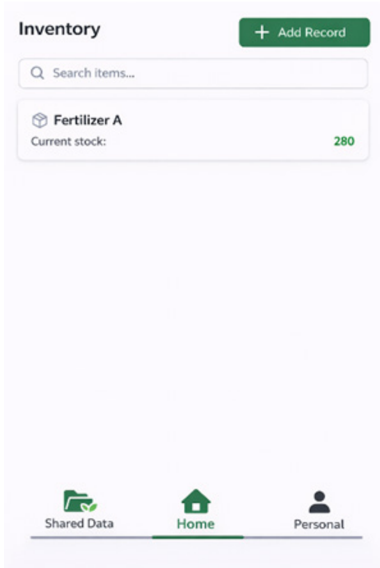


(a) APP Home Page: The main interface presents the entry points for all major functions, allowing users to easily navigate across different modules.

(b) Login Interface: By tapping the “Profile” icon at the bottom-right corner, users can access the login screen. The system supports third-party authentication (e.g., Google or Line). Without logging in, users may browse only the shared data module but cannot perform personalized operations or data entry.

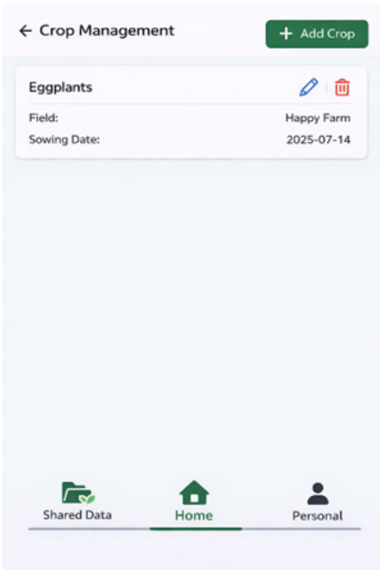


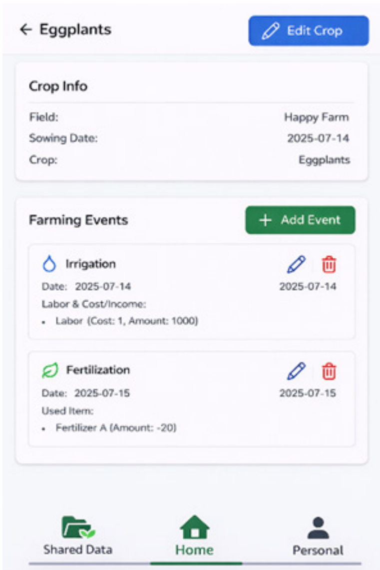




(c)(d) Farmland Management Module: Enables users to register and manage farmland and cadastral information. A cadastral number must be created before adding a new farmland record to ensure data integrity and maintain correct linkages for subsequent cultivation records.

(e) Inventory Management: Displays the inventory status of agricultural materials and products, supporting input, output, and query functions to help users monitor resource utilization effectively.





(f)(g) Cultivation Management: Lists the crops associated with the user's farmland. Selecting a crop allows the user to access the "Cultivation Events" interface, where various farming activities—such as fertilization, irrigation, and pest control—can be recorded and tracked by stage.

(h) Shared Data Module: Currently includes "Pest and Disease Management" and "Pesticide Management." These modules are connected to governmental open databases, providing up-to-date information on pest control and pesticide regulations to support accurate and timely agricultural decision-making.

Based on the system architecture and functional framework introduced in the previous section, the developed mobile application comprises three major functional modules—Shared Data Maintenance, Cultivation Data Maintenance, and Inventory Management. Each module is designed to streamline specific agricultural operations while maintaining interoperability with the others. After multiple stages of testing and refinement, the application runs smoothly on mobile devices and effectively supports data entry, query, notification, and synchronization features.

The main interfaces and features of the developed system are illustrated in Table 4. Overall, the current implementation represents the initial development stage of the Smart Agricultural Information Management System.

The system already supports key user workflows—from login and data browsing to record management—and demonstrates the feasibility of integrating open data for real-time agricultural information updates. In the next stage, user experience testing and feedback collection will be conducted to evaluate practical usability in real farming scenarios. The insights obtained will guide further improvements in interface design, workflow optimization, and system stability, ensuring the application evolves toward a more efficient and user-friendly smart agriculture solution.

4.4 Key Factors Influencing the Adoption of the Smart Farming Management System

The interview findings indicate that the primary factors influencing agricultural practitioners' adoption of the smart farming management system can be categorized into two major dimensions:

1. Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)

Respondents generally agreed that if the smart farming management system could effectively simplify farm management, improve operational efficiency, and enhance the yield and quality of agricultural products, its adoption value would be higher (which supports H3). When the system demonstrates significant usefulness, agricultural practitioners are more inclined to continue using it (supporting H1). Likewise, an intuitive and user-friendly interface can lower technical barriers and prevent operational difficulties from reducing users' intention to adopt (supporting H2).

2. Perceived Privacy (PP) and Perceived Security (PS)

Concerns over data privacy and information security were identified as major barriers to adoption (supporting H4). Several respondents emphasized that if the system incorporated comprehensive data protection mechanisms—such as encryption and access control—it could effectively strengthen users' trust and increase their intention to adopt (supporting H5 and H6).

These findings are consistent with previous studies. On one hand, most respondents' views align with the literature, indicating that privacy concerns weaken users' trust and adoption tendencies [18]. On the other hand, some respondents stated that if the system provides substantial and tangible benefits—such as pest and disease control recommendations—they might still choose to use it despite potential privacy or security risks. This observation is consistent with the arguments of Alharbi, who emphasized that trust serves as a mediating factor in the process of technology adoption [19].

Overall, the findings confirm that perceived usefulness and perceived ease of use remain the core determinants of agricultural practitioners' adoption of smart farming management systems, while privacy and security constitute the key foundation of trust in the adoption process. When system performance and convenience are balanced with robust privacy and security protections, users develop more positive attitudes and stronger intentions to adopt. In summary, the promotion of smart farming management systems should focus simultaneously on functional benefits and risk management. Through the dual approach of benefit demonstration and trust building, system acceptance and continued usage in agricultural practice can be effectively enhanced.

4.5 Hypothesis Verification Results

Based on the findings from the interviews and the literature review, all six hypotheses (H1–H6) proposed in this study were supported, as summarized in Table 5.

- **H1 (Perceived Usefulness (PU) → Attitude Toward Use): Supported.**
  Respondents indicated that if the smart farming management system could enhance farm productivity, management efficiency, and product quality, they would be more willing to adopt it.
- **H2 (Perceived Ease of Use (PEOU) → Attitude Toward Use): Supported.**
  When the system interface is intuitive and user-friendly, it effectively lowers technological barriers and fosters a positive attitude toward use.
- **H3 (Perceived Ease of Use (PEOU) → Perceived Usefulness (PU)): Supported.**
  A simple and easy-to-use system increases users' perception of its usefulness, thereby enhancing their overall perceived value.
- **H4 (Attitude Toward Use → Behavioral Intention): Supported.**
  Users who hold a positive attitude toward the system exhibit a significantly higher intention to adopt it.

- **H5 (Perceived Privacy (PP) → Attitude Toward Use): Supported.**
  If the system lacks adequate privacy protection mechanisms, users' trust decreases, thereby diminishing their positive attitude toward use.
- **H6 (Perceived Security (PS) → Attitude Toward Use): Supported.**
  Robust information security measures (such as data encryption and access control) enhance user trust and strengthen their positive attitude toward use.

Table 5. Summary of hypothesis verification results

Hypothesis No.	Path relationship	Result
H1	PU → Attitude Toward Use	Supported
H2	PEOU → Attitude Toward Use	Supported
H3	PEOU → PU	Supported
H4	Attitude Toward Use → Intention to Use	Supported
H5	PP → Attitude Toward Use	Supported
H6	PS → Attitude Toward Use	Supported

4.6 Discussion and Practical Contributions

The research findings indicate that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) remain the core determinants of agricultural practitioners' adoption of the Smart Farming Management System, consistent with the theoretical framework of the Technology Acceptance Model (TAM). When the system combines functional benefits with ease of operation, users develop more positive attitudes toward it, thereby enhancing their intention to adopt the technology.

In addition, this study found that Perceived Privacy (PP) and Perceived Security (PS) play a crucial role in establishing user trust. This result is consistent with the studies of Merhi, which indicate that users who have concerns about privacy protection tend to exhibit lower adoption intentions [18]. However, some respondents stated that if the system provides substantial benefits—such as pest and disease control recommendations—they may still choose to use it despite potential privacy or security risks. This phenomenon aligns with the perspective of Merhi et al. (2019), who emphasized the critical role of trust in technology adoption [18].

1. Practical Contributions

The Smart Farming App offers multiple benefits for agricultural management practices:

(1) Efficiency Enhancement:
By automating and digitizing key agricultural operations—such as seeding, fertilization, irrigation, and harvesting—the system can significantly reduce time and labor costs, thereby improving overall agricultural productivity.

(2) Information Management:
The system assists agricultural practitioners in tracking and managing crop-related information in real time and integrates other critical data, thereby providing a solid information base for decision-making.

(3) Sustainability Promotion:
Through precise monitoring of land and resource utilization, the Smart Farming App supports efficient resource allocation, promotes environmentally friendly practices, and facilitates sustainable agricultural development.

(4) Data Analytics and Decision Support:
With built-in data collection and analytical functions, the system provides actionable insights that help farmers optimize yields, enhance product quality, and monitor income and expenditures, thereby strengthening their managerial decision-making capabilities.

(5) Overall Benefits:
By offering digital management tools and resources, the Smart Farming App helps agricultural practitioners increase productivity, reduce resource waste, and plays a critical role in the digital transformation and modernization of agriculture.

2. Theoretical Contributions

At the theoretical level, this study extends the Technology Acceptance Model (TAM) by incorporating two

external variables—Perceived Privacy (PP) and Perceived Security (PS)—to address data-related risks that have been relatively underexplored in prior research on smart agricultural technology adoption.
The results not only confirm the effects of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) on users' behavioral intentions but also underscore the pivotal roles that privacy and security concerns play in shaping adoption decisions. Moreover, the findings suggest potential mediating or moderating effects of trust between these factors. This extended TAM framework contributes valuable theoretical insights for future studies on smart farming technology adoption.

3. Future Research Directions
Future research is encouraged to integrate the proposed framework into actual system development and conduct large-scale empirical testing to validate the extended TAM model proposed in this study. By involving agricultural practitioners across varying scales and backgrounds, future empirical analyses can further refine and optimize the system design, thereby enhancing the model's applicability and explanatory power across diverse agricultural contexts.

5 Conclusion and Research Contributions

This study extends the Technology Acceptance Model (TAM) by incorporating Perceived Privacy (PP) and Perceived Security (PS) to examine agricultural practitioners' adoption intentions and functional requirements toward big data–driven smart farming management systems in Taiwan. The results show that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) remain the core determinants of adoption, while privacy and security concerns influence trust, which subsequently shapes users' intention to adopt the system. In-depth interviews further revealed that smart farming management systems should integrate functions such as farmland and crop management, pest and pesticide control, inventory tracking, cost and profit analysis, and personalized reminders.

5.1 Theoretical Contribution

Theoretically, this study enriches the TAM framework by addressing privacy and security concerns that have been insufficiently examined in previous smart agriculture research. By integrating perceived privacy and security, the extended TAM provides a more comprehensive understanding of users' adoption behavior. Furthermore, based on the in-depth interview results, nine key functional requirements were identified—such as pest and disease early warning, cost and profit management, and irrigation and fertilization reminders. A practical framework for the Smart Farming Management App was also developed, serving as a reference for future system designers and researchers.

5.2 Practical Contribution

Practically, this study provides valuable insights for both system developers and policymakers.

First, in system design, the Smart Farming App should feature a simple and intuitive interface, prioritizing key functions such as farmland and crop management, pest and pesticide alerts, cost and profit analysis, and personalized notifications to meet the needs of farmers across various farm sizes and age groups.

Second, data privacy and security must be emphasized through data encryption, access control, and compliance-oriented design to strengthen user trust.

Third, implementation strategies should follow a phased approach—beginning with young farmers who possess higher digital literacy, and gradually engaging older farmers through training programs, demonstration farms, and subsidy initiatives to bridge the digital divide.

Finally, policymakers should incorporate smart agriculture into national sustainable development strategies and accelerate the digital transformation of the agricultural sector through inter-ministerial collaboration, public–private partnerships, and policy incentives.

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