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DEVELOPMENT OF AN IOT-ENABLED SMART FARMING APPLICATION WITH INTEGRATED FINANCIAL MANAGEMENT AND COLLABORATIVE KNOWLEDGE SHARING

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ABSTRACT

The integration of the Internet of Things (IoT) in agriculture has led to the development of smart farming solutions that enhance planting management and control. This study presents the design and development of a smart farming application that utilizes IoT technology to optimize crop cultivation. The proposed system incorporates IoT sensors to monitor soil moisture, temperature, and water levels in real time, enabling automated irrigation and lighting control. Moreover, the application allows farmers to track crop growth, manage income and expenses, access agricultural knowledge, and interact with a community forum. A usability evaluation, conducted with IT experts and end-users, demonstrated high levels of satisfaction in terms of user interface design, learnability, efficiency, memorability, correctness, security, and overall functionality. The findings suggest that the developed application provides a practical and efficient tool for farmers, reducing operational costs, conserving resources, and improving crop yields. Furthermore, the financial management and knowledge-sharing functionalities contribute to better decision-making and increased collaboration within the agricultural sector.

Keywords: *Internet of Things, Smart Farming, Mobile Application, Planting Management, Remote Monitoring and Control*

1. INTRODUCTION

In today's digital age, information technology has come to play a significant role in shaping the behavior and lifestyle of the new generation, which differs markedly from the traditional patterns of older generations [1]. Those who have better access to information possess a competitive advantage in conducting various activities. Consequently, information has become a crucial resource in managing operations across various domains, influencing planning, control, and decision-making processes [2]. Additionally, in the present era, smartphones have become an integral part of people's lives. Almost everyone carries a smartphone at all times, making mobile applications crucial for users in numerous ways. These applications enable them to live more conveniently, save time and expenses, enhance work productivity, and facilitate access to information [3].

The Internet of Things (IoT) [4,5] refers to a network of interconnected devices that exchange data with each other. These devices may include machinery, vehicles, digital equipment, household appliances, and common electronic devices, often embedded technologies such as various measurement sensors and control software. This enables connection and data exchange with other devices and systems via the internet. Moreover, IoT technology connects people with various electronic devices used in daily life through intelligent interactions via various applications [6]. Currently, around ten billion IoT devices are connected globally, and experts forecast that this number will grow to nearly thirty billion by 2030. Furthermore, the IoT market is expected to reach a valuation of thirty billion US dollars by 2027 [7].

In addition, IoT technology has come to play a crucial role in various industrial sectors and has expanded its scope to agriculture and crop

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cultivation [8]. In recent years, the application of IoT technology in the agricultural sector has rapidly increased, with the goal of enhancing productivity, reducing costs, minimizing crop losses, and increasing returns for both small-scale farmers and large-scale agricultural operations [9]. The benefits of IoT technology in improving the efficiency and success of crop cultivation include: (1) Crop monitoring and data collection systems, which help gather real-time data on various factors affecting plant growth, such as soil moisture, air humidity, temperature, and light levels. Continuous monitoring and collection of this data help farmers understand the specific needs of each crop type and the optimal environmental conditions. (2) Intelligent resource management systems, which can analyze collected data and use it to manage various resources intelligently. For example, automatic tree watering systems adjust water quantities based on real-time soil moisture data. This helps conserve water by only using the necessary amount, which is especially crucial in water-scarce areas. (3) Remote control and data access systems, which allow farmers to access data collected by sensor devices and remotely control various equipment through mobile applications. This enables farmers to make decisions and address potential issues early, even when not physically present at the cultivation site. For instance, adjusting appropriate water quantities, temperature, or fertilizer amounts before they impact plant growth. Moreover, IoT technology helps reduce costs in several aspects, such as labor costs, travel expenses, and other production costs including water, electricity, and fertilizer expenses [10].

Furthermore, recent studies consistently highlight that existing smart farming solutions are often fragmented, addressing only a single aspect of the farming process, such as irrigation or environmental monitoring. This fragmentation forces farmers to adopt multiple systems, which can be costly and complex to manage.

Based on the aforementioned reasons, this paper aims to design and develop a smart application for managing and controlling plant cultivation using Internet of Things (IoT) technology. The application utilizes IoT sensors to collect real-time data on soil moisture, temperature, and water levels, enabling data-driven decision-making for optimal plant growth. The application enables users to record and monitor plant cultivation data and check income-expense information, post and answer questions about plant cultivation, access academic articles related to plant cultivation, configure automatic watering and lighting systems, control the on/off functions for watering and lighting systems, check soil moisture levels, and monitor water levels in storage tanks. Unlike existing solutions that focus solely on environmental sensing or automation, the novelty of this study lies in its multi-functional integration, allowing farmers to monitor, control, analyze, learn, and collaborate on crop cultivation data within a single platform. This holistic approach addresses both the technical and socio-economic dimensions of smart farming. The purpose is to provide convenience for farmers in managing and controlling plant cultivation efficiently and effectively. Furthermore, integrating financial management function for tracking income and expenses will empower farmers with real-time insights into the profitability of their operations, facilitating better budgeting and investment decisions. Moreover, accessing a repository of agricultural knowledge can bridge the gap between research and practice by equipping farmers with the latest best practices and technological innovations. Finally, community forums foster an essential network for peer-to-peer support, collaborative problem-solving, and the exchange of insights, which are particularly valuable in an era marked by rapid technological and environmental changes. Additionally, it helps conserve water and electricity resources, as well as reduce labor costs and travel expenses for crop maintenance. The scope of this research is limited to the development of a prototype system that integrates environmental monitoring, irrigation and lighting automation, financial management, agricultural knowledge sharing, and a community forum within a single mobile application. However, the current implementation focuses primarily on small-scale or household farming scenarios, assuming consistent internet connectivity and access to smartphones for operation. A key limitation is that the scalability of the current system for large-scale agricultural operations was not addressed in this study. The evaluation of the application's quality and user satisfaction was conducted through a satisfaction survey, involving two groups: 5 IT experts and 70 target users. The evaluation results indicated consistently high satisfaction across multiple domains, including user interface design, learnability, efficiency, memorability, correctness, security, and overall outcome.

2. LITERATURE REVIEW

Smart farming has emerged as a global trend, with farmers increasingly adopting advanced technologies to optimize their agricultural practices

[11-13]. By applying modern technologies such as IoT, artificial intelligence (AI), cloud computing, and big data, farmers can manage their agricultural operations more efficiently, accurately, and sustainably. Key benefits of smart farming include reducing production costs, minimizing crop losses, increasing income, and improving both yield and quality. In the context of crop cultivation, these technologies can be applied throughout various processes, starting from the pre-harvest stage such as soil analysis and seed selection. During the harvest phase, they can assist with weather analysis, crop growth monitoring, automated irrigation and fertilization, as well as plant disease analysis and prevention. In the post-harvest period, smart farming technologies can enable automated systems for sorting, storing, and processing agricultural products [14].

Several studies have applied IoT technology to cultivation practices, aiming to enhance efficiency and success in crop production. However, there are still many issues and challenges that can be explored, researched, and developed to achieve more effective smart farming systems. For instance, Mujawar et al. [15] demonstrated the significant potential of IoT-enabled intelligent irrigation systems in rice agriculture. By integrating real-time environmental data collection through sensors and applying machine learning models such as artificial neural networks (ANN), support vector machines (SVM), decision trees (DT), and random forests (RF), the system is able to accurately predict future water demand. However, it lacked financial management and knowledge-sharing components, which are essential for effective decision-making in real-world farming contexts. In addition, Raju et al. [16] introduced a significant advancement in hydroponic farming through the development of an AI-based smart hydroponics expert system integrated with IoT technology by addressing the challenges of monitoring and managing complex systems. The system is equipped with real-time sensors for monitoring plant nutrient levels, sunlight, turbidity, pH, temperature, water level, and visual data from camera modules. Moreover, a deep learning convolutional neural network (DLCNN) model is applied for nutrient level prediction and plant disease detection. The plant disease status and sensor data are accessible through mobile application. Additionally, Shin et al. [17] developed an IoT-enabled smart hydroponic system, called SMART GROW, which allows farmers to monitor and control key parameters such as pH, electrical conductivity (EC) of water, and water level in vegetable plots through mobile application. The system can be adapted for managing the cultivation of other types of crops, such as vegetables, fruits, and herbs. However, the systems are limited in scope to specific farming methods and do not address the broader operational needs of general farmers. Furthermore, an IoT-driven automated irrigation system was developed for watering tomato gardens [18]. To optimize water usage, the system employs soil moisture sensors to determine irrigation requirements. The system resulted in a 10% reduction in water usage, along with a 71% improvement in watering consistency, and a 27.5% increase in crop yield. In addition, Arreerard et al. [19] proposed an IoT-based system to support community lime planting. Key components of the system include data receivers (soil moisture, temperature, pH, and nutrient level), control units (water supply, spraying, and nutrient distribution), and a mobile application for real-time monitoring and control. The system significantly increased lime yield, size, and weight compared to traditional cultivation practices. Moreover, the study of Evan and Jayadi [20] presented an IoT-enabled smart vertical farming system, designed to optimize microgreen cultivation in urban area where space is limited. The prototype integrates sensors, such as soil moisture sensor as well as temperature and humidity sensor, with a microcontroller to collect real-time environmental data. It facilitates automated control of irrigation and lighting, ensuring optimal water and light supply tailored to the plants' needs. Furthermore, Fajar et al. [21] introduced a mobile application for agrotechnology systems using IoT, designed to aid in crop planting productivity. The system focuses on enabling urban agricultural communities to efficiently manage plant maintenance during planting and harvesting. The system architecture incorporates sensors for temperature, humidity, light, CO_2, and soil pH, connected to a microcontroller which transmits data to cloud storage. Users can set standard measurement data for plants, view plant details, and monitor measurement data. However, it lacked automation features such as real-time control of irrigation or lighting systems as well as collaborative components like knowledge-sharing functionalities, which are crucial for supporting decision-making among farmers.

While existing research on IoT-enabled smart farming systems has made significant strides in enhancing environmental control and automation in agriculture, there remain substantial needs to broaden these systems. Integrating functionalities that can track crop growth, manage financial information, access agricultural knowledge, and

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connect users to community forums would not only complement the current technological framework but also promote a more holistic approach to smart farming. Addressing these gaps could significantly enhance both the productivity and sustainability of agricultural practices, ultimately contributing to the long-term resilience of the farming sector.

It is hypothesized that the developed IoT-enabled smart farming application will significantly enhance users' ability to monitor and control crop cultivation activities by providing real-time data and automated control features, surpassing the limitations of traditional tools. Furthermore, by integrating financial management, agricultural knowledge resources, and peer-to-peer interaction into a single platform, the application is expected to positively impact farmers' decision-making processes, improve operational efficiency, and foster greater collaboration within the agricultural community.

3. SYSTEM DESIGN

The operation of the smart plant cultivation system consists of three main components (as shown in Figure 1): (1) an IoT-based smart plant cultivation application that is installed and operated on a mobile device, (2) a network of IoT sensors and actuators which is deployed within the smart farm, and (3) a centralized server which stores the system's database. These three components communicate with each other to ensure real-time data exchange.

The IoT-enabled smart farming application was developed using the Flutter [22] framework for cross-platform mobile application deployment. The system architecture integrated IoT sensors with the ESP32 [23] WiFi microcontroller. Data was stored in the SQLite [24] database and managed via the Django [24] backend. The application included modules for crop monitoring, automated irrigation and lighting control, income-expense tracking, agricultural article access, and user community forums.

Farmers can utilize the IoT-based smart plant cultivation application to control the on/off function of the grow light [25] and irrigation systems in the smart farm. Additionally, real-time data on soil moisture, temperature, and water levels in the storage tank can be monitored. Furthermore, the application allows for various data management tasks related to crop cultivation, such as crop management, tracking income and expenses related to cultivation, and accessing features like a forum for questions and answers as well as articles on farming practices.

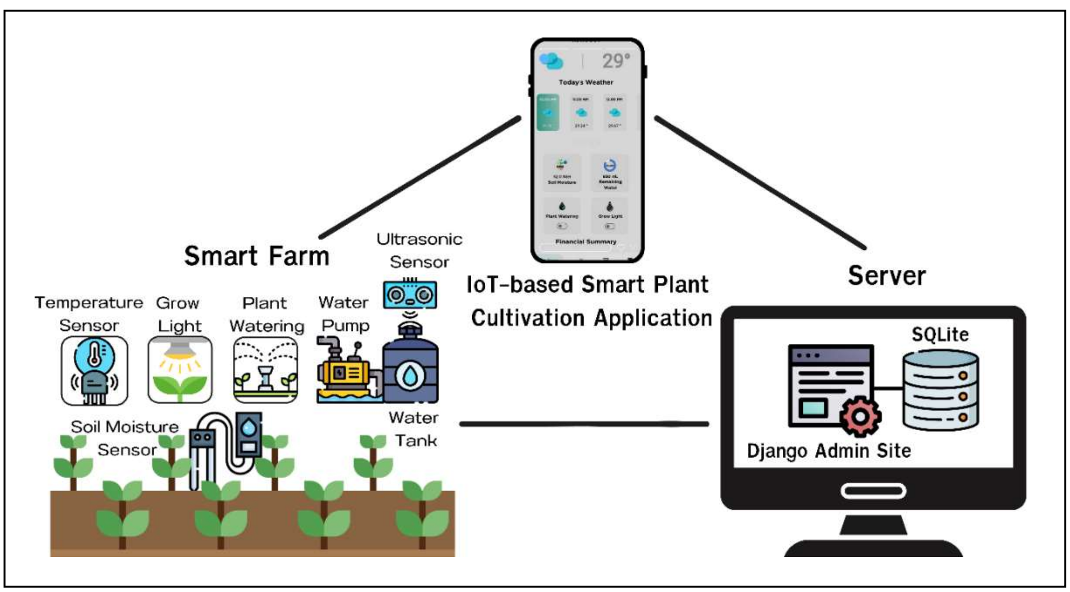

Figure 1: Main Components of the IoT-Based Smart Plant Cultivation System

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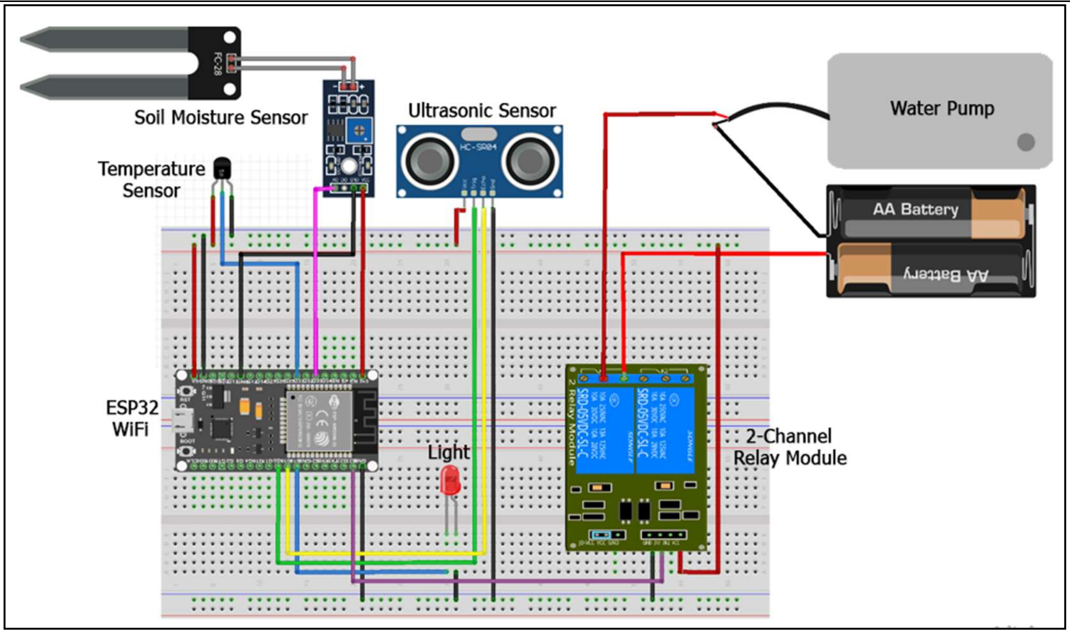

Figure 2: Circuit Diagram for the IoT-Based Smart Plant Cultivation System in the Smart Farm

The smart farm is equipped with IoT devices and various plant cultivation-related equipment (as depicted in Figure 2), with the following details:

- *Soil Moisture Sensor*: The soil moisture sensor [26] is used to continuously monitor the moisture content in the soil, providing farmers with accurate and timely data. This helps in making precise irrigation decisions to avoid over- or under-watering, which can lead to crop stress or wastage of water resources. By integrating soil moisture data with irrigation systems, farmers can automate the irrigation process. The sensor communicates with the controller that adjusts water supply based on current soil conditions, ensuring that crops receive the optimal amount of water.
- *Temperature Sensor*: The temperature sensor [27] is able to continuously track ambient temperature, giving farmers up-to-date information on environmental conditions. Accurate temperature readings are crucial for effective irrigation management. Higher temperatures can increase evaporation rates, leading to increased water demand for crops. Farmers can adjust their irrigation practices based on real-time temperature data to ensure optimal water usage and prevent water stress in plants.
- *Ultrasonic Sensor*: By utilizing the ultrasonic sensor [28], water levels in the tank are measured in real-time using a non-contact method, providing critical data for optimizing water management and irrigation. Using the speed of sound, the sensor calculates the distance from the sensor to the water surface based on the time taken for the sound waves to travel to the surface and back. This distance can be converted into a water level measurement by subtracting it from the total height of the tank.
- *ESP32 WiFi Microcontroller*: The ESP32 WiFi microcontroller [23] is a highly versatile and widely-used system-on-chip (SoC) developed by Espressif Systems. It is designed for IoT-based applications, featuring integrated Wi-Fi and Bluetooth capabilities. The ESP32 is connected to the temperature sensor and soil moisture sensor to monitor ambient temperature and soil moisture content, respectively. This data helps farmers optimize growing conditions and make informed decisions regarding irrigation and crop management. When moisture levels fall below a certain threshold, the microcontroller activates water pumps, ensuring that crops receive adequate hydration without waste. Moreover, the ESP32 interfaces with the ultrasonic sensor to measure water levels in the tank. By sending water level data to the mobile application, farmers can monitor

their water supply in real-time. This capability prevents overflows or shortages and ensures efficient water management. Furthermore, the ESP32 can enable remote access and on-off control of the irrigation and grow lighting system through the smartphone. It is also able to automate the irrigation and grow lighting system based on specific schedules.

In addition, data collected from various sensors and user inputs through the mobile application are transmitted and stored in the SQLite [24] database system on the server via the internet. The system administrator can manage the data in this database through the Django [24] admin site interface.

Figure 3 illustrates the use case diagram of the IoT-based smart plant cultivation application, highlighting the main functionalities and the types of application users, along with the relationships between them. The primary users are categorized into two types: administrator and general users or farmers. The main functionalities of the system are as follows: (1) managing user account and the login system, (2) managing plant cultivation data, (3) controlling the on/off status of grow lights, (4) controlling the irrigation system, (5) viewing real-time air temperature data, (6) viewing real-time soil moisture data, (7) viewing real-time water level data in the storage tank, (8) sending alerts when the water level in the tank is below the specified threshold, (9) managing income and expense records related to plant cultivation, (10) managing the posting of questions and responses on forums related to plant cultivation, and (11) managing academic articles related to plant cultivation.

4. APPLICATION FUNCTIONALITIES

The System Development Life Cycle (SDLC) model [29] is employed as a framework for guiding the IoT-enabled application development process. The application is developed using the Flutter framework [22], which supports cross-platform development. The functionalities and user interfaces of the application are systematically analyzed, designed, and implemented to align with specified user requirements.

When users launch the application, the “Login” page is displayed (as displayed in Figure 4), prompting them to enter their email address and password to access the system. For first-time users, registration is required. Users must provide their full name, email address, and password to create an account on the “Sign Up” page (see Figure 5). Upon successful login, if the user has not yet connected to the IoT devices in the smart farm, they must establish a connection and input relevant crop planting information on the “Add Planting Information” page (as presented in Figure 6). This includes details such as the type of crop being cultivated, the desired soil moisture level for automated irrigation, and the automated schedule for turning the grow light on and off. Once the initial setup is complete, the application presents the main dashboard on the “Home” page (see Figure 7), which displays real-time data collected from various sensors. This data includes soil moisture level, farm temperature, and the remaining water volume in the storage tank. Additionally, users can monitor the operational status of the irrigation system and the on/off state of the grow light as well as view a monthly summary of income and expenses related to crop cultivation. Furthermore, users also have the capability to manually control the irrigation system and grow light directly through the application, allowing for precise customization of the growing environment. Figure 8 displays the operational results of the irrigation system. The results of the on-off light operation are shown in Figure 9(a) and Figure 9(b).

For the functionality of other tabs in the application, users can view and edit crop planting information in the "Plant" tab (as depicted in Figure 10). Furthermore, in the "Money" tab, users are able to review income, expenses, and net balances (see Figure 11). Users can also add, edit, or delete the income or expense record. In the "Q&A" tab, users are allowed to participate in a forum system by posting questions, responding to other users' inquiries, and viewing answers provided to various questions (as shown in Figure 12).

The application's sidebar menus (as illustrated in Figure 13) consist of the following menus: (1) "Profile" menu which allows users to add or edit personal information, such as full name, contact number, occupation, and profile picture (see Figure 14), (2) "Articles" menu that provides access to academic articles related to crop cultivation (as depicted in Figure 15), (3) "Record History" menu where users can view historical data, such as crop planting records, financial history, and forum activities (see Figure 16), (4) "Contact Us" menu which contains the Administrator's contact information, and (5) "Log Out" menu that allows users to exit the application securely.

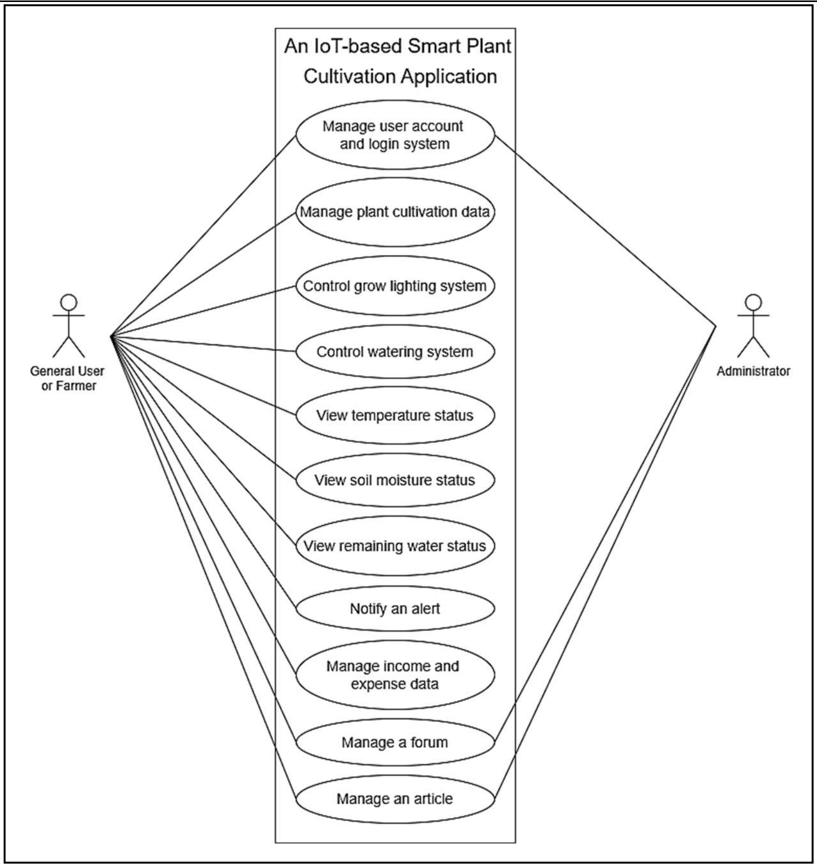

Figure 3: Use Case Diagram for the IoT-Based Smart Plant Cultivation Application

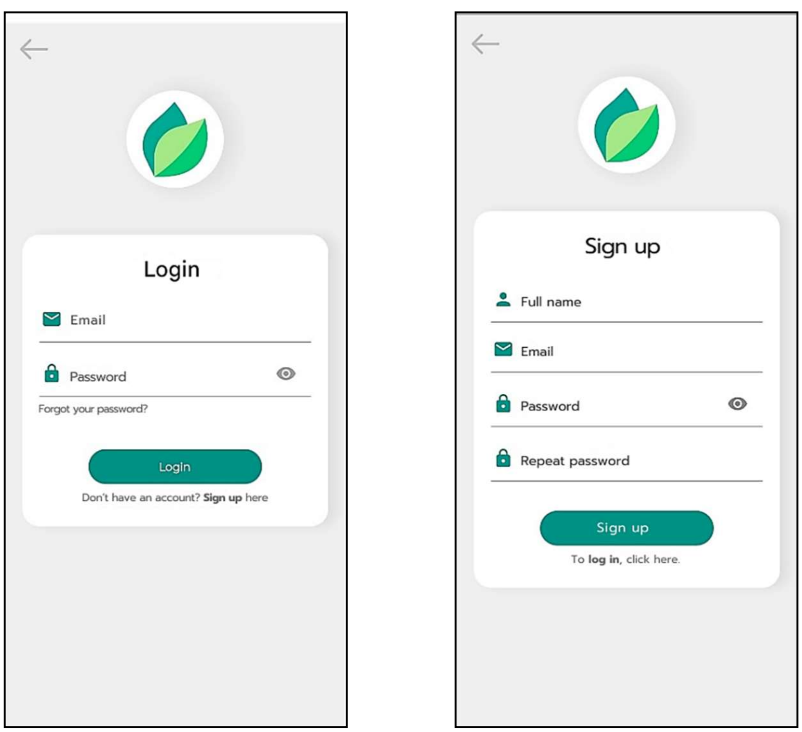

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Figure 4: "Login" Page

Figure 5: "Sign Up" Page

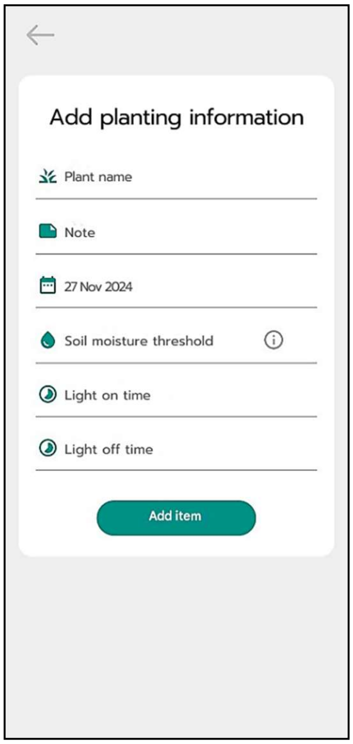

Figure 6: "Add Planting Information" Page

Figure 7: "Home" Page

Figure 8: Operational Results of the Irrigation System

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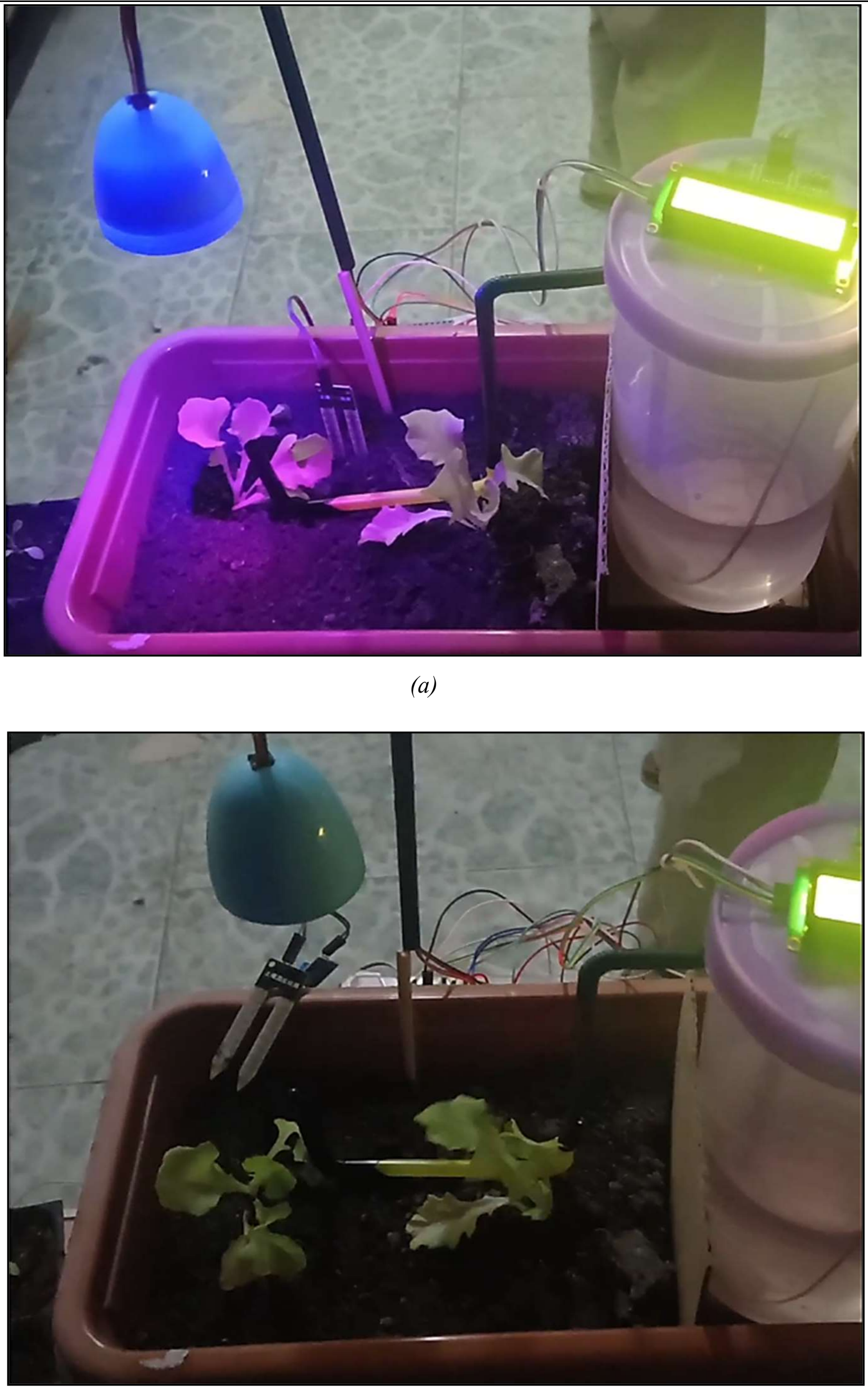

(a)

(b)

Figure 9: Results of the On-Off Light Operation: (a) "On" Status, and (b) "Off" Status

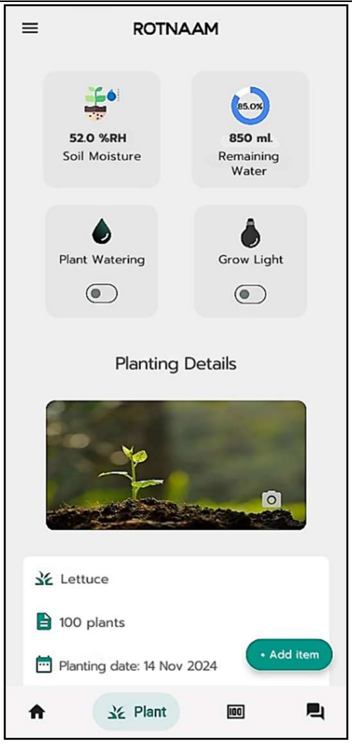

Figure 10: "Plant" Tab

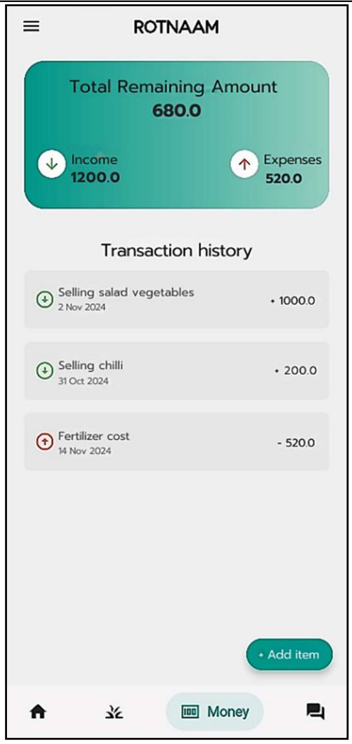

Figure 11: "Money" Tab

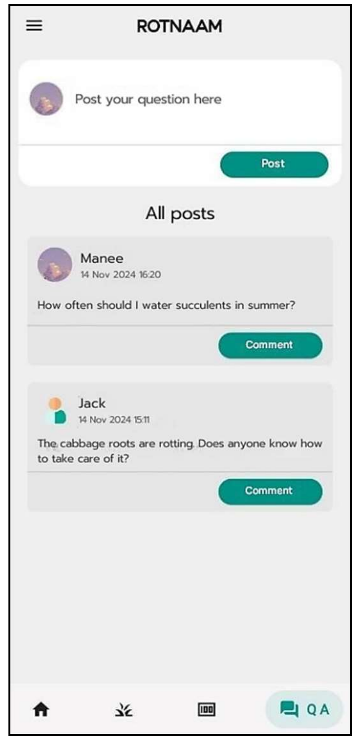

Figure 12: "Q&A" Tab

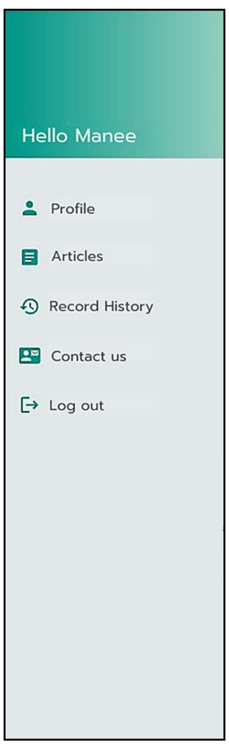

Figure 13: Sidebar Menus

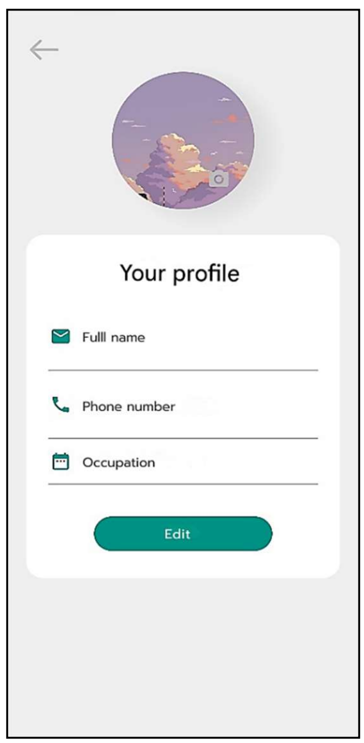

Figure 14: "Profile" Page

Journal of Theoretical and Applied Information Technology
15th December 2025. Vol.103. No.23

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Figure 15: "Articles" Page

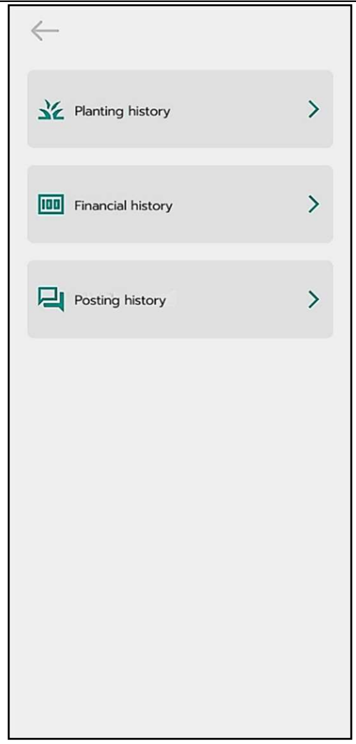

Figure 16: "Record History" Page

5. RESEARCH TOOL VALIDATION

Validating a research instrument is a critical step in ensuring the quality and reliability of research findings. For this study, the user satisfaction assessment form was analyzed, designed, and developed to evaluate user satisfaction with the application. The questionnaire items were reviewed and assessed by three IT experts to evaluate their content validity. A Likert scale [30] ranging from 1 to 5 was used to measure responses, with the following categories: 1 for "Very Inappropriate," 2 for "Inappropriate," 3 for "Neutral," 4 for "Appropriate," and 5 for "Very Appropriate". The Aiken Index [31,32], also known as Aiken's V, was employed to assess the content validity of the research instrument. This method evaluates whether the questionnaire items adequately represent the construct being measured, ensuring that the instrument effectively captures the intended content. As presented in Table 1, question items with a V value below 0.4 are considered invalid. Items with a V value between 0.4 and 0.8 are categorized as valid, while those with a V value greater than 0.8 are deemed very valid [33].

Table 2 displays the results of the questionnaire validity assessment, which was determined using the Aiken Index. The high Aiken Index values and consistent expert ratings suggest that the questionnaire items effectively capture the intended aspects of user satisfaction with the application. These results imply that the instrument is well-suited for collecting valid and reliable data on user satisfaction.

Table 1: Interpretation of Aiken's Validity Index (V).

Aiken Index (V)	Interpretation
$0 \leq V < 0.4$	Not Valid
$0.4 \leq V \leq 0.8$	Valid
$0.8 < V \leq 1$	Very Valid

In addition, a reliability analysis was conducted to assess the internal consistency of the research questionnaire, which was distributed to 30 respondents who participated in a try-out test. The purpose of the try-out was to evaluate the reliability of the research instrument before its full-scale implementation. Cronbach's Alpha (α) [34,35] was used as the measure of internal consistency, with values above 0.7 indicating acceptable reliability. The results, summarized in Table 3, demonstrate that the questionnaire exhibits strong reliability across different satisfaction domains.

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Table 2: Questionnaire Validity Analysis Results.

Satisfaction Domains	Satisfaction Factors	Questionnaire Items	Item Score			x̄	S.D.	Aiken Index (V)	Interpretation of Aiken Index
			1st Expert	2nd Expert	3rd Expert				
User Interface Design	Color Selection	Color schemes are appropriately selected to enhance visual clarity and usability.	5	5	4	4.67	0.58	0.92	Very Valid
	Font Size	The font size chosen is suitable for readability and usability.	4	5	4	4.33	0.58	0.83	Very Valid
	Font Style	The font style chosen is suitable for readability and usability.	4	5	4	4.33	0.58	0.83	Very Valid
	Imagery and Icons	The imagery and icons used are appropriate for their intended purpose.	5	5	4	4.67	0.58	0.92	Very Valid
	Image Sizing	Images are sized appropriately to ensure visual clarity and usability.	5	5	4	4.67	0.58	0.92	Very Valid
	Button Design	Buttons are designed with appropriate size and style for effective user interaction.	4	5	4	4.33	0.58	0.83	Very Valid
	Layout Simplicity	The layout of application interface is designed for ease of use.	5	5	4	4.67	0.58	0.92	Very Valid
	Aesthetic Design	The user interface (UI) is designed with aesthetic appeal.	5	5	4	4.67	0.58	0.92	Very Valid
Learnability	Readability and Usability	The formatting is designed to be easily readable and user-friendly.	5	4	4	4.33	0.58	0.83	Very Valid
	Intuitive Page Design	Each page within the application is designed to be visually appealing and easy to understand.	5	4	4	4.33	0.58	0.83	Very Valid
	Rapid User Onboarding	Users are able to quickly learn and understand how to use the application.	4	5	4	4.33	0.58	0.83	Very Valid
Efficiency	Ease of Use	The system's functions are designed to be simple and uncomplicated.	5	5	4	4.67	0.58	0.92	Very Valid
	Accuracy and Precision	The system's functions are accurate and precise in their operations.	4	5	4	4.33	0.58	0.83	Very Valid
	Responsiveness	The application responds to user input within an acceptable timeframe.	4	5	4	4.33	0.58	0.83	Very Valid
Memorability	Visual Recognition	Users are able to easily recognize and distinguish between different pages within the application.	4	5	4	4.33	0.58	0.83	Very Valid
	Design Consistency	The design maintains consistency throughout the application.	4	5	4	4.33	0.58	0.83	Very Valid
	Modern and Engaging Design	The design exhibits contemporary appeal and engaging features.	5	5	4	4.67	0.58	0.92	Very Valid
Correctness	Data Accuracy and Completeness	The data within the system is accurate and comprehensive.	5	5	4	4.67	0.58	0.92	Very Valid
	Data Reliability	The data within the system is reliable.	4	5	4	4.33	0.58	0.83	Very Valid
Security	User Authentication System	The mechanisms in place to verify the identity of users when they log in to the application.	4	5	5	4.67	0.58	0.92	Very Valid
	User Authorization and Access Control	Granting users permission to perform actions on the data after they have successfully logged in.	4	5	5	4.67	0.58	0.92	Very Valid
	Data Security Confidence	Assurance in the security measures that protect the data.	5	5	4	4.67	0.58	0.92	Very Valid
Outcome	User-Friendliness	The application is designed to interact with users in a way that is easy to understand.	4	4	4	4.00	0.00	0.75	Valid
	User Engagement	The application is appealing to users and encourages continued use.	5	4	4	4.33	0.58	0.83	Very Valid
	Data Presentation	The data is presented in a clear, concise, and informative manner.	4	5	4	4.33	0.58	0.83	Very Valid

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Satisfaction Domains	Satisfaction Factors	Questionnaire Items	Item Score			x̄	S.D.	Aiken Index (V)	Interpretation of Aiken Index
			1st Expert	2nd Expert	3rd Expert				
	User Expectations	The application produces results that meet user expectations.	4	5	4	4.33	0.58	0.83	Very Valid
	Sufficient Information	The application provides enough information to enable users to make informed decisions to use the application.	5	5	4	4.67	0.58	0.92	Very Valid
	Cost-Efficiency	The application helps to reduce the costs associated with crop cultivation, such as water, travel-related expenses, etc.	5	5	4	4.67	0.58	0.92	Very Valid
	Convenience	The application facilitates crop cultivation management, such as water and light automation control, accounting management, etc.	5	5	4	4.67	0.58	0.92	Very Valid

Table 3: Questionnaire Reliability Analysis Results.

Satisfaction Domains	Number of Questionnaire Items	Cronbach's Alpha (α)	Interpretation of α
User Interface Design	8	0.921	Excellent
Learnability	3	0.868	Good
Efficiency	3	0.888	Good
Memorability	3	0.719	Acceptable
Correctness	2	0.816	Good
Security	3	0.871	Good
Outcome	7	0.909	Excellent
All Domains	**29**	**0.967**	**Excellent**

6. RESULTS AND DISCUSSION

To evaluate the application's quality and user satisfaction, a two-group sample of users participated in a trial period. During this phase, participants were informed about the study and provided with ample time to complete a satisfaction survey. The first group consisted of five IT experts, providing a technical perspective. The second group comprised 70 users, including individuals with prior plant cultivation experience, representing the target user base. Purposive sampling was employed to ensure that the selected individuals met specific inclusion criteria relevant to the study. Responses were collected using a 5-point Likert scale, ranging from "Very Dissatisfied" (1- point) to "Very Satisfied" (5-point). Descriptive statistics, specifically the mean ($\bar{x}$) and standard deviation (S.D.), were employed to analyze the collected data. Furthermore, the Customer Satisfaction (CSAT) score [36,37] was calculated to quantify user satisfaction with the application by using the following formula:

$$CSAT = \frac{Total\ number\ of\ positive\ results}{Total\ number\ of\ respondents}\ x\ 100$$

where positive results are defined as user responses of 4 ("Satisfied") or 5 ("Very Satisfied"), reflecting satisfaction with the application. The criteria for interpreting the CSAT score are presented in Table 4 [37].

Table 4: Interpretation Criteria of CSAT Score.

CSAT Score Range	Interpretation
0% - 35%	Highly Unsatisfied
35% - 50%	Unsatisfied
50% - 65%	Quite Satisfied
65% - 80%	Satisfied
80% - 100%	Highly Satisfied

The CSAT evaluation results for the application, assessed by five IT experts (as shown in Table 5), reveal a high level of satisfaction across multiple domains, including user interface design, learnability, efficiency, memorability, correctness, security, and overall outcome. The application received consistently high scores, with mean values ranging from 4.4 to 5 and standard deviations between 0 and 0.55, resulting in a CSAT score of 100% for all factors. In the domain of user interface design, aspects such as color selection, font size and style, imagery and icons, image sizing, button design, layout simplicity, and aesthetic appeal were highly rated, indicating that the application is visually clear, readable, and user-friendly. Learnability was also a strong point, with high scores for readability, intuitive page design, and rapid user onboarding, suggesting that users can quickly understand and use the application. Efficiency was highlighted by the simplicity, accuracy, and responsiveness of the system's functions, with a perfect score in responsiveness indicating that the application meets user expectations for performance. Memorability was supported by high scores in visual recognition, design consistency, and engaging design, helping users easily navigate and remember different pages. Correctness and security were also well-rated, with accurate, comprehensive, and reliable data, as well as strong user authentication, authorization, and data security measures. The overall outcome showed high satisfaction in user-friendliness, engagement, data presentation, meeting user expectations, providing sufficient information, cost-efficiency, and convenience. These positive feedbacks underscore the application's potential to effectively support smart farming by enhancing usability, efficiency, and security, ultimately fulfilling user expectations and providing practical benefits for managing plant cultivation.

Table 5: Evaluation of User Satisfaction by IT Experts.

Satisfaction Domains	Satisfaction Factors	Questionnaire Items	Results from IT Experts					x̄	S.D.	CSAT Score (%)	Interpretation of CSAT Score
			1st	2nd	3rd	4th	5th				
User Interface Design	Color Selection	Color schemes are appropriately selected to enhance visual clarity and usability.	4	5	5	4	4	4.4	0.55	100	Highly Satisfied
	Font Size	The font size chosen is suitable for readability and usability.	4	4	5	5	5	4.6	0.55	100	Highly Satisfied
	Font Style	The font style chosen is suitable for readability and usability.	5	5	5	4	4	4.6	0.55	100	Highly Satisfied
	Imagery and Icons	The imagery and icons used are appropriate for their intended purpose.	5	5	5	5	4	4.8	0.45	100	Highly Satisfied
	Image Sizing	Images are sized appropriately to ensure visual clarity and usability.	5	4	5	4	5	4.6	0.55	100	Highly Satisfied
	Button Design	Buttons are designed with appropriate size and style for effective user interaction.	4	5	5	5	5	4.8	0.45	100	Highly Satisfied
	Layout Simplicity	The layout of application interface is designed for ease of use.	5	5	5	4	5	4.8	0.45	100	Highly Satisfied
	Aesthetic Design	The user interface (UI) is designed with aesthetic appeal.	5	5	5	4	5	4.8	0.45	100	Highly Satisfied
Learnability	Readability and Usability	The formatting is designed to be easily readable and user-friendly.	5	5	5	5	4	4.8	0.45	100	Highly Satisfied
	Intuitive Page Design	Each page within the application is designed to be visually appealing and easy to understand.	4	5	5	5	5	4.8	0.45	100	Highly Satisfied
	Rapid User Onboarding	Users are able to quickly learn and understand how to use the application.	5	5	5	5	4	4.8	0.45	100	Highly Satisfied
Efficiency	Ease of Use	The system's functions are designed to be simple and uncomplicated.	5	5	5	4	5	4.8	0.45	100	Highly Satisfied
	Accuracy and Precision	The system's functions are accurate and precise in their operations.	4	4	5	4	5	4.4	0.55	100	Highly Satisfied
	Responsiveness	The application responds to user input within an acceptable timeframe.	5	5	5	5	5	5	0.00	100	Highly Satisfied
Memorability	Visual Recognition	Users are able to easily recognize and distinguish between different pages within the application.	4	5	5	5	4	4.6	0.55	100	Highly Satisfied
	Design Consistency	The design maintains consistency throughout the application.	5	4	5	5	5	4.8	0.45	100	Highly Satisfied
	Modern and Engaging Design	The design exhibits contemporary appeal and engaging features.	5	5	5	5	5	5	0.00	100	Highly Satisfied
Correctness	Data Accuracy and	The data within the system is accurate and comprehensive.	5	4	5	4	4	4.4	0.55	100	Highly Satisfied

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Satisfaction Domains	Satisfaction Factors	Questionnaire Items	Results from IT Experts					x̄	S.D.	CSAT Score (%)	Interpretation of CSAT Score
			1st	2nd	3rd	4th	5th				
	Completeness										
	Data Reliability	The data within the system is reliable.	4	5	5	4	5	4.6	0.55	100	Highly Satisfied
Security	User Authentication System	The mechanisms in place to verify the identity of users when they log in to the application.	5	5	5	4	5	4.8	0.45	100	Highly Satisfied
	User Authorization and Access Control	Granting users permission to perform actions on the data after they have successfully logged in.	5	5	4	4	5	4.6	0.55	100	Highly Satisfied
	Data Security Confidence	Assurance in the security measures that protect the data.	5	5	5	5	4	4.8	0.45	100	Highly Satisfied
Outcome	User-Friendliness	The application is designed to interact with users in a way that is easy to understand.	5	4	5	5	4	4.6	0.55	100	Highly Satisfied
	User Engagement	The application is appealing to users and encourages continued use.	5	5	4	5	5	4.8	0.45	100	Highly Satisfied
	Data Presentation	The data is presented in a clear, concise, and informative manner.	5	5	5	5	4	4.8	0.45	100	Highly Satisfied
	User Expectations	The application produces results that meet user expectations.	4	5	5	5	5	4.8	0.45	100	Highly Satisfied
	Sufficient Information	The application provides enough information to enable users to make informed decisions to use the application.	5	4	4	5	5	4.6	0.55	100	Highly Satisfied
	Cost-Efficiency	The application helps to reduce the costs associated with crop cultivation, such as water, travel-related expenses, etc.	4	5	5	5	5	4.8	0.45	100	Highly Satisfied
	Convenience	The application facilitates crop cultivation management, such as water and light automation control, accounting management, etc.	5	5	4	5	5	4.8	0.45	100	Highly Satisfied

Moreover, a comprehensive evaluation of user satisfaction across the application's various domains was conducted with 70 target users (As presented in Table 6). The results indicate high satisfaction levels, with mean scores ranging from 4.33 to 4.59 and standard deviations between 0.55 and 0.79, resulting in CSAT scores between 85.71% and 97.14%. In the domain of user interface design, users rated color selection, font size, imagery and icons, and image sizing highly, with mean scores of 4.41, 4.5, 4.49, and 4.53, respectively, indicating that the application is visually clear and user-friendly. Font style received a slightly lower mean score of 4.36. Button design, layout simplicity, and aesthetic design were also well-received, with mean scores of 4.47, 4.51, and 4.47, respectively. The application demonstrates strong usability and performance across several key metrics. Learnability was a significant strength, evidenced by high scores for readability, intuitive page design, and rapid user onboarding, indicating ease of understanding and use. System efficiency was confirmed by the simplicity, accuracy, and responsiveness of its functions, achieving mean scores of 4.51, 4.43, and 4.43, respectively. Memorability was facilitated by the application's visual recognition and design consistency, with mean scores of 4.34 and 4.49, suggesting ease of navigation and recall. The modern and engaging design also received positive feedback, with a mean score of 4.44. Additionally, the evaluation indicated strong performance in data correctness and security, as evidenced by user ratings of data accuracy, comprehensiveness, and reliability, as well as the effectiveness of user authentication, authorization, and data security measures, with mean scores ranging from 4.33 to 4.51. The overall outcome was high across multiple dimensions, including user-friendliness, engagement, data presentation, user expectations, information sufficiency, cost-efficiency, and convenience, with mean scores ranging from 4.41 to 4.59. The highest mean score of 4.59 was for convenience, indicating that the application effectively facilitates crop cultivation management. These findings align closely with the feedback from the IT experts, reinforcing the application's strengths in enhancing usability, efficiency, and user satisfaction. Furthermore, the application demonstrates strong performance in

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supporting smart farming by providing practical benefits and meeting user expectations in planting management and control using IoT technology.

Compared to existing smart farming solutions offered by Mujawar et al. [15] and Raju et al. [16] which focus on a specific functionality such as automation control, environmental monitoring, or disease detection, the proposed system offers a unique strength through its holistic integration of real-time crop monitoring, automated control, financial management, agricultural knowledge access, and community forums within a single mobile application. Additionally, this study presents a more user-centric and comprehensive tool, particularly suitable for smallholder farmers. However, this system currently relies on rule-based control thresholds and lacks AI-driven analytics.

Table 6: Evaluation of User Satisfaction by Sample Users Representing the Target User Base.

Satisfaction Domains	Satisfaction Factors	Questionnaire Items	x̄	S.D.	CSAT Score (%)	Interpretation of CSAT Score
User Interface Design	Color Selection	Color schemes are appropriately selected to enhance visual clarity and usability.	4.41	0.65	91.43	Highly Satisfied
	Font Size	The font size chosen is suitable for readability and usability.	4.50	0.58	95.71	Highly Satisfied
	Font Style	The font style chosen is suitable for readability and usability.	4.36	0.80	85.71	Highly Satisfied
	Imagery and Icons	The imagery and icons used are appropriate for their intended purpose.	4.49	0.65	91.43	Highly Satisfied
	Image Sizing	Images are sized appropriately to ensure visual clarity and usability.	4.53	0.63	95.71	Highly Satisfied
	Button Design	Buttons are designed with appropriate size and style for effective user interaction.	4.47	0.65	91.43	Highly Satisfied
	Layout Simplicity	The layout of application interface is designed for ease of use.	4.51	0.61	94.29	Highly Satisfied
	Aesthetic Design	The user interface (UI) is designed with aesthetic appeal.	4.47	0.61	94.29	Highly Satisfied
Learnability	Readability and Usability	The formatting is designed to be easily readable and user-friendly.	4.51	0.56	97.14	Highly Satisfied
	Intuitive Page Design	Each page within the application is designed to be visually appealing and easy to understand.	4.53	0.63	92.86	Highly Satisfied
	Rapid User Onboarding	Users are able to quickly learn and understand how to use the application.	4.46	0.65	94.29	Highly Satisfied
Efficiency	Ease of Use	The system's functions are designed to be simple and uncomplicated.	4.51	0.61	94.29	Highly Satisfied
	Accuracy and Precision	The system's functions are accurate and precise in their operations.	4.43	0.65	91.43	Highly Satisfied
	Responsiveness	The application responds to user input within an acceptable timeframe.	4.43	0.60	94.29	Highly Satisfied
Memorability	Visual Recognition	Users are able to easily recognize and distinguish between different pages within the application.	4.34	0.72	88.57	Highly Satisfied
	Design Consistency	The design maintains consistency throughout the application.	4.49	0.61	94.29	Highly Satisfied
	Modern and Engaging Design	The design exhibits contemporary appeal and engaging features.	4.44	0.67	90.00	Highly Satisfied
Correctness	Data Accuracy and Completeness	The data within the system is accurate and comprehensive.	4.49	0.61	94.29	Highly Satisfied
	Data Reliability	The data within the system is reliable.	4.44	0.58	95.71	Highly Satisfied
Security	User Authentication System	The mechanisms in place to verify the identity of users when they log in to the application.	4.51	0.65	94.29	Highly Satisfied
	User Authorization and Access Control	Granting users permission to perform actions on the data after they have successfully logged in.	4.41	0.60	94.29	Highly Satisfied
	Data Security Confidence	Assurance in the security measures that protect the data.	4.33	0.77	88.57	Highly Satisfied

Satisfaction Domains	Satisfaction Factors	Questionnaire Items	x̄	S.D.	CSAT Score (%)	Interpretation of CSAT Score
Outcome	User-Friendliness	The application is designed to interact with users in a way that is easy to understand.	4.49	0.70	91.43	Highly Satisfied
	User Engagement	The application is appealing to users and encourages continued use.	4.43	0.71	90.00	Highly Satisfied
	Data Presentation	The data is presented in a clear, concise, and informative manner.	4.44	0.67	90.00	Highly Satisfied
	User Expectations	The application produces results that meet user expectations.	4.46	0.70	91.43	Highly Satisfied
	Sufficient Information	The application provides enough information to enable users to make informed decisions to use the application.	4.49	0.68	92.86	Highly Satisfied
	Cost-Efficiency	The application helps to reduce the costs associated with crop cultivation, such as water, travel-related expenses, etc.	4.41	0.79	88.57	Highly Satisfied
	Convenience	The application facilitates crop cultivation management, such as water and light automation control, accounting management, etc.	4.59	0.55	97.14	Highly Satisfied

7. CONCLUSIONS

This paper demonstrates the design and development of a smart farming application for planting management and control utilizing IoT technology to provide farmers with real-time data and remote control capabilities. The system provides real-time monitoring of critical environmental parameters, such as soil moisture, temperature, and water levels in the storage tank. It also enables automation and remote on-off control of the irrigation and lighting system, leading to improved resource utilization and reduced operational costs.

The novelty of this study lies in its integrated design, which goes beyond conventional IoT-based farming solutions by combining automation, financial management, agricultural knowledge access, and a collaborative community forum within a single mobile application. This comprehensive and user-centered approach addresses both technological and socio-economic challenges faced by farmers in a digital agriculture context.

The key research contributions include: (1) the development of a multi-functional mobile platform that supports both operational control and decision-making in agriculture, (2) the integration of financial tracking and knowledge sharing to empower data-driven farm management, and (3) the validation of the system's usability through a two-group evaluation involving both technical experts and end-users, demonstrating effectiveness of the application in terms of interface design, efficiency, and security.

In the context of current agricultural challenges, such as climate variability, resource constraints, and knowledge gaps among smallholder farmers, the findings highlight the potential of IoT-driven, multifunctional tools to promote smarter, more sustainable farming practices. By equipping users with real-time insights, automation features, and access to expert knowledge and peer support, the proposed application contributes to improving productivity and sustainability in modern agriculture.

Despite its effectiveness, the current implementation has certain limitations. The system's reliance on predefined thresholds for automated irrigation and lighting may not account for dynamic environmental changes. Future research will focus on enhancing the smart farming application by incorporating AI-driven predictive analytics to improve crop management and optimize irrigation and lighting schedules. Machine learning models can be integrated to analyze historical data and predict future environmental conditions, enabling more adaptive and intelligent decision-making. Furthermore, conducting large-scale field trials will validate the system's effectiveness across diverse farming environments and help refine its features based on real-world use cases.

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