A Prototype of Mobile-Based Application for Smart Agriculture System

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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 study developed a mobile-based smart farming application integrated with Internet of Things (IoT) sensors to support real-time monitoring of agricultural land conditions. The application monitored air temperature, soil moisture, and light intensity using IoT devices and presented the data through a simple and user-friendly mobile interface. The Prototype development method was applied to actively involve farmers during the early stages of system design and evaluation. The development process included user requirement identification through farmer interviews, UI/UX prototyping, application development using Flutter and Firebase, IoT data integration, and field testing. System evaluation was conducted using functional testing and usability testing with the System Usability Scale (SUS). The results showed that the application successfully displayed real-time sensor data and historical graphs, and provided timely notifications for critical land conditions. Usability testing involving ten farmers produced a SUS score of 86, indicating excellent usability and high user acceptance. The proposed mobile–IoT smart farming application demonstrated its potential to support efficient land monitoring and data-driven decision-making for farmers with limited digital experience.

Keywords:

Smart farming; Mobile application; Internet of Things; Usability testing; Prototype method; Soil moisture monitoring

1. Introduction

The agricultural sector is a strategic sector for supporting national economic growth and food security in Indonesia, with more than 30% of the population depending on this sector as their primary source of livelihood [1]. Although Indonesia is one of the world's largest rice producers, dependence on food imports remains relatively high, indicating challenges in sustainably increasing agricultural productivity and efficiency [2]. This condition demands innovation and transformation within the agricultural system, specifically through the utilization of digital technology.

Technological advancements are driving a shift from conventional farming to smart farming, which utilizes mobile applications and the Internet of Things (IoT). Several studies indicate that the application of mobile-based agricultural apps can increase farmer productivity and reduce the excessive use of agricultural inputs by providing information and real-time monitoring [3]. However, in Indonesia, the adoption rate of digital agricultural technology remains classified as low. Only a small fraction of farmers currently uses agricultural applications, and the majority have trouble understanding application interfaces due to limited digital literacy and system designs that are not user-friendly [2].

Mobile applications integrated with IoT sensors hold great potential as innovative solutions to address these issues. Through this integration, land condition data—such as temperature, soil moisture, light intensity, and crop water requirements—can be monitored in real-time and presented as information that is easily understood by farmers [4]. Nevertheless, the main challenge lies in designing an application that is simple, intuitive, and aligned with the needs and local conditions of the farmers.

Based on the aforementioned issues, this research aims to design and develop a mobile-based smart farming system application integrated with IoT devices, specifically for monitoring paddy field conditions. The application is designed with a user-friendly interface to ensure ease of use for farmers, thereby supporting rapid and accurate data-driven decision-making. The innovation of this research lies in the development of a mobile application that not only presents environmental data in real-time but also emphasizes ease of use for farmers as the primary users. Consequently, it is expected to enhance land management efficiency and agricultural productivity in Indonesia.

Sensor-based monitoring approaches, such as measuring temperature, humidity, light intensity, acidity levels, and plant nutrient conditions as applied in hydroponic systems, demonstrate that the integration of IoT and digital applications is capable of providing real-time information on plant environmental conditions [5]. This information serves as a vital basis for decision-making regarding plant care, while also underscoring that an integrated monitoring system accessible via digital platforms is a crucial requirement in the development of smart farming.

In addition to sensors and mobile applications, long-range communication technologies such as Long Range (LoRa) play a significant role in supporting smart farming systems, particularly in rural areas with network constraints. LoRa offers low power consumption, broad coverage, and efficient operational costs, thereby holding the potential to support the reliable and sustainable transmission of agricultural IoT data [6]. Previous research findings indicate that the integration of IoT technology, LoRa communication, and mobile applications constitutes an effective approach to supporting the efficient automation and monitoring of irrigation systems, making it feasible for development as a smart farming solution capable of addressing infrastructure limitations in remote regions [7].

2. Related Works

Various prior studies indicate that the implementation of mobile-based smart farming systems holds significant potential for enhancing agricultural efficiency and productivity. However, these systems still face contextual challenges in Indonesia, such as infrastructure limitations, farmers' digital literacy, and the suitability of system design. [8] asserts that dependence on traditional farming methods and limited access to technology remain primary obstacles; thus, digital transformation through IoT-based smart farming and mobile applications is viewed as a relevant solution.

Research by Ginardi [9] developed an automated irrigation system using BME280 and ESP32 sensors, capable of optimizing water and labor usage through automatic watering based on temperature and humidity data. The primary contribution of this research lies in IoT-driven operational efficiency; however, limitations in internet connectivity and electricity in rural areas, combined with minimal attention to UI/UX aspects, render this system less optimal for the context of Indonesian farmers. This highlights the necessity for better integration between IoT technology and user-friendly mobile applications.

A different approach is demonstrated by Alhafiz and Sela [3] through the development of an agricultural mobile application that functions offline and features fertilizer recommendations. This application has been proven to increase agricultural yields and fertilizer efficiency while being relatively easy to use. Nevertheless, challenges remain regarding farmers' understanding of technical terms, suggesting that the User Experience (UX) aspect has not yet been fully optimized. These findings are highly relevant to this research, which emphasizes the importance of simplifying the application interface and language.

regarding development methodologies, Rahmawati [10] developed the web-based TI-FARM system using the Agile methodology to provide comprehensive agricultural information. While Agile allows the system to adapt to user needs, it demands intensive coordination between developers and farmers. Meanwhile, Syahaddan and Waluyo [11] employed the Waterfall approach to develop an Android-based paddy monitoring system integrated with IoT. This system is effective for remote monitoring but lacks flexibility in addressing changing user requirements during the development process.

Furthermore, research by Juanto et al [12] ,offers a significant contribution using the Prototype method in developing the "Jembatani" mobile application, which is integrated with soil moisture and DHT11 sensors. The prototyping approach enables iterative development with direct farmer involvement, thereby enhancing flexibility, operational efficiency, and the ease of technology adoption. These results suggest that the Prototype method is more suitable for agricultural contexts characterized by diverse levels of digital literacy.

Collectively, these studies confirm that the success of mobile-based smart farming applications is determined not only by technological sophistication but also by the selection of flexible development methodologies, intuitive UI/UX design, and alignment with infrastructure conditions and farmer characteristics. The existing gap—specifically regarding the integration of IoT with user-friendly mobile applications developed through participatory methods—serves as the foundation and primary relevance for this research.

3. Proposed Method

This study employs the Prototyping development model to design the Mobile-Based Smart Farming System application. This model was selected because it is well-suited for addressing farmers' requirements, which are often not fully defined in the initial stages and require refinement through continuous feedback. This model facilitates iterative and collaborative system development, commencing with communication to identify user requirements, followed by quick planning, modeling (quick design), prototype construction, and concluding with user testing and evaluation.

Each prototype is tested directly by farmers and refined based on their feedback until a system that aligns with field requirements is achieved. This approach aims to produce a user-friendly application that is adaptive to the real-world needs of farmers and capable of supporting real-time agricultural monitoring, while simultaneously minimizing design errors and irrelevant features from the early stages of development.

3.1 Modeling (Quick Design)

The modeling phase aims to generate a visual and structural representation of the system prior to further development. In this phase, the system architecture, Use Case Diagrams, and Entity Relationship Diagrams (ERD) are designed to facilitate the understanding of the system workflow and data relationships. The System Architecture Diagram is presented as follows:

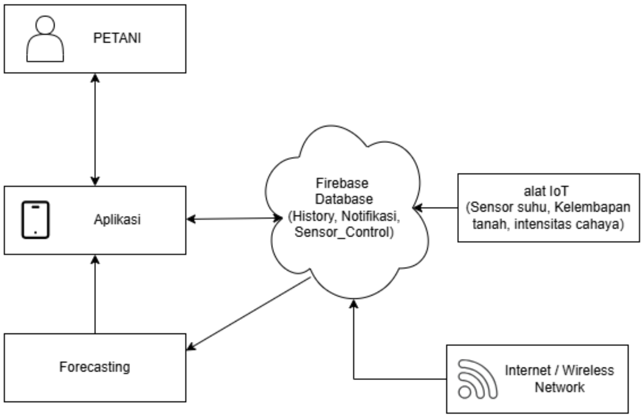

Figure 1. diagrammatic architecture

3.2 Construction of Prototype

Following the establishment of the use case diagram, the subsequent phase involves designing the User Interface (UI) prototype, structured according to the system modeling results. This design process utilizes the Figma tool to generate wireframes as the initial visual representation of the application. These wireframes are designed to align with user needs, ensuring that the application workflow is intuitive, simple, and easily comprehensible for farmers as the primary users. The established wireframe designs are presented below:

The Wireframe and UI/UX design encompasses several key interfaces: the landing page, land data input page, main dashboard, and notification page. The landing page serves as the application's gateway, displaying the system identity alongside user login and registration options. The land data input page is utilized for entering basic agricultural land information to be stored in the database. The main dashboard is designed as the central hub for presenting sensor-based information, displaying real-time data on temperature, soil moisture, and light intensity. Meanwhile, the notification page serves to provide alerts to the user regarding land conditions based on time and specific environmental parameters.

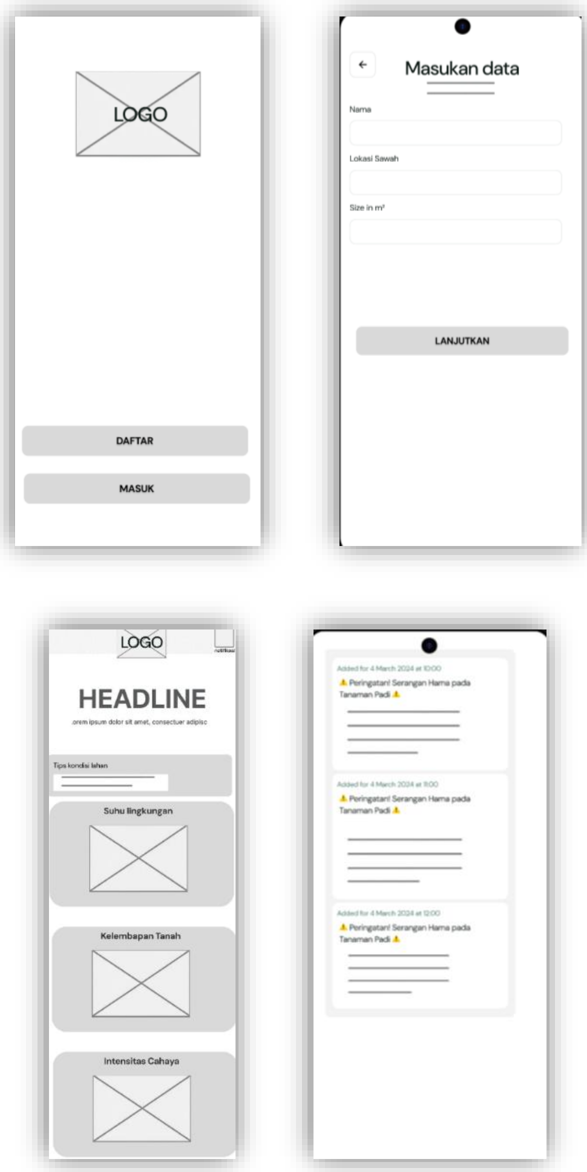

Figure 2. wireframe design

Based on these wireframe designs, an application version was subsequently developed by implementing the user interface, core feature logic, and database connectivity using Firebase. The resulting prototype is functional yet remains open to further refinement. Therefore, the prototype undergoes functional testing to ensure that every feature operates as designed prior to user validation.

4. Experimental Setup

This section outlines the testing procedures and instruments employed to validate the system's performance. Data Collection Requirement data was collected through in-depth interviews with farmers at the study site. This qualitative data was utilized to determine priority features, such as temperature and humidity monitoring, as well as notifications for extreme conditions. Quantitative data was obtained from sensor testing in paddy fields to ensure the accuracy of temperature and soil moisture readings relative to actual conditions. System Configuration The experiments were conducted using the following hardware and software components:

- Mobile Device: An Android Smartphone used to run the Smart Farm application.
- IoT Platform: Integrated sensor devices used to read environmental parameters (Temperature, Humidity, Light Intensity).
- Software Development Kit: Flutter SDK for interface development and Firebase SDK for database management.

Testing Procedure The testing procedure is divided into two main stages:

1. Black Box Testing: This involves testing the functionality of application features (Login, Monitoring, Notifications) without examining the internal code structure. The objective is to ensure that user inputs yield the appropriate outputs.
2. Usability Testing: This utilizes the System Usability Scale (SUS) method to measure the level of user satisfaction and the ease of use for farmers. SUS questionnaires were distributed to respondents after they attempted to use the application to monitor land conditions.

5. Result and Analysis

This section details the implementation results of the developed application. This mobile-based smart farming application is constructed to monitor agricultural environmental conditions in real-time, display historical data in a graphical format, deliver notifications regarding critical conditions, and provide educational features on smart farming. Figure 3 depicts the UI implementation of the Smart Farm application developed using the prototyping model.

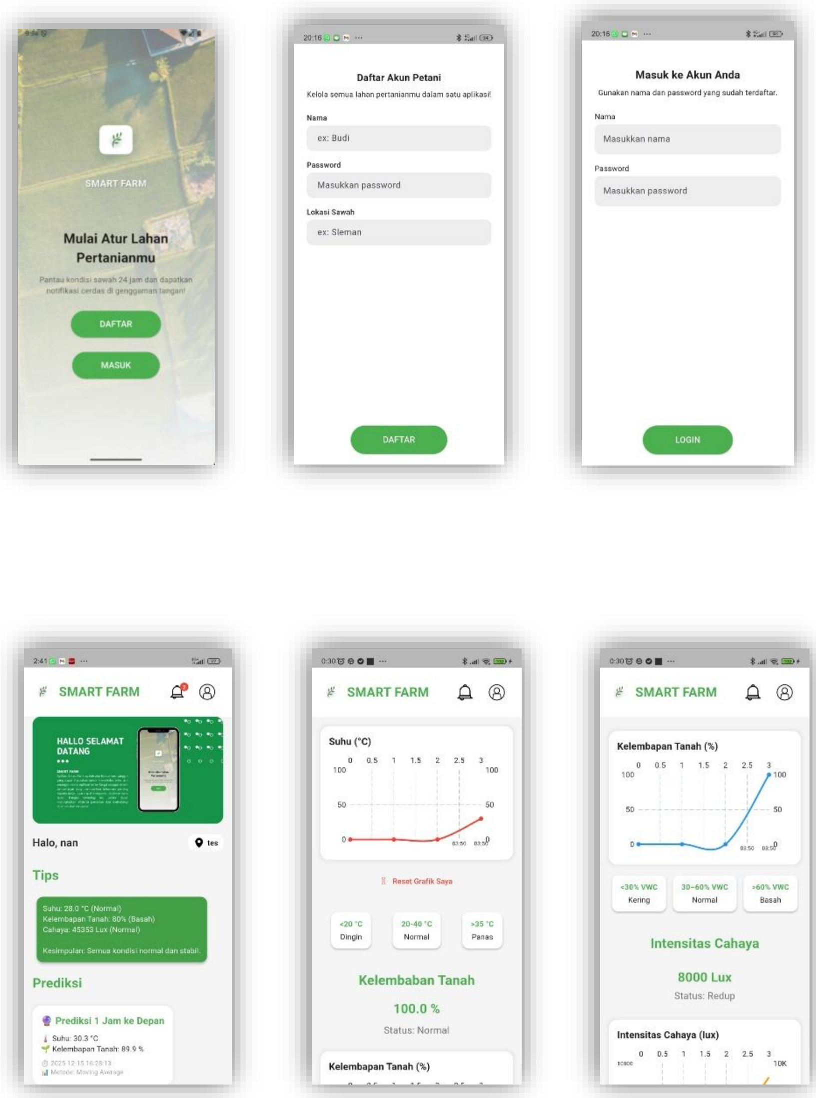

Figure 3. application implementation

The developed application features a simplified interface tailored to the characteristics of farmers, who may possess limited digital literacy. Key features include a homepage that displays real-time sensor data (Temperature, Humidity, and Light Intensity).

Black Box Testing Analysis Functional testing conducted using the Black Box method demonstrated that all primary application features functioned in accordance with the designed scenarios. Table 1 summarizes these testing results.

Table 1. Black Box Testing Results

No.	Tested Feature	Test Scenario	Expected Result	Actual Result	Status
1	Registration	Input valid email and password	Account successfully created and stored in Firebase	Account created	Passed

				successfully without errors	
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, and light intensity data in real-time	Data displayed and updates as sensor values change	Passed
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

Usability testing (User Experience) for the Smart Farm application was conducted using the System Usability Scale (SUS) method, utilizing a Likert-scale questionnaire (1–5) involving 10 farmer respondents aged 23 to 70 years from various villages. This testing aimed to evaluate aspects of ease of use, feature comprehension, and user comfort, wherein respondents were required to respond to 10 statements after testing the application's core features. Based on the data analysis, the total contribution score for positive aspects was 18.4, and for negative aspects was 16.0, resulting in a final SUS score of 86. This score is significantly above the global average of 68, indicating that the application possesses a high level of usability and is well-accepted by users [13] The complete data from this testing is presented in the following table:

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

Conclusion This study successfully developed a mobile-based smart farming system application using the Prototyping method, alongside Flutter and Firebase technologies, which proved effective in delivering environmental data in real-time aligned with farmers' needs. Based on Black Box testing, all core features functioned according to specifications, while the usability evaluation using the System Usability Scale (SUS) yielded a score of 86, indicating a high level of acceptance and ease of use among farmers. Thus, this application is not only functionally valid but also serves as a practical solution that supports decision-making and has the potential to enhance efficiency and productivity within the agricultural sector.

For future research development, it is recommended that the Smart Farm application be enhanced with advanced features, such as soil pH monitoring, automated fertilizer recommendations, and weather forecast integration, to support more comprehensive decision-making. Furthermore, expanding the scope of testing with a more representative number of respondents, as well as the permanent deployment of IoT sensors in the field, is highly recommended to obtain accurate long-term data analysis. Finally, continuous refinement of the user interface (UI/UX) is necessary, specifically through navigational and visual adjustments for elderly users, to ensure optimal usability.

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