

Evaluation of Smart Agriculture Prototype using SUS Method

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Abstract

Agriculture plays a strategic role in Indonesia's economy. However, the adoption of digital farming technology among farmers remains low due to limited digital literacy and complex application interfaces. This paper proposes a mobile-based smart farming application for real-time agricultural monitoring. We develop the system using the prototyping approach to ensure the application meets farmers' practical needs. The application monitors environmental parameters such as temperature, humidity, and light intensity. We verify system functionality using Black Box testing on five main features: registration, login, monitoring, data storage and visualization, and notification services. The results show that all tested features operate correctly according to the designed scenarios. We evaluate system usability using the System Usability Scale (SUS) involving 10 farmer respondents aged 23–70 years. The analysis produces a total contribution score of 18.4 for positive statements and 16.0 for negative statements. The SUS calculation results in a final usability score of 86. This value exceeds the global average SUS benchmark of 68 and indicates a high level of usability and strong user acceptance. These results show that the proposed application functions reliably and provides a user-friendly interface for farmers. The high SUS score confirms that the system supports practical use in agricultural monitoring and can assist farmers in accessing environmental information efficiently.

Keywords:

Evaluation, Smart Farming Application, SUS Testing, Prototype

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1. Introduction

The agricultural sector plays a crucial role in ensuring food security and sustaining national economic stability. Governments and researchers increasingly emphasize the importance of improving agricultural productivity through technological innovation and digital transformation. Traditional farming practices often rely on manual observation and experience-based decision-making, which can limit efficiency and responsiveness to environmental changes. As agricultural activities become more complex due to climate variability and increasing demand for food production, farmers require better tools to monitor and manage their fields effectively. Digital agriculture initiatives aim to address these challenges by integrating information technology into farming activities, enabling more accurate monitoring and data-driven decision-making processes. However, many farming communities still experience limitations in adopting digital tools due to usability barriers and lack of user-friendly system designs [12], [18].

Recent developments in smart agriculture demonstrate the increasing role of Internet of Things (IoT) technology in supporting agricultural monitoring and automation. IoT-based systems allow sensors and connected devices to collect environmental data such as soil moisture, temperature, humidity, and light intensity in real time. These systems enable

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farmers to monitor field conditions remotely and respond quickly to changes that may affect crop growth. Several studies develop IoT-based monitoring systems to improve irrigation efficiency, reduce manual labor, and enhance crop productivity. Although these technologies provide significant benefits, many implementations primarily focus on system functionality and technical performance. Researchers often overlook how farmers interact with these technologies, which may influence the long-term success and adoption of smart agriculture systems [4], [21].

Various IoT-based agricultural applications have been developed to support field monitoring, irrigation control, and crop management. For example, IoT smart farming platforms integrate sensors, communication networks, and data processing systems to provide real-time agricultural insights. These systems demonstrate the potential to increase operational efficiency and support precision agriculture practices. Nevertheless, many prototypes remain experimental and lack proper evaluation of user interaction and usability. Farmers may encounter difficulties when operating complex interfaces or interpreting sensor data presented by the system. Without proper usability evaluation, even technically advanced systems may fail to deliver practical benefits in real agricultural environments [9], [22].

Digital agricultural platforms also include mobile applications designed to support farmers through consultation services, monitoring dashboards, and decision-support tools. These applications aim to simplify access to agricultural information and improve communication between farmers and agricultural experts. Mobile technologies provide a convenient way to deliver real-time data and recommendations directly to farmers in the field. However, the effectiveness of these applications depends heavily on their usability and ease of use. Farmers with different levels of technological literacy may struggle to operate complex digital interfaces. Therefore, developers must ensure that agricultural systems are designed with user-centered approaches to improve accessibility and practical adoption among farming communities [13].

Usability evaluation becomes an essential step in ensuring that technological systems can be effectively used by their intended users. In human–computer interaction research, usability refers to how easily and efficiently users can interact with a system to achieve specific goals. Poor usability can reduce user satisfaction, increase operational errors, and ultimately discourage users from adopting the technology. Researchers emphasize that usability testing helps identify design weaknesses, interface complexity, and user interaction issues before a system is widely implemented. For smart agriculture systems, usability evaluation is particularly important because many farmers may have limited experience with digital technologies, making intuitive system design a critical requirement [23].

One widely accepted method for evaluating system usability is the System Usability Scale (SUS). The SUS method provides a simple yet reliable questionnaire-based approach to measure user perceptions of system usability. It consists of ten standardized questions that capture users' impressions regarding system effectiveness, complexity, and ease of use. The SUS method has been widely adopted in various domains, including mobile applications, wearable technologies, healthcare systems, and educational platforms. Researchers demonstrate that SUS provides consistent usability scores and can quickly identify whether a system meets acceptable usability standards. Its simplicity and reliability make it suitable for evaluating technological prototypes in practical environments [1], [4].

Several studies apply the SUS method to evaluate different types of digital systems and user interfaces. Researchers use SUS to assess the usability of mobile banking applications, wearable devices, virtual reality systems, and health information platforms. These studies show that usability evaluation helps developers improve system design and enhance user satisfaction. The results also demonstrate that systems with higher SUS

scores tend to achieve better user acceptance and operational efficiency. Despite its widespread use in software and interface evaluation, the application of SUS in smart agriculture systems remains relatively limited, particularly in evaluating prototypes designed for farmers in real agricultural environments [3], [7], [9].

Based on these challenges, evaluating the usability of smart agriculture systems becomes an important research objective. Many IoT-based agricultural prototypes demonstrate promising technical capabilities but lack systematic evaluation of how farmers perceive and interact with the technology. Without understanding user acceptance and usability performance, developers cannot ensure that these systems will be effectively adopted in real farming practices. Therefore, this study focuses on evaluating a smart agriculture prototype using the System Usability Scale (SUS) method. By collecting feedback directly from farmers and system users, the study aims to measure the usability level of the developed system and identify potential improvements for future smart agriculture applications [1], [23].

2. Related Works

Several studies have examined the theoretical foundation and reliability of the System Usability Scale (SUS) as a standard method for evaluating system usability. James R. Lewis and Jeff Sauro analyzed the factor structure of SUS and confirmed that the instrument effectively measures perceived usability through a simple ten-item questionnaire. Their study demonstrated that SUS provides reliable usability measurements across various software systems and user groups. The authors highlighted that SUS offers strong internal consistency and requires minimal evaluation time. However, their work mainly focused on statistical validation of the scale rather than evaluating specific application domains, leaving room for further studies that apply SUS in practical technological environments such as smart agriculture systems.

Several researchers applied SUS to evaluate usability in specialized software environments. For example, Antonis Macris and colleagues evaluated three digital smile design software systems using SUS. Their study compared different software interfaces used in dental visualization and design workflows. The results showed that SUS effectively distinguished usability differences among competing systems and helped identify interface complexity issues. The study demonstrated the usefulness of SUS in professional software evaluation. However, the research focused on specialized medical design software with highly trained users, which differs significantly from agricultural systems used by farmers with varying levels of digital literacy.

Other studies investigated SUS in mobile application environments. Novi Setiyawati and Daniel H. Bangkalang compared the usability of mobile banking applications using both the User Experience Questionnaire (UEQ) and SUS. Their findings showed that SUS produced clear usability scores that aligned with user experience indicators obtained from other evaluation methods. The study demonstrated that SUS provided a quick and reliable usability benchmark for mobile services. However, the evaluation focused on financial applications designed for frequent smartphone users. The context differs from agricultural monitoring systems where users may have limited technological familiarity.

Research has also explored SUS for evaluating wearable and smart device interfaces. Mansour A. Alshamari and colleagues conducted a usability evaluation of smartwatch interfaces using heuristic evaluation and SUS. Their results showed that combining heuristic analysis with SUS improved the identification of usability problems in small-screen interactive systems. The study highlighted that user satisfaction strongly depended on interface simplicity and navigation clarity. Although the research provided valuable insights for wearable technologies, the study focused on consumer electronics rather than environmental monitoring systems used in agricultural fields.

Educational and technology-supported learning systems have also adopted SUS for usability assessment. Panagiota Vlachogianni and colleagues conducted a systematic review on usability evaluation methods for educational technology systems. Their review identified SUS as one of the most frequently used tools due to its simplicity, reliability, and ease of interpretation. The study concluded that usability evaluation plays an important role in ensuring that technological systems are accessible to diverse user groups. However, the review primarily focused on learning technologies and did not specifically address agricultural technology applications.

Recent research also proposed improvements to the traditional SUS framework. Jure Lorincz and colleagues introduced the Hybrid System Usability Scale (H-SUS) to enhance usability evaluation by integrating additional usability indicators. Their study demonstrated that the hybrid model produced more detailed evaluation results compared to the original SUS approach. The authors argued that enhanced usability metrics could improve system evaluation accuracy in complex digital systems. Nevertheless, the study mainly addressed methodological improvement rather than evaluating real-world agricultural monitoring platforms.

Several studies evaluated usability in immersive and advanced interface technologies. Mohd K. Othman and colleagues assessed the usability of a virtual reality smartphone application using SUS. Their findings showed that SUS successfully captured user perception of immersion, navigation comfort, and system accessibility. Similarly, Ritwik Dutta and colleagues evaluated augmented reality mobile applications using both SUS and HARUS methods. These studies demonstrated that SUS could effectively evaluate emerging interface technologies. However, the systems tested in these studies relied on entertainment or visualization technologies rather than agricultural monitoring systems that require practical usability in outdoor environments.

Usability evaluation has also been applied in healthcare and information management systems. Siti D. Alfian and colleagues evaluated a health information system using SUS to measure user satisfaction among healthcare professionals. The study reported that SUS successfully captured usability perception and helped identify areas requiring interface improvement. Similarly, D. Moyaki and colleagues evaluated virtual reality laboratories in higher education using SUS and reported positive usability scores that indicated good user acceptance. While these studies confirmed the effectiveness of SUS across different domains, they did not specifically investigate usability evaluation for smart agriculture systems used directly by farmers. Therefore, evaluating IoT-based agricultural prototypes using SUS remains an important research direction for understanding system acceptance and practical usability in real farming environments.

3. Proposed Method

This study proposes the development of a mobile-based smart farming system using the prototyping development model. We select this model because farmers' requirements are often not fully defined at the early stages and require gradual refinement through continuous interaction with users. The proposed method emphasizes iterative and collaborative development, where we begin with requirement identification through communication with farmers, followed by quick planning and rapid system design. We then construct an initial prototype and perform direct testing with potential users. Based on the feedback obtained during testing, we refine and improve the prototype iteratively until the system meets practical agricultural needs. Through this approach, this paper aims to develop a user-friendly application that supports real-time agricultural monitoring while reducing design errors and unnecessary system features from the early development stages.

In the modeling phase, we design a structural representation of the system to clarify system workflow and data relationships before implementation. This study develops several system models, including a system architecture diagram, use case diagram, and entity relationship diagram (ERD). These models help describe how users interact with the system and how sensor data are processed and stored within the platform. The system architecture illustrates the interaction between field sensors, the mobile application, and the cloud-based database. Meanwhile, the use case diagram explains the main user activities such as accessing monitoring data, managing land information, and receiving notifications. The ERD defines the structure of the database used to manage sensor readings and user information. These modeling activities help ensure that the proposed system architecture supports reliable and efficient agricultural monitoring. Fig. 1 depicts the system architecture as follows:

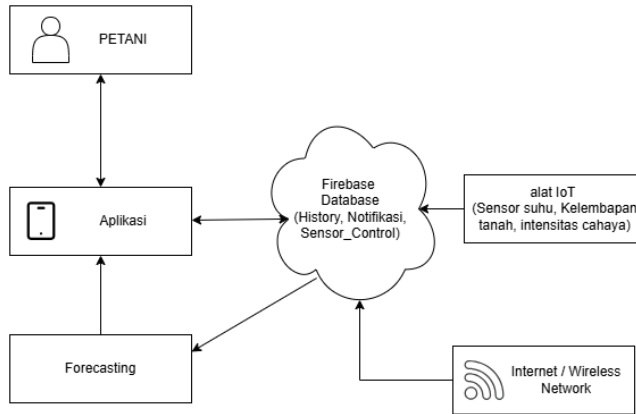


Fig. 1 system architecture

The SUS is calculated by converting the responses from the ten questionnaire items into a standardized usability score. Each item is rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scoring procedure adjusts responses differently for positively and negatively worded items to maintain consistency in usability interpretation. Let R_i denote the user response for item i , where $i = 1, 2, \dots, 10$

For positively worded items (items 1,3,5,7, and 9), the contribution score is obtained by subtracting 1 from the response value:

$$S_i = R_i - 1, i \in \{1,3,5,7,9\}$$

For $S_i = 5 - R_i, i \in \{2,4,6,8,10\}$ (items 2,4,6,8, and 10), the contribution score is calculated by subtracting the response from 5:

$$S_i = 5 - R_i, i \in \{2,4,6,8,10\}$$

After obtaining the adjusted contribution scores for all items, the final SUS score is calculated by summing the contributions and multiplying the result by 2.5 to convert the score into a range of 0–100:

$$SUS = 2.5 \times \sum_{i=1}^{10} S_i \quad (1)$$

In this study, we apply this formulation to evaluate the usability of the proposed smart farming prototype based on responses collected from farmers during the system evaluation phase. The resulting SUS score provides a quantitative measure of system usability, where higher scores indicate better perceived usability and stronger user acceptance of the developed agricultural monitoring system.

4. Experimental Setup

This paper constructs an experimental setup to validate the functionality and usability of the proposed smart farming system. In this study, we collect requirement data through in-depth interviews with farmers at the study location to understand their practical needs in agricultural monitoring. The qualitative information helps identify priority system features, including temperature monitoring, humidity observation, and notification alerts for extreme environmental conditions.

5. Result and Analysis

This section presents the implementation results of the developed application. We implement a mobile-based smart farming application to monitor agricultural environmental conditions in real time. Fig. 2 illustrates the user interface implementation of the Smart Farm application developed using the prototyping model.

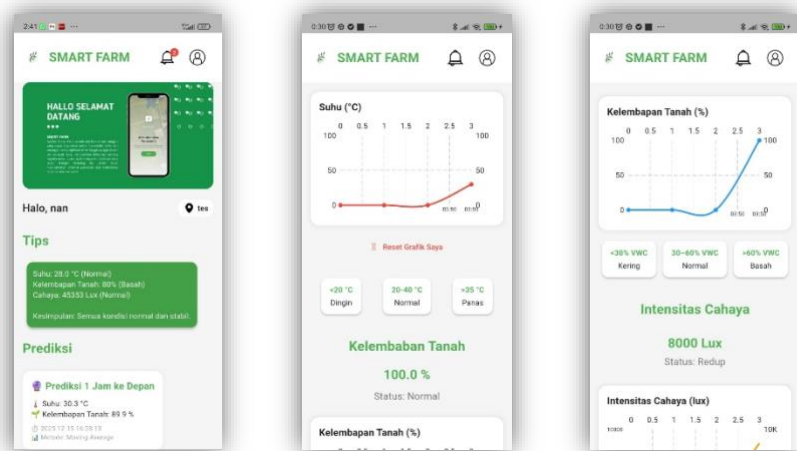


Fig. 2 Prototype Testing

The application uses a simple interface designed for farmers with limited digital literacy. The main page displays real-time sensor data, including temperature, humidity, and light intensity. We conduct functional testing using the Black Box method. The results show that all main application features operate according to the designed scenarios. Table 1 summarizes the testing results.

Table 1. Black Box Testing Results

No.	Feature	Test Scenario	Expected Result	Actual Result	Status
1	Registration	Input valid email and password	Account successfully created and stored in Firebase	Account created successfully without errors	Passed
2	Login	Empty input (fields left blank)	System rejects login and displays error message "Email/Password cannot be empty"	Error message displayed as expected	Passed
3	Monitoring	Sensor data reading	Application displays temperature, soil moisture,	Data displayed and updates as	Passed

			and light intensity data in real-time	sensor values change	
4	Data Graph & Storage	Sensor data storage and graph display	Data history logged into database; graph displayed based on stored data	Graph appears and history successfully stored in Firebase	Passed
5	Notification	Notification trigger when conditions exceed limits	System sends automatic notification if temperature/humidity/light exceeds threshold	Notification appears according to sensor conditions	Passed

We conduct usability testing for the Smart Farm application using the System Usability Scale (SUS) method. We distribute a Likert-scale questionnaire (1–5) to 10 farmer respondents aged 23–70 years from several villages. The test evaluates ease of use, feature understanding, and user comfort. Each respondent answers 10 SUS statements after testing the main features of the application. Our analysis shows a total contribution score of 18.4 for positive items and 16.0 for negative items. These values produce a final SUS score of 86. This score is well above the global average of 68, which indicates high usability and strong user acceptance of the application [13]. Table 2 presents the complete results of the usability testing.

Table 2. System Usability Scale (SUS) Testing Results

No	Statement	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1.	I found this application easy to use.	4	5	4	3	5	5	5	5	5	5
2.	I found this application too complex for farmers to use.	1	1	2	4	1	1	2	2	1	1
3.	I found the application features easy to understand.	5	5	4	3	5	5	5	5	5	5
4.	I found some parts of the application confusing.	1	1	2	4	1	1	2	2	1	2
5.	I found the sensor information (temperature, soil moisture, light intensity) very helpful.	5	5	5	5	5	5	5	5	5	5
6.	I thought I would need the support of another person to use this application.	1	1	2	4	1	1	3	2	2	3
7.	I found the text, numbers, and icons in the application easy to read.	4	5	4	3	4	5	5	5	5	4
8.	I found the information in the application difficult to understand.	1	1	1	4	1	1	2	1	1	2
9.	I felt confident using this application without assistance.	5	5	5	3	5	5	4	4	5	4
10.	I needed to learn a lot of things before I could use this application.	2	3	2	4	1	1	2	2	1	2

For odd-numbered questions (representing positive statements), the score is calculated by subtracting one from the user's response. Conversely, for even-numbered questions (representing negative statements), the score is obtained by subtracting the user's response from five. Subsequently, the final SUS score is computed by summing the adjusted scores of all questions and multiplying the total by 2.5 [13].

Table 3 Positive Aspects

Nomor	Statement	Mean Score	Contribution Score
1	The application is easy to use	4.6	3.6
3	The features are easy to understand	4.7	3.7
5	The sensor information is very helpful	5.0	4.0
7	The text/numbers are easy to read	4.5	3.5
9	Confident in using the application	4.6	3.6
Total Positive Aspects			18.4

Table 4. Negative Aspects

Nomor	Statement	Mean Score	Contribution Score
2	The application is too complex	1.6	3.4
4	Some parts are confusing	1.7	3.3
6	Need support from another person	2.0	3.0
8	The information is difficult to understand	1.7	3.3
10	Need to learn a lot before using	2.0	3.0
Total Negative Aspects			16.0

$$scoreSUS = (18.4 + 16.0) \times 2.5 = 34.4 \times 2.5 = 86.0$$

6. Conclusion

This paper proposes a mobile-based smart farming application developed using the prototyping approach to support real-time agricultural monitoring. We implement key system features that include real-time environmental monitoring, historical data visualization, automatic notifications for critical conditions, and educational information related to smart farming practices. Our study conducts functional testing using the Black Box method to verify system performance. The testing results show that all main features, including registration, login, monitoring, data storage, graph visualization, and notifications, operate according to the designed scenarios. These findings confirm that the developed prototype functions reliably and supports the intended monitoring activities in agricultural environments.

Our study also evaluates system usability through the System Usability Scale (SUS) method involving ten farmer respondents aged between 23 and 70 years. The results show that the positive aspects obtain a total contribution score of 18.4, while the negative aspects obtain a score of 16.0. Based on the SUS calculation, the system achieves a final usability score of 86. This score is significantly higher than the global average SUS benchmark of 68, which indicates a high level of usability and strong user acceptance. The evaluation results demonstrate that farmers can easily understand the application features, read the displayed information, and operate the system with confidence even with limited digital literacy.

Overall, this study demonstrates that the proposed smart farming application can effectively support agricultural monitoring while maintaining a high level of usability for farmers. The combination of reliable system functionality and a high SUS score confirms that the application design successfully addresses usability challenges commonly faced by agricultural users. Our study shows that integrating real-time monitoring, data visualization, and notification features within a simple interface can improve the practicality of smart farming technologies. Future work may extend this system by integrating additional agricultural sensors, advanced data analytics, and wider field testing to further improve system capability and scalability.

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