Mobile Application for Garlic Land Suitability: Supporting On-Site Assessment in Network-Limited Areas

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Abstract
Garlic land suitability assessment is essential to support the government's program to increase local garlic production. This study aims to develop an Android-based mobile application that facilitates on-site garlic land suitability evaluation for agricultural extension officers, advanced farmers, and others conducting garlic land suitability assessments. This application allows users to obtain land suitability classes based on garlic growth requirement factors, namely soil and weather characteristics. Spatial data on these factors is provided by the application, with real-time weather data management to deliver suitability classes according to current weather conditions. Functionality testing of the application through black box testing has been conducted, showing results in line with the developer's expectations. Additionally, usability testing was performed to evaluate system usefulness, information quality, interface quality, and overall assessment. The evaluation employed the Post-Study System Usability Questionnaire (PSSUQ) version 3, which uses a 7-point Likert scale where 1 represents "strongly agree" (indicating high user satisfaction) and 7 represents "strongly disagree." Lower scores therefore reflect more favorable user evaluations of the system. On average, the system's overall score reached 2.06, system usefulness 2.02, information quality 2.09, and interface quality 2.06, indicating that users agree or strongly agree with the Mobile Application Usability Indicators. These results demonstrate that the mobile application is well-received and effectively supports usability for its target users. Its key innovation is the integration of real-time weather data with soil information to provide dynamic and accurate land suitability assessments. By offering an intuitive interface and tailored recommendations, the application enables data-driven decision-making for improved garlic cultivation planning.

Keywords: Garlic Productivity, Land Suitability, Mobile Application, Spatial Decision Support System

1. Introduction

Garlic (*Allium sativum*) is widely used in Indonesia for both culinary and health purposes. As consumption continues to rise [1], domestic production has declined significantly, from 45,092 tons in 2021 to 30,582 tons in 2022 [2]. To reduce import dependency, the government has launched strategic programs supported by Ministerial Regulation No. 38 of 2017 on Horticultural Product Import Recommendations (RIPH) [3], including a 5% expansion of planting areas and the development of production centers in Tegal (Central Java), East Lombok, and West Nusa Tenggara. East Lombok alone offers 10,000 hectares of potential land across five districts [4]. A long-term roadmap from the Directorate General of Horticulture targets garlic self-sufficiency by 2030–2045 [5].

However, the success of these policy initiatives depends not only on expanding garlic planting areas but also on accurately identifying land that is truly suitable for cultivation. This requirement highlights the critical role of geospatial assessment and technical tools, which face challenges such as limited data accessibility, reliance on static models, and the need for timely, field-ready evaluation methods.

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Despite these efforts, farmers and agricultural extension officers face several challenges in evaluating land suitability for garlic cultivation. These challenges include limited time, high costs, and restricted access to comprehensive and up-to-date environmental data. Manual processes for land assessment often require specialized expertise and are time-consuming, hindering rapid decision-making in the field [6].

Land suitability assessments are essential, as agricultural planners require information on land suitability classes to recommend optimal garlic cultivation areas. Several studies have evaluated the potential for garlic cultivation in East Lombok Regency, West Nusa Tenggara, examining land characteristics and suitability in Sembalun District [7]. GIS modeling has been used to map land use for crops, including garlic, based on agro-ecosystem and agro-economic suitability, identifying approximately 7,000 hectares as suitable for garlic development [8]. Additionally, studies have analyzed the relationship between rainfall and temperature with garlic productivity, showing that annual rainfall negatively correlates with productivity in Sembalun, Lombok [9]. Other studies have utilized spatial decision tree algorithms for land suitability evaluations, achieving classification model accuracy of 94.34% [10].

While GIS-based tools have significantly transformed agricultural land management by enabling faster spatial data visualization and assessments [11][12] and [13], existing approaches remain limited by static datasets and lack real-time adaptability. Current research relies on static models, which fail to account for changing weather conditions. Garlic is particularly sensitive to shifts in climate, such as temperature and rainfall, making static models insufficient for timely and accurate decision-making, especially in regions with unpredictable weather. To date, no study has developed a mobile solution tailored specifically for garlic cultivation that integrates both dynamic weather data and soil information for on-site decision-making. This scientific gap underlines the urgent need for a field-ready, adaptive system that can bridge the disconnect between static land evaluation models and the dynamic environmental conditions faced by farmers in remote areas.

By integrating dynamic weather data, land suitability assessments could become more accurate, allowing for recommendations that truly reflect the current conditions and ensuring that chosen lands remain suitable for garlic cultivation. Our previous work has successfully developed the backend module of the agroecological land suitability assessment system for garlic [14]. This backend system consists of a database with 16 tables, 37 Application Programming Interfaces (APIs), and a scheduler. The backend has been designed to integrate dynamic weather data, allowing for land suitability assessments that adjust to real-time environmental conditions, making it a robust foundation for more accurate and responsive garlic land suitability evaluations.

Accordingly, this study is guided by the following research question, can a mobile application that integrates real-time weather data with soil information provide more accurate and field-ready garlic land suitability assessment compared to existing static approaches. Based on this, we hypothesize that such integration will enhance the accuracy, usability, and timeliness of suitability assessments, particularly for remote areas with limited connectivity. Building on this foundation, the current study aims to develop a mobile application for agroecological land suitability assessment that integrates real-time weather data with soil information through a dynamic backend system [14]. Unlike previous models that rely on static environmental datasets, this application offers a novel, field-ready solution that enables users to make timely and context-aware cultivation decisions based on current environmental conditions. This mobile application would address the limitations of manual assessment methods, such as inconsistencies and time delays, by enabling agricultural extension workers to input and store data, receive instant analysis, and access real-time climate data and soil information. With such a tool, extension officers, farmers, and planners could make well-informed decisions directly in the field, supporting the government's goal of garlic self-sufficiency by maximizing the potential of every piece of land for garlic cultivation in Indonesia. This solution not only enhances the efficiency and accuracy of land suitability evaluations but also plays a pivotal role in boosting garlic productivity and reducing the nation's reliance on imports, contributing to the broader agricultural development goals outlined by the Ministry of Agriculture.

2. Material and Methods

2.1 Backend System Architecture

The backend system architecture for the Agroecological Land Suitability Assessment System for Garlic in [14] is designed to evaluate land suitability based on specific criteria essential for garlic cultivation. This architecture comprises of several key components. First component is Database Layer [15]. The database consists of 16 tables that store various data, including user information, land characteristics, environmental parameters, and assessment results.

The land characteristics and environmental parameters stored in the database include twelve key garlic growth variables categorized into uncontrollable factors (e.g., weather and relief), correctable factors (e.g., soil depth and pH), and controllable factors (e.g., drainage and texture). These data are sourced from Visual Crossing API, BMKG (Meteorology, Climatology, and Geophysics Agency), BBSDLP (Agricultural Land Resources Center), and USGS (United States Geological Survey) in various formats, including numeric, vector, and tabular data.

The database layer serves as the central repository for all data, ensuring organized storage and efficient retrieval necessary for land suitability evaluations. The assessment uses a weighted overlay method, where each growth factor is assigned a weight and a class score based on expert consultation with horticulture specialists. Each suitability class, S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N (not suitable) is given a numerical score (S1 = 4, S2 = 3, S3 = 2, N = 1), and the final score is calculated by summing the weighted values of all factors. The resulting scores are then mapped to suitability classes using expert-defined intervals, following the FAO (1976) framework for land evaluation.

Second component is Application Programming Interfaces (APIs). There are 37 APIs developed to handle different functionalities. These APIs facilitate communication between the backend and frontend applications, enabling operations such as user registration, data input for land assessments, retrieval of assessment results, and interaction with the database. Third component is scheduler. A scheduler is implemented to manage periodic tasks, such as updating environmental data or recalculating land suitability scores based on new information. It ensures that the system remains up-to-date with the latest data, maintaining the accuracy and relevance of the assessments. The APIs and scheduler handle core tasks such as weather data retrieval, user data management, and suitability calculations, integrating data from external sources like Visual Crossing (weather), BMKG (sunlight duration), and OpenTopoData (elevation). The system employs a client-server architecture consisting of a Docker-based backend service using PostgreSQL/PostGIS for spatial data, a frontend web application, and a mobile app for field usability, all connected via APIs.

2.2 The Development of a Mobile Application

The system development methodology adopts a prototyping approach, which allows for iterative application development, starting from an initial prototype to a functional final version [16] and [17]. This approach enables flexibility for incorporating user feedback and improving the system throughout the development process. The key stages of this methodology include requirement gathering, prototype design, and system development and testing.

2.2.1 Requirement gathering

The first stage in prototyping involves understanding user needs and identifying the required data to support garlic land suitability assessments. This process includes communication stage which involved discussing the system requirements with the system development team and stakeholders, namely 1) staff of the Directorate of Vegetables and Medicinal Plants, Directorate General of Horticulture, Ministry of Agriculture; 2) agricultural extension officers and advanced farmers in Magetan, East Java, Magelang, Central Java, East Lombok, West Nusa Tenggara Indonesia. Based on the discussion results, it was known that in the garlic suitability assessment, users still had difficulties in manually inputting data on growing conditions, so it was agreed to create an automatic growth condition factor input feature. Users wanted to see the land that had been assessed visually, and also, users wanted to be able to delete only the history selected in one land suitability class, so it was agreed that field documentation is important to be stored in the application. Table 1 summarizes evaluation results as a user story.

2.2.2 Prototype design

This stage consists of quick planning and rapid design modeling stages and quickly builds a visual representation. The quick planning stage is carried out by designing use case diagrams, use case descriptions, and activity diagrams sourced from user stories created at the communication stage. There are 14 use cases implemented in the mobile application for garlic land suitability assessment. All of these use cases are user registration, conducting land suitability assessments, viewing a list of previously assessed lands, viewing all lands that have been assessed by other users on the map, viewing the history of a land class, reading a term dictionary, viewing user profiles, requests for account active period extensions, requests to change passwords, login, logout, and delete the history of a land class, filling in growth requirement parameters automatically. All use cases are presented in Figure 1. The workflow of the application is then presented in an activity diagram. The activity diagram for land suitability assessment is shown in Figure 2.

Table 1: User story of mobile application

No	As	I want	So I
1	User	Registering users on the mobile application	Can access land suitability assessment features
2	User	Inputting data on garlic growth requirements	Can find out the land suitability class in an area
3	User	Automatically inputting data on garlic growth requirements	Can make it easier to fill in garlic growth requirement factors
4	User	Observation time, observation date, and location data (province, district, sub-district, and village/village) can be inputted automatically by the application	Save time filling in garlic growth requirement data
5	User	Seeing the land assessment time that corresponds to the time zone in Indonesia	Can see the assessment time of the land suitability class with the time format of parts in Indonesia
6	User	Inputting documentation from the land to be assessed	Can see land that will be or has been assessed
7	User	Seeing a list of land history that has been assessed	Do not re-assess land that has been assessed
8	User	Seeing the class history of a land	Can see changes in the class of a land in a certain time period
9	User	Deleting the class history of a land as selected	Can delete only the history selected in one land suitability class
10	User	Seeing all land that has been assessed by other users	No need to input growth requirement data in areas that have been previously inputted
11	User	Knowing what is meant by the relief factor	Understand the meaning of the relief factor itself by looking at the explanation in the term dictionary
12	User	Knowing which user is currently logged in	Can see the email address used to log in the profile menu
13	User	Re-logging in without re-downloading the mobile application	There is no need to re-download the application when the login token has expired
14	User	Requesting to extend the active period of the account	Can access all features in the application
15	User	Requesting to reset the password	Can log back into the application

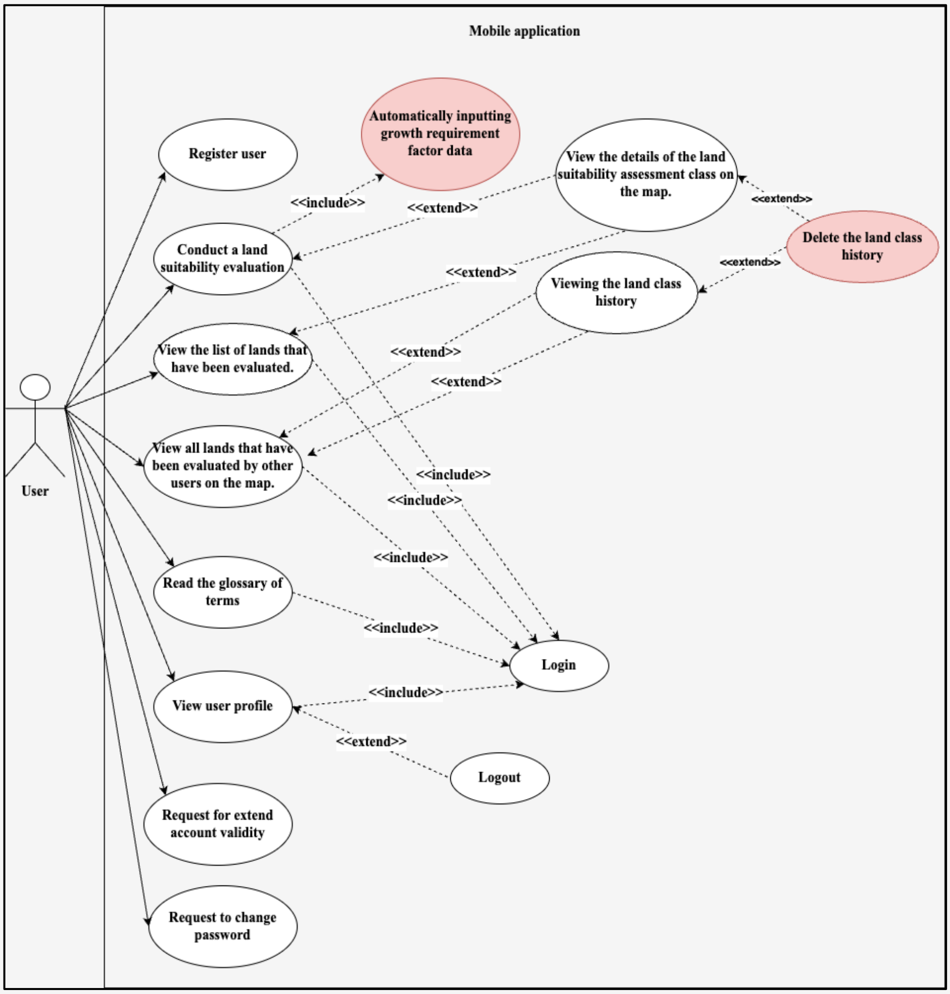

Figure 1: Use case diagram of mobile application

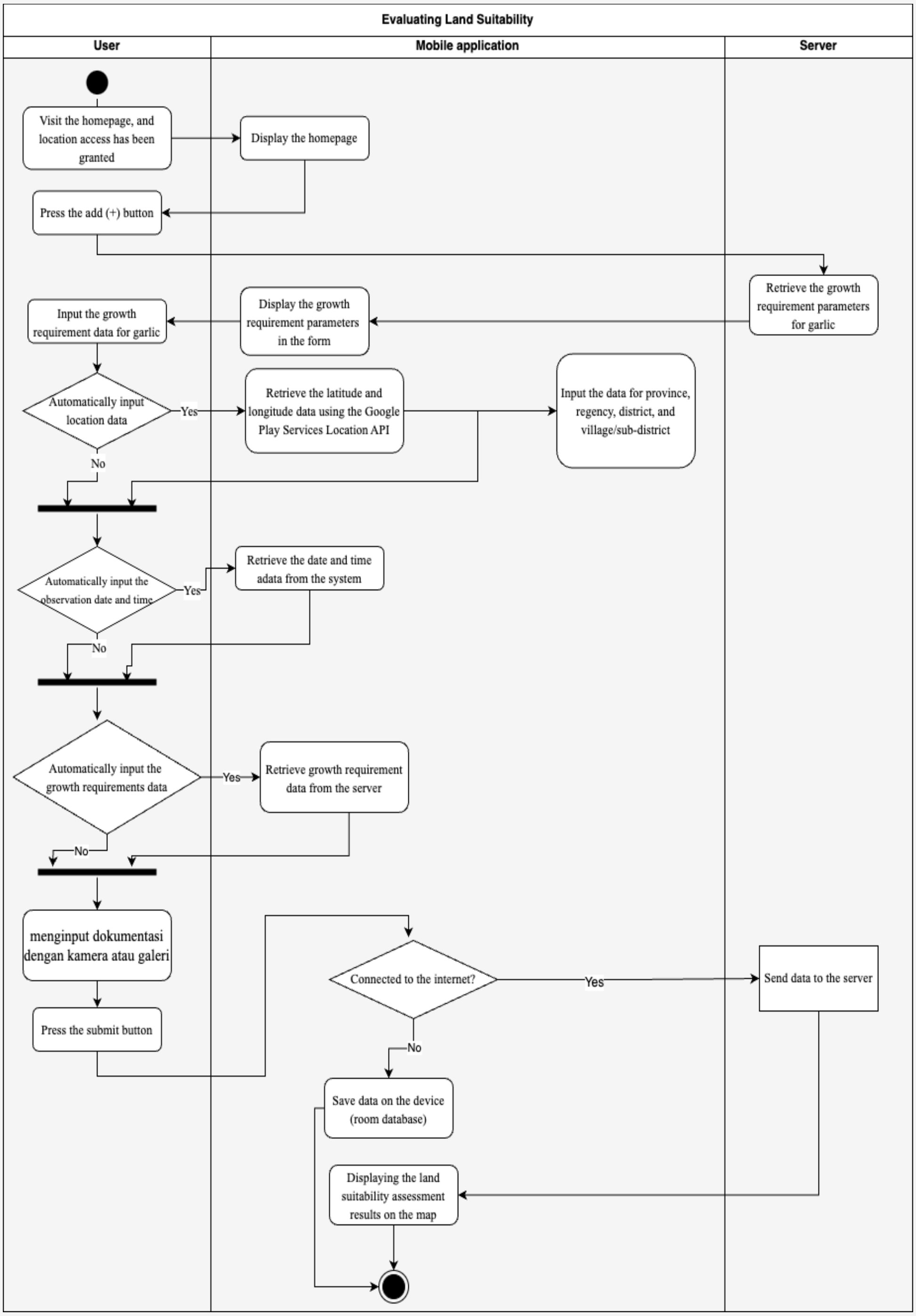

Figure 2: Activity diagram of evaluating land suitability

The application workflow in Figure 2 includes this condition: in the growth requirement data input page, after user filling in time, date, and location fields, user also can choose to input growth factor manually or automatically by the system. When the system detects automatic data input, the application will retrieve the growth requirement data from the backend module [14]. Then, after the system passes the latest module in the application flow, user can click submit button to run the calculation of land suitability assessment for garlic. In the rapid design modeling stage, a high-fidelity user interface prototype was created using Figma as the development tool [18].

High-fidelity was chosen because it provides a clear representation of the application's features, functions, and user interface design [19] and [20]. We introduced distinct colors for each land suitability class, as shown in Figure 3. The use of different colors for each land suitability class is intended to make it easier for users to identify the results of land suitability assessments through the user interface [21]. We also used a color palette to determine the application's interface colors, as shown in Figure 4. In Figure 3, different colors indicate suitability classes: green for S1 (highly suitable), yellow for S2 (moderately suitable), brown for S3 (marginally suitable), and red for N (not suitable). The grey color indicates unidentified due to incomplete values of garlic growing conditions. Throughout the entire time, users will be faced with a color theme that will become the platform's theme color. An inappropriate color design can cause users to quickly lose interest and decide to stop using the application. On the other hand, a well-applied color design can enhance participation rates [22]. The use of a color palette in this application can helps users easily locate icons or buttons to perform specific functions.

At this stage, a near-final design of the mobile application was developed, featuring structured input screens and results display screens to ensure a comprehensive and user-centered experience. The high-fidelity user interface of mobile application is shown in Figure 5. The Input Data screens enable users to input critical parameters such as the land name, location, and observation date. The input fields are systematically organized, with drop-down menus facilitating the selection of predefined values for factors including climate (temperature, rainfall), soil characteristics, and relief. These factors are categorized into three groups: uncontrollable and unmodifiable factors (e.g., temperature and rainfall), correctable factors (e.g., soil mineral content and saturation), and controllable factors (e.g., soil drainage and texture). Additional features, such as an information pop-up, provide detailed guidance on specific parameters, while image upload functionality allows users to attach visual documentation of land conditions.

The Results Display screens present the land suitability assessment in a clear and intuitive format. Each factor is displayed with detailed scores, while color-coded indicators (e.g., green for highly suitable, yellow for moderately suitable, and red for not suitable) aid users in quickly interpreting the results. Uploaded images are integrated into the assessment results, offering additional visual context. A recommendation button is also provided, enabling users to generate actionable insights for improving land suitability. The interface has been designed to ensure interactivity and usability. It adheres to a consistent layout across all screens, complemented by intuitive labels and icons that facilitate navigation while minimizing cognitive load. Realistic design elements, such as clickable buttons and functional drop-down menus, closely simulate the final product's behavior.

Figure 3: Land suitability class color

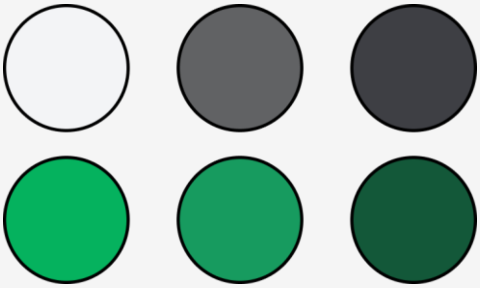

Figure 4: Color palette

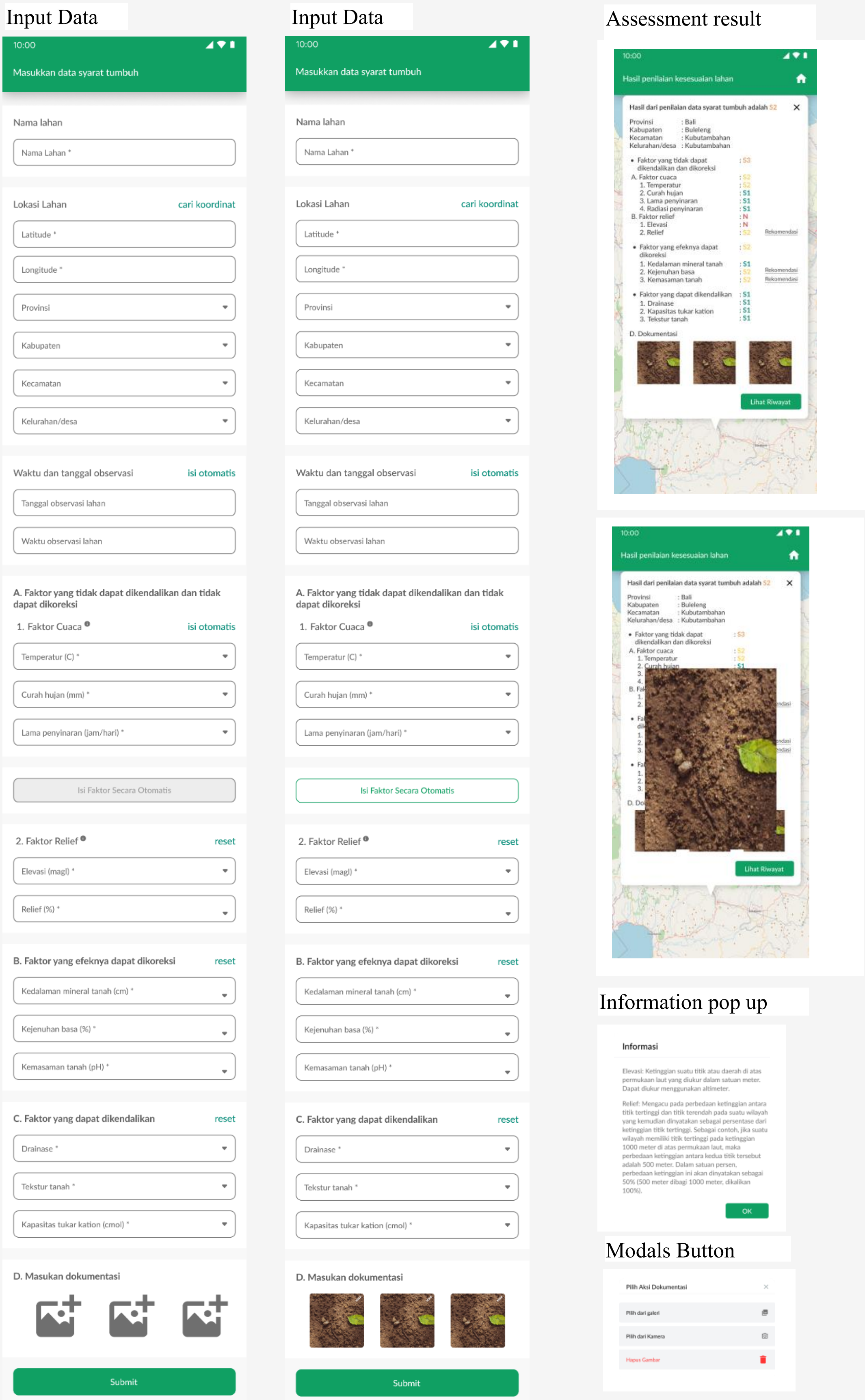

Figure 5: High-fidelity user interface of mobile application

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The use of a carefully selected color palette enhances the clarity of the interface, particularly in distinguishing land suitability classes. While the prototype primarily focuses on system functionality, its design adheres to usability principles, laying the groundwork for a seamless user experience and facilitating subsequent usability testing. This high-fidelity prototype provides stakeholders with a detailed and accurate representation of the application's features and functionality, serving as a strong foundation for feedback and iterative improvements prior to full-scale implementation.

2.2.3 Data and system design for garlic agroecological suitability assessment

The mobile application was designed to facilitate the evaluation of garlic agroecological suitability by incorporating land and weather parameters. These parameters are categorized into three groups, as detailed in Table 2. The application offers several key features, including account registration and management, suitability assessment for garlic cultivation, historical records of land assessments, spatial data visualization, and a glossary of relevant terms, as illustrated in Figure 6. The workflow for determining land suitability classes through the application is depicted in Figure 7.

2.2.4 System development and testing

The system development followed a prototyping approach, where the high-fidelity prototype was implemented as an Android mobile application due to its strategic advantages [23] and [24]. Android is the most widely used mobile operating system globally [25], including in Indonesia, making it the ideal choice to reach the target audience, particularly extension officers and farmers.

Table 2: Land and weather factors for garlic agroecological suitability assessment

Category	Factor	Source
Controllable factors	Drainage Cation Exchange Capacity (cmol) Soil Texture Soil Acidity (pH)	Land map from the Center for Agricultural Land Resources
Factors whose effects can be corrected	Base Saturation (%) Soil Mineral Depth (cm)	Land map from the Center for Agricultural Land Resources
Factors that cannot be controlled and corrected	Weather factors: Rainfall (mm) (total per month), Sunlight Duration (hours per day) (monthly average), Sunlight Radiation (Watt/m^2)	Weather Data & API, Visual Crossing Weather (https://www.visualcrossing.com/) Meteorology, Climatology and Geophysics Agency
	Relief Factors: Elevation (magl), Relief (%)	Land map from the Center for Agricultural Land Resources

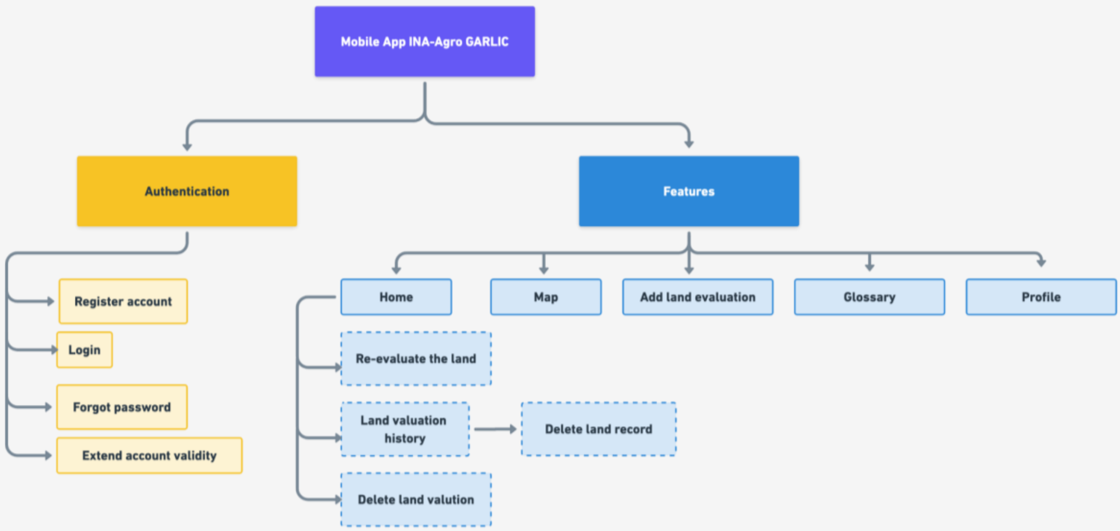

Figure 6: Features in the garlic agroecological suitability assessment mobile application

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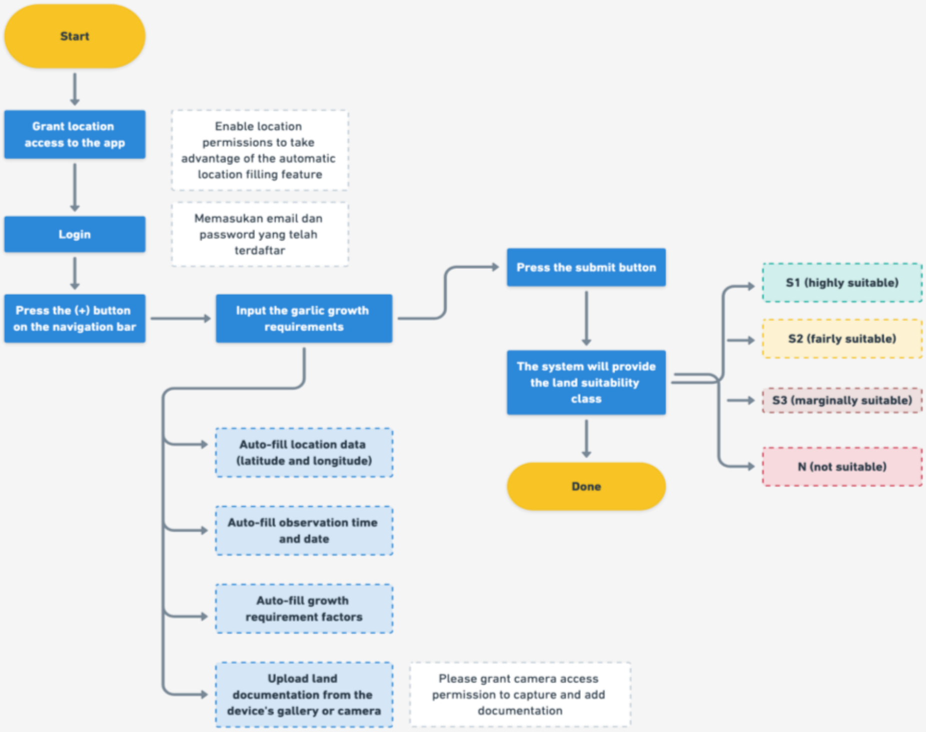

Figure 7: Flow of class suitability assessment using the mobile application

The platform’s affordability and accessibility ensure that the application can be used on a wide range of devices, including entry-level smartphones, addressing technological constraints in rural agricultural settings. Additionally, Android's open-source nature provides flexibility and cost-effectiveness during the development process, enabling the integration of essential features such as GIS-based data visualization and API connectivity for real-time agroecological assessments. These considerations align with the goal of creating an inclusive and functional application that supports effective agricultural decision-making.

The prototype development phase commenced after the system requirements were clearly defined in the preceding stages. During this phase, the coding process was conducted based on the design created during the rapid design modeling stage and guided by the workflow diagram developed during the rapid planning stage. The high-fidelity user interface was implemented using the Kotlin programming language, leveraging Jetpack Compose and adopting the Model-View-View Model (MVVM) architecture [26] and [27]. The mobile application developed incorporates several key features aimed at enhancing its functionality and usability. The Delete Land Suitability Assessment History feature allows users to manage the history of multiple land assessments by providing the option to delete specific entries or observations from the history page. The Automatic Input for Growth Requirement Data Factors simplifies data entry by automatically populating growth requirement fields based on the land's geographic coordinates. Users can input data such as land name, location, and observation time, and then activate a "Fill Automatically" button, which triggers the system to retrieve data via an API.

The backend processes parameters such as latitude, longitude, province, and district, returning a JSON response containing the required values. These values, sourced from the Land Map Unit stored as polygons in the backend and weather data from Visual Crossing, automatically populate the respective fields, with users retaining the ability to edit values for accuracy. The application also features a Login System utilizing a token-based mechanism for user authentication. A token is generated upon successful login, valid for 24 hours, and stored locally on the device. Once expired, the system redirects the user to the login page for re-authentication. To further strengthen reliability, token caching is implemented to maintain session continuity, while error handling mechanisms provide informative feedback to users in cases of failed API communication. In addition, a basic local caching strategy was introduced to temporarily store input data, which can later be synchronized once internet connectivity is restored. Although full offline functionality remains a future enhancement, these mechanisms already contribute to improved robustness in real-world field conditions.

Additionally, the Enhanced Assessment Time Display on the Home Page improves the user experience by displaying land suitability classes (S1, S2, S3, and N), along with the most recent assessment date and time. The page also includes action buttons for adding new assessments, viewing history, and deleting previous assessments, with the displayed time synchronized to Indonesia's time zones.

To ensure system reliability, Mobile Application Functionality Testing was conducted using a black-box testing approach [28]. This testing involved 50 positive and negative test cases derived from the activity diagram flow, validating the application's behavior under various scenarios. Internal testing was performed prior to field testing by end users to ensure stability and robustness. These features demonstrate the successful integration of core functionalities with backend processes, ensuring that the application aligns with its design and planning objectives while delivering a user-friendly and reliable tool for land suitability assessments.

Usability testing using PSSUQ was performed to evaluate the Agroecological Assessment System mobile application. The testing involved 30 respondents, including farmers (8 respondents), agriculture officers (8 respondents), and local extension officers (14 respondents). Usability testing was conducted during the field visit to Magetan, East Java (28–29 August 2023), Magelang, Central Java (21–22 September 2023), and Sembalun, East Lombok, West Nusa Tenggara (2–3 October 2023). The respondents were asked to complete tasks on garlic land suitability assessment based on the garlic growing conditions.

3. Results and Discussion

The methodological framework described in the previous section outlines the data parameters, system design, and workflow implemented in the Garlic Agroecological Suitability Assessment mobile application. Based on this framework, the following section presents a visual representation of the application's interface and demonstrates how the designed features have been implemented.

Figure 8 illustrates the user interface (UI) design and core functionalities of the Garlic Agroecological Suitability Assessment mobile application. The login page serves as the entry point, enabling users to authenticate using their registered email and password, with additional options for password recovery, account registration, and validity extension. The main page provides an overview of land suitability assessments, categorizing them as assessed or not assessed. If no data is available, a placeholder message prompts users to add new assessments. The input page for garlic growing conditions allows users to enter critical data such as land name, geographic location (manually or automatically retrieved), observation time and date, and growth requirement factors, which can also be populated automatically via backend integration.

The assessment location page visualizes the geographic placement of the land on an interactive map, enabling users to validate and analyze location-specific data. The assessment results page presents the suitability class (e.g., "S2" for moderately suitable) alongside detailed scores for each factor and color-coded indicators for easy interpretation. Additionally, the application provides recommendations for each factor, offering actionable insights such as improving soil organic material to enhance land suitability. The land history page tracks previously assessed locations, displaying suitability classes and assessment dates, with options to view, edit, or delete historical data.

The application also features visualizations of different land classes, using color-coded markers (e.g., red for "N" and yellow for "S2") to distinguish between them. The suitability classes filtering function enables users to sort data by specific classes, streamlining data management for multiple assessments. A term dictionary provides definitions and explanations of agronomic terms, with a search feature to improve accessibility for non-expert users. Lastly, the profile page displays user details, including name, email, job, and agency information, allowing users to update their profiles or log out of their accounts. Collectively, these features demonstrate a comprehensive, user-friendly design aimed at facilitating garlic land suitability evaluations for extension officers and farmers. The mobile application was tested using the Black Box approach. Table 3 provides the results of Black Box testing summarized from 50 test cases. The successful testing status indicates that the developed features functioned well based on positive and negative test scenarios.

In addition to conducting functional testing through the Black Box method, this study also performed usability testing on the mobile application. Usability testing involves directly testing the product with users or potential users [29] and aims to enhance user convenience in achieving desired outcomes. This process generally involves assigning specific tasks to users related to the application under evaluation, observing their performance, and gathering feedback to improve usability.

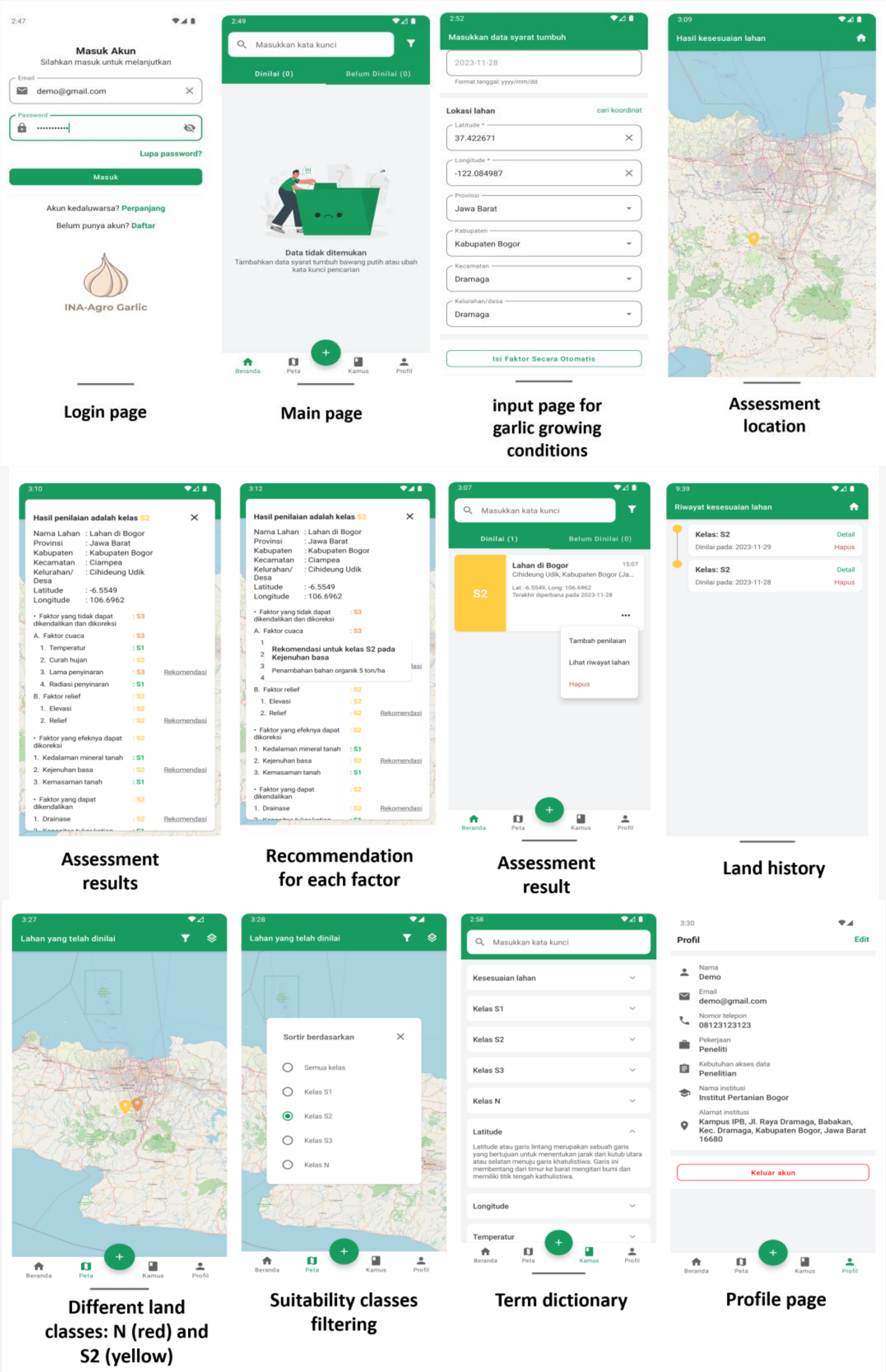

Figure 8: User interface of garlic agroecological suitability assessment mobile application

Table 3: Mobile application testing results using Black Box approach

Category	Scenario Examples	Type	Expected Outcome	Status
Login Functionality	Logging in with correct/incorrect credentials	Positive/Negative	Successful login or appropriate error messages	Success
	Login button availability based on input completeness	Positive/Negative	Login button active/inactive as expected	Success
Land Assessment Input	Filling in land details (name, location, date, factors)	Positive	Successful entry of required data	Success
	Submitting incomplete data	Negative	Submit button disabled	Success
	Auto-filling growth factors from backend	Positive	Data correctly populated	Success
Assessment Results	Viewing suitability class results	Positive	Results displayed with appropriate details	Success
	Viewing recommendations for improvements	Positive	Recommendations displayed accurately	Success
Land History Management	Viewing history of assessed lands	Positive	History displayed correctly	Success
	Deleting/reassessing failed assessments	Positive/Negative	History updated or error messages displayed	Success
Map Visualization	Viewing assessed lands on map	Positive	Land markers displayed with correct classifications	Success
	Filtering land classes on map	Positive	Filtered markers displayed correctly	Success
Term Dictionary	Searching for terms in dictionary	Positive/Negative	Results displayed or "not found" message shown	Success
Profile Management	Viewing and editing profile information	Positive	Profile updated successfully	Success
	Logging out	Positive	User redirected to login page	Success
Account Registration	Registering an account	Positive	Registration successful with notification	Success
	Missing details during registration	Negative	Register button inactive	Success
	Extending account validity	Positive/Negative	Success message or error message displayed	Success

During usability testing, testers observe users as they attempt to complete assigned tasks, assessing whether the tasks are completed successfully. The observation includes monitoring the time required to complete the tasks and identifying any errors or difficulties encountered during the process. Additionally, testers may collect users' opinions and feedback on their experience with the application.

In this study, usability testing was conducted with participants following a demonstration of the application. After the demo, participants were presented with a series of test scenarios to complete. The researcher evaluated whether participants could successfully execute the assigned tasks independently or required assistance. The outcomes of the usability testing for the mobile application are presented in Table 4. In Table 4, the completion rate of 20/20 indicates that all 20 participants successfully completed the assigned task, reflecting a 100% success rate. However, the lowest success rate was observed in scenario number 4, where participants were tasked with conducting a manual land assessment. In this scenario, only 13 out of 20 participants succeeded, which was lower than in scenario 5, where participants were tasked with conducting an automatic land assessment. The higher score for the automatic method indicates that users find this process easier, more efficient, and more convenient compared to the manual method. This aligns with the objectives of usability, in which automation plays a role in reducing the user's workload. The automation feature has been proven to provide a more positive user experience, with several possible reasons, including the reduction of data input steps, as location, observation time, and growth factors are automatically filled in through system integration, whereas in the manual method, users must enter data one by one, which is time-consuming and prone to errors. In addition, automation reduces cognitive load because users do not need to recall or search for information, and it also minimizes the risk of input errors such as typos or incorrect selections. For future development, the application will focus on enhancing and expanding automation features while improving the manual input process to make it faster, more intuitive, and less error-prone.

The Agroecological Assessment System mobile application was introduced during a series of field visits, including Magetan, East Java (28–29 August 2023), Magelang, Central Java (21–22 September 2023), Sembalun, East Lombok, West Nusa Tenggara (2–3 October 2023), Cianjur, West Java (22–23 August 2024), Kendal, Central Java (18–19 September 2024), and Karanganyar, Central Java (20–21 September 2024).

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Table 4: Mobile application usability testing results

No.	Task	Instruction	Completion rate
1.	Start testing.	You will conduct a usability test on the mobile application with the help of several moderators	-
2.	Install the mobile application.	You must download and install the application via the available drive link, how do you do it?	20/20
3.	Log in to the mobile application	Try logging into the mobile application	20/20
4.	Conduct new land assessments by manually filling in the growing requirements according to the current point and location	You act as a researcher on the land where you are currently located, then you want to assess the land manually, how do you do it?	13/20
5.	Conduct new land assessments in Magetan automatically	You act as a land researcher in Magetan, then you want to assess the land automatically, how do you do it?	16/20
6.	View the newly entered land assessment results	You have finished assessing the land, then now you want to see the results of the land assessment that has just been inputted on the land suitability map, how do you do it?	18/20
7.	View the recommendations listed in the land assessment results	You want to see expert recommendations regarding land management that you have assessed, how do you do it?	18/20
8.	View the list of assessed lands	You plan to see the entire list of lands that have been assessed, how do you do it?	19/20
9.	View the history of one of the lands on the land list	You want to see the assessment history of one of the lands on the land list, how do you see the assessment history of the land?	20/20
10.	Conduct a re-assessment of the land	You want to assess a land and you have entered all the growing requirement data, but in the middle of the process you lose your internet signal and the land data has not been saved. Then after getting the signal back you want to do a re-assessment, how do you do it?	19/20
11.	Add new observations to the assessed land	You are visiting a land that has been previously assessed, but after visiting it turns out that there are some changes in conditions and you want to do a new "add assessment" on the land, how do you do a new "add assessment" on the land?	19/20
12.	Users delete land suitability assessments	You no longer need the assessment record of a land that you have previously assessed, so you want to delete it, how do you do it?	20/20
13.	Search and view a list of terms used in the application	You are confused by an existing term and want to look up the definition of the term in the term dictionary	20/20
14.	Users log out of their accounts	You have finished doing activities in the INA Agro-GARLIC application; then you want to exit the application; how do you do it?	20/20
15.	Users register their accounts	You want to try to register your personal account, how do you do it?	20/20

These outreach activities were conducted in collaboration with research partners, including the Directorate of Vegetables and Medicinal Plants (STO), the Directorate General of Horticulture, and the Ministry of Agriculture. Figure 9 illustrates the Sembalun area in East Lombok, West Nusa Tenggara, and the result of the garlic land suitability assessment in the Sembalun Lawang, one of the sub-districts in Sembalun. During the field visits in 2023, usability testing was conducted using the Post-Study System Usability Questionnaire (PSSUQ) version 3 [30]. PSSUQ evaluates usability across four categories: system usefulness, information quality, interface quality, and overall assessment. Participants rated the system on a 7-point Likert scale [31], where 1 indicates "strongly agree" and 7 indicates "strongly disagree". The results, presented in Figure 10, demonstrate an average overall system usability score of 2.06 across the three test locations (Magetan, Magelang, and Sembalun). The specific category scores include an average of 2.02 for system usefulness, 2.09 for information quality, and 2.06 for interface quality. These scores suggest that users generally agree or strongly agree with the usability of the mobile application, indicating a positive reception of its design and functionality.

The PSSUQ results show that, overall, all test locations scored below 2.3 on a 1–7 scale (1 = strongly agree, 7 = strongly disagree), indicating a positive perception of the application's usability. Magelang recorded the best scores in all categories, particularly in interface quality (1.90) and overall (1.93), which may be influenced by better agricultural infrastructure and internet connectivity, as well as a higher level of familiarity among local extension officers and farmers with digital technology, making it easier to adapt to the application. Sembalun obtained the highest score (2.23) in information quality, which may be due to its mountainous topography and high microclimate variability, resulting in weather and land data that are less accurate or not always aligned with field conditions, thus affecting the perceived quality of information.

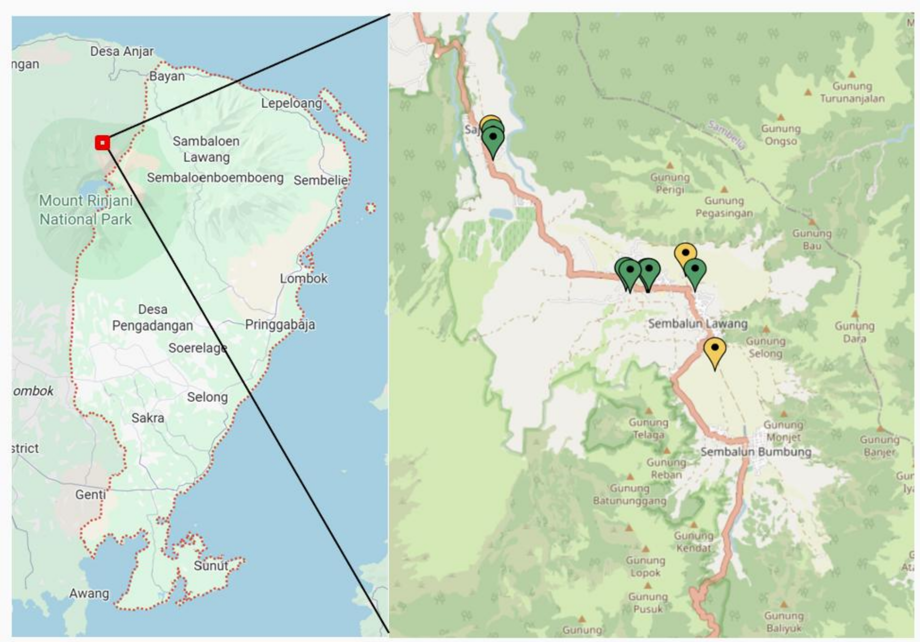

Figure 9: Garlic land suitability assessment from the mobile application (yellow pin is moderately suitable, and green pin is highly suitable)

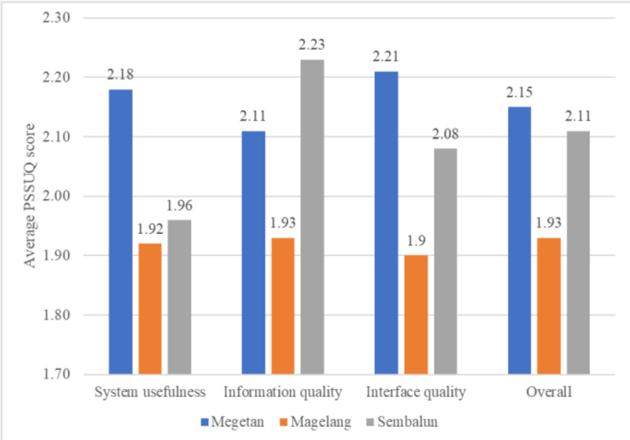

Figure 10: Usability testing result of mobile applications for garlic agroecological suitability assessment

Magetan ranked in the middle across all categories, with a need for improvement in system usefulness and interface quality, which may be related to uneven digital technology adoption among farmer groups and varying levels of user experience with similar applications.

The mobile application for garlic agroecological land suitability assessment offers significant advantages, establishing itself as a vital tool in modern agricultural practices. Designed to support agricultural extension officers and advanced farmers, this application facilitates efficient land suitability assessments directly in the field. It provides comprehensive data on garlic growth requirements, covering key factors such as soil conditions and weather, which are critical to cultivation success. Compared to conventional techniques, the application ensures that land suitability classes are determined based on current and accurate environmental conditions through real-time weather data integration. Additionally, the application enables real-time monitoring of assessment results, enhancing decision-making processes and allowing users to respond promptly to specific field conditions. The results of usability and functionality testing demonstrate the application's ability to effectively meet user needs. Its intuitive interface, real-time data integration, and tailored recommendations significantly assist farmers and extension officers in conducting field operations.

These features not only simplify the assessment process but also empower users to make data-driven decisions.

In the current development, the mobile application is designed in Bahasa Indonesia to ensure accessibility and ease of use for its primary target users, extension officers and farmers, who are generally more familiar with the local language. This language choice is intended to enhance usability and facilitate better adoption in the field. However, if the application is to be implemented in a broader, international context in the future, the addition of other language options, such as English or Mandarin, will be technically feasible and can be integrated without altering the core functionalities of the system.

4. Conclusions

The Garlic Agroecological Suitability Assessment mobile application addresses critical challenges faced by agricultural planners and extension officers in evaluating land suitability for garlic cultivation. Current research relies on static models, which fail to account for changing weather conditions, making the proposed system a key differentiator and a significant step forward from such models. Beyond field-level use, the system also has broader research and policy implications. It can support the government's garlic self-sufficiency program and be aligned with national agricultural planning through integration with Ministry of Agriculture datasets.

By integrating real-time environmental data and automating land assessment processes, the application significantly enhances both efficiency and accuracy. Functional testing conducted using the Black Box method, confirmed the system's reliability, with all 50 test cases successfully meeting expected outcomes. Usability testing performed at multiple regions, demonstrated high user satisfaction with an average PSSUQ score of 2.06, indicating strong agreement on the system's usefulness, information quality, and interface design. Key features, including automated data input, real-time GIS visualization, and tailored recommendations, proved particularly beneficial for supporting decision-making in the field. These functionalities empower agricultural extension officers and farmers to conduct efficient and accurate assessments, reducing time and resource constraints. Additionally, the tool aligns with broader agricultural development goals by boosting garlic productivity, optimizing land use, and reducing reliance on imports. The successful testing outcomes and positive user feedback affirm the application's potential as a transformative tool for modern agricultural practices.

However, limitations remain in areas where challenging topography and microclimate variability reduce data accuracy, as well as where uneven digital adoption and varying user experience affect perceived usefulness and interface quality. In addition, the system's reliance on stable internet connectivity may pose challenges in rural or remote areas, which should be addressed in future development. Another limitation is that agronomic field validation, such as soil testing and yield comparison, has not yet been conducted and will be addressed in future research**.** Future work will focus on improving user experience and system reliability by enhancing interface clarity, refining information presentation, expanding login and location selection options, and adding features to prevent data loss. Improvements will also include better error handling, clearer agricultural terminology, and increased accessibility through offline functionality to support use in low-connectivity environments. In the longer term, the system will be expanded beyond garlic to other strategic horticultural crops by adapting crop-specific suitability parameters. Additionally, AI-based models will be explored to improve predictive accuracy, automate classification, and enable scalable adoption in diverse agroecological contexts.

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References

[1] Average Per Capita Weekly Consumption of Several Essential Food Ingredients, 2007-2023. Central Statistics Agency of Indonesia. [Online]. Available: https://www.bps.go.id/id/statistics-table/1/OTUwIzE=/rata-rata-konsumsi-per-kapita-seminggu-beberapa-macam-bahan-makanan-penting--2007-2022.html. [Accessed: Aug. 8, 2024].

[2] Vegetable Crop Production 2021-2023. Central Statistics Agency of Indonesia. [Online]. Available: https://www.bps.go.id/id/statistics-table/2/NjEjMg==/produksi-tanaman-sayuran.html. [Accessed: Aug. 8, 2024].

[3] Regulation of The Minister of Agriculture of The Republic of Indonesia Number 38/Permentan/ HR.060/11/2017 concerning Horticultural Product Import Recommendations. Minister of Agriculture of The Republic of Indonesia. [Online]. Available: https://peraturan.bpk.go .id/Home/Download/153591/PermentanNomor 38Tahun 2017.pdf. [Accessed: Aug. 8, 2024].

[4] Zulkarnain, (2013). *Budidaya Sayuran Tropis [Tropical Vegetable Cultivation].* PT Bumi Aksara, Jakarta.

[5] Ministry of Agriculture. National Garlic Development in 2017. [Online]. Available: https://riph.pertanian.go.id/asset/media/downlo ad/file/547a6106025e209a3517aa07db2f27b7. pdf. [Accessed: Aug. 8, 2024].

[6] Agrawal, N., Govil, H. and Kumar, T., (2025). Agricultural Land Suitability Classification and Crop Suggestion using Machine Learning and Spatial Multicriteria Decision Analysis in Semi-Arid Ecosystem. *Environment, Development and Sustainability,* Vol. 27. https://doi.org/10.1007/s10668-023-04440-1.

[7] Mayanda, D. P., Ratna Adi, I. G. P. and Kusmiyarti, T. B., (2019). Evaluation of Land Suitability of Horticultural Crops in Sembalun Sub-district, East Lombok Regency, Indonesia. *IOP Conference Series: Earth and Environmental Science,* Vol. 313. https://doi. org/10.1088/1755-1315/313/1/012018.

[8] Muslim, R. Q. and Mulyani, A., (2019). Land Characteristics and Suitability for Development of Garlic in East Lombok Regency, West Nusa Tenggara Province. *IOP Conference Series: Earth and Environmental Science,* Vol. 393. https://doi.org/10.1088/1755-1315/393/1/0120 79.

[9] Mahmudah, N., June, T. and Impron, (2021). Adaptive Garlic Farming on Climate Change and Variability in Lombok. *Agromet,* Vol. 35. https://doi.org/10.29244/j.agromet.35.2.116-124.

[10] Nurkholis, A., Sitanggang, I. S., Annisa, A. and Sobir, S., (2021). Spatial Decision Tree Model for Garlic Land Suitability Evaluation. *IAES International Journal of Artificial Intelligence,* Vol. 10. https://doi.org/10.11591/ijai.v10.i3.pp 666-675.

[11] Bilas, G., Karapetsas, N., Gobin, A., Mesdanitis, K., Toth, G., Hermann, T., Wang, Y., Luo, L., Koutsos, T. M., Moshou, D. and Alexandridis, T. K., (2022). Land Suitability Analysis as a Tool for Evaluating Soil-Improving Cropping Systems. *Land,* Vol. 11. https://doi.org/10.339 0/land11122200.

[12] Reddy, G. P. O. and Singh, S. K., (2018). Geospatial Technologies in Land Resources Mapping, Monitoring and Management. *Geotechnologies and the Environment*. Springer Cham. https://doi.org/10.1007/978-3-319-78711-4.

[13] Khan, M. R., Crabbe, R. A., Malik, N. A. and O'Meara, L., (2023). Chapter 5 - Applications of Geospatial Technologies for Precision Agriculture. *Precision Agriculture: Evolution, Insights and Emerging Trends.* Academic Press. 71-83.

[14] Annisa, A., Reyhan, M., Sitanggang, I. S., Agmalaro, M. A., Sobir, S., Semadi, I., Noormandiri, F. and Mustafidah, H., (2024). Development of the Backend Module of the Agroecological Land Suitability Assessment System for Garlic. *International Journal of Geoinformatics,* Vol. 20. https://doi.org/10.52 939/ijg.v20i4.3157.

[15] Hellerstein, J. M., Stonebraker, M. and Hamilton, J., (2007). Architecture of a Database System. *Foundations and Trends in Databases*, Vol. 1. https://doi.org/10.1561/1900000002.

[16] Pressman, R. S. and Maxim, B. R., (2015). Software Engineering: A Practitioner's Approach. 8th International Edition. McGraw-Hill, New York.

[17] Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., Otto, K. and Wood, K., (2017). Design Prototyping Methods: State of The Art in Strategies, Techniques, and Guidelines. *Design Science,* Vol. 3. https://doi.org/10.1017/dsj.2017.10.

[18] Staiano, F., (2023). *Designing and Prototyping Interfaces with Figma: Elevate your Design Craft with UX/UI Principles and Create Interactive Prototypes*, Vol. 2. Packt Publishing Ltd.

[19] Gunadi, G. and Budiyantara, A., (2022). Implementation of High Fidelity Prototyping in Online Field Placement Program System Design. *Infotech Journal of Technology and Information,* Vol. 7. https://doi.org/10.37365/ jti.v7i2.118.

[20] Mugisha, A., Babic, A., Wakholi, P. and Tylleskär, T., (2019). High-fidelity Prototyping for Mobile Electronic Data Collection Forms through Design and User Evaluation. *JMIR Human Factors,* Vol. 6. https://doi.org/10.219 6/11852.

[21] Wright, P., Mosser-Wooley, D. and Wooley, B., (1997). Techniques & Tools for Using Color in Computer Interface Design. *XRDS Crossroads, ACM Magazine Students,* Vol. 3. https://doi. org/10.1145/270974.270976.

[22] Isnina, T. and Irene, C., (2024). UI / UX Design Impact on E-Commerce Attracting Users. *Procedia Computer Science,* Vol. 245. https://doi.org/10.1016/j.procs.2024.10.336.

[23] Patokar, A. M. and Gohokar, V. V., (2024). Design and Development of an Intuitive Android Application for Smart Farming. *Current Agriculture Research Journal,* Vol. 12. https://doi.org/10.12944/carj.12.1.33.

[24] Oteyo, I. N., Marra, M., Kimani, S., Meuter, D. and Boix, E. G., (2021). A Survey on Mobile Applications for Smart Agriculture. *SN Computer Science,* Vol. 2. https://doi.org/10.1007/s42979-021-00700-x.

[25] Okediran, O. O., Arulogun, O. T., Ganiyu, R. A. and Oyeleye, C. A., (2014). Mobile Operating Systems and Application Development Platforms: A Survey. *International Journal of Advanced Networking and Applications,* Vol. 2201.

[26] Pratama, A. N. and Ardiani, F., (2023). Optimization of Model-View-ViewModel (MVVM) Architecture Pattern and RESTfull API on Android-based E-Learning Application. *International Journal of Computer Applications,* Vol. 185. https://doi.org/10.5120/ijca2023923261.

[27] Wilson, A., Wedyan, F. and Omari, S., (2022). An Empirical Evaluation and Comparison of the Impact of MVVM and MVC GUI Driven Application Architectures on Maintainability and Testability. *Proceedings of the 2022 International Conference on Intelligent Data Science Technologies and Applications (IDSTA), San Antonio, TX, USA.* https://doi.org/10.1109/IDSTA55301.2022.9923083.

[28] Hamza, Z. A. and Hammad, M., (2019). Web and Mobile Applications' Testing using Black and White Box Approaches. *IET Conference Publications,* Vol. 2019. https://doi.org/10.1049/cp.2019.0210.

[29] Sagar, K. and Saha, A., (2017). A Systematic Review of Software Usability Studies. *International Journal of Information Technology*. https://doi.org/10.1007/s41870-017-0048-1.

[30] Sauro, J. and Lewis, J. R., (2016). *Quantifying the User Experience: Practical Statistics for User Research.* 2nd ed., San Francisco, CA: Morgan Kaufmann.

[31] Joshi, A., Kale, S., Chandel, S. and Pal, D., (2015). Likert Scale: Explored and Explained. *Current Journal of Applied Science and Technology,* Vol. 7. https://doi.org/10.9734/bjast/2015/14975.