Jurnal Teknik Informatika (JUTIF)
P-ISSN: 2723-3863
E-ISSN: 2723-3871

Vol. 7, No. 2, April 2026, Page. 1455-1467
https://jutif.if.unsoed.ac.id
DOI: https://doi.org/10.52436/1.jutif.2026.7.2.5471

Geographic Information System for Land Suitability Mapping of Partner Farmers at Okiagaru Indonesia Agricoop Using Rule-Based System and Prototype Methodology

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Received : Nov 27, 2025; Revised : Jan 15, 2026; Accepted : Jan 16, 2026; Published : Apr 15, 2026

Abstract

Geographic Information System (GIS) for land suitability assessment integrates spatial and attribute data to evaluate and map areas for food crops and horticulture. The system applies parameters such as temperature, rainfall, water pH, clay CEC, organic carbon, and other soil characteristics, analyzed through a rule-based approach. Its main goal is to optimize agricultural land use by aligning crop selection with physical and environmental conditions. GIS-based analysis enables accurate digital mapping and categorizes land into highly suitable, moderately suitable, marginally suitable, and unsuitable classes, providing valuable insights for farmers, governments, and stakeholders in sustainable land management. System development employed the Prototype methodology, emphasizing iterative stages of requirement gathering, rapid design, prototype construction, user evaluation, and refinement. The Land Suitability GIS (SigKL) was tested at five partner-farmer sites in Cianjur and Sukabumi. Black Box Testing confirmed that all 20 functional features achieved a 100% success rate. The system supports the identification of potential new agricultural areas and offers recommendations for improving less productive land. The novelty of this research lies in integrating FAO (1976) classification with interactive digital mapping and locally tailored knowledge rules, enabling real-time accessibility. Unlike prior studies limited to static analysis, SigKL introduces an adaptive, rule-based GIS prototype with interactive visualization, directly supporting decision-making for sustainable agriculture. This innovation enhances transparency and accessibility, contributing to the Sustainable Development Goals (SDGs) related to food security and sustainable farming.

Keywords : *Geographic Information System, Land Suitability Mapping, Okiagaru Indonesia Agricoop, Prototype Method, Rule-Based System.*

1. INTRODUCTION

One way to increase food crop production is to evaluate the land and select food and horticultural crops that match the soil's characteristics. Farmers can conduct a land evaluation process before planting. Land evaluation can be done by comparing land use requirements with the quality (characteristics) of the land [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11]. Land suitability refers to the suitability of a plot of land for a particular type of use (land utilization type), so management aspects must be considered. For example, for irrigated or tidal rice fields, cassava, soybeans, oil palm plantations, and industrial acacia or meranti plantations [12].

Land evaluation can be conducted to improve the quality and quantity of agricultural commodities [13] [14] [15] [16]. One way to do this is to determine land-use requirements based on land characteristics [17]. In the land suitability process, numerous factors are used as parameters, including

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physical and chemical characteristics, climate, and environmental influences [18] [19] [20] [21] [22] [23] [24] [25]. The ever-changing environment can render established *rules* invalid. However, previous studies have been limited to static land-suitability analyses and are less adaptable to environmental change. This creates a research gap in developing a land evaluation system that is adaptive, interactive, and easily accessible to field users. The novelty of this research lies in integrating the FAO classification with an adaptive rule-based system developed through a GIS-based prototyping methodology.

Okiagaru Indonesia Agricoop Cooperative, a company operating in the agribusiness sector, faces the challenge of identifying the crop types suitable for the agricultural land owned by its partner farmers. The hope is that when crops are planted in accordance with the conditions and characteristics of the partner farmers' land, production results will be maximized, thereby positively impacting the welfare of the partner farmers. The application of a geospatial information system is expected to provide more optimal support for mapping the land of partner farmers of the Okiagaru Agricoop Cooperative, given that their land is spread across various regions. One way to increase agricultural yields is by implementing a land suitability system. To align with one of the Sustainable Development Goals (SDGs), specifically ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture.

2. METHOD

The main issue addressed in this study is the limitation faced by partner farmers of Okiagaru Indonesia Agricoop in rapidly, accurately, and adaptively determining the types of crops suitable for their land conditions. Therefore, this study focuses on the development of a rule-based Land Suitability Geographic Information System (SigKL) using a Prototype methodology approach. The *prototype method* is a system development technique that helps users to get an overview of the system to be built or developed. Ideally, the prototype serves as a mechanism to identify software requirements [26]. The *Prototype methodology* has been applied in various applications, including the development of laboratory information systems [27], the creation of digital village applications [28], the development of the Mulyaharja tourist village website [29], and the creation of an accounting information system [30]. The steps in *the Prototype method* are illustrated in Figure 1, which include communication, quick planning, modeling, quick design, construction of the *prototype, and deployment, delivery & feedback*.

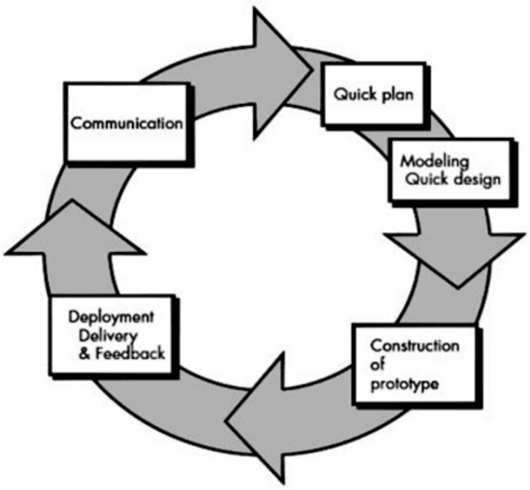

Figure 1. *Prototype System Development Methods [26]*

The following is a detailed explanation of the steps in the prototype method:

1. *Communication*: At this stage, developers and users communicate to understand their needs and expectations for the system being built. This communication is crucial to ensure developers have

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a clear understanding of what users want. Structured and effective communication enables each party to convey their expectations, needs, and feedback explicitly, ensuring that the resulting prototype meets the desired standards.

2. *Quick Plan*: After gathering requirements, developers create a quick plan for building the prototype. This plan outlines the key features to be incorporated into the prototype, the technologies to be utilized, and the development schedule. Within the framework of the prototype methodology, the quick plan is understood as a project planning stage prepared briefly yet systematically, with an emphasis on flexibility and the acceleration of the development process. This stage involves formulating core steps and prototype implementation phases, with a focus on achieving initial outputs that can be promptly tested. This approach deliberately reduces the level of planning detail, allowing the system construction process to commence immediately and enabling faster iterations. The quick plan is designed to provide high adaptability to user needs and changes that arise during development. Thus, the quick plan serves not only as a technical guideline but also as an early verification mechanism to confirm that user requirements have been accommodated.
3. *Quick Design Modeling*: At this stage, developers begin drafting the initial prototype design. This design typically includes the user interface (UI) and the basic system architecture. This design is not detailed, but it is sufficient to demonstrate how the system will generally function.
4. *Prototype Construction*: Once the initial design is approved, developers begin building a prototype. This prototype is a functional representation of the proposed system, though it may include only a small portion of the functionality that will be present in the final system. This prototype allows users to experience how the system will operate.
5. *Deployment, Delivery & Feedback*: The prototype is then handed over to users for testing. Users provide feedback on the prototype, which is then used to refine and improve the system. This process can be repeated several times until the prototype meets user needs and expectations and is ready to be developed into a live system.

The initial stage in the system involves entering land characteristic data and spatial land data. The process then continues by matching these land characteristic data with pre-defined rules. The evaluation process uses the maximum limited factor principle. The result of this process is crops that are suitable for the existing land characteristics, based on their limiting factors. These results are visualized in the distribution of farmers' land location maps.

3. RESULT

3.1. *Communication*

The communication process was conducted using interviews with representatives from Okiagaru Indonesia Agricoop and the Center for the Implementation of Agricultural Instrument Standards (BBPSIP). This stage involved identifying land suitability *rules* and analyzing the needs of a land suitability mapping system for food crops and horticulture. In addition to the interviews, a survey of Okiagaru Indonesia Agricoop's partner farmers' land was conducted at five locations in Cianjur and Sukabumi.

3.2. *Quick Plan*

The technology used in SigKL is PHP with the CodeIgniter *framework*. *The database* will be MariaDB. System development is scheduled to begin in July 2024 and is expected to be completed by October 2024. The functional and feature requirements are presented in Table 1.

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Table 1. Functional Requirements / SigKL Features

No. Features	Feature Name	Description
SKPL.SIGKL.001	Sign In	Authentication feature for User accounts
SKPL.SIGKL.002	Displaying the Dashboard Page	Admin can view the summary statistics of the data
SKPL.SIGKL.003	Managing Land Quality Data	Admins can add, edit, delete, search for, activate, and deactivate land quality data, as well as view land characteristic data by land quality.
SKPL.SIGKL.004	Managing Land Characteristics Data	Admins can add, edit, delete, search, activate, and deactivate land characteristics data, and filter by land quality.
SKPL.SIGKL.005	Managing Order Data	Admin can add, edit, delete, search, activate, and deactivate order data, as well as view class data based on orders.
SKPL.SIGKL.006	Managing Class Data	Admins can add, edit, delete, search, activate, and deactivate class data, and filter by order.
SKPL.SIGKL.007	Managing Plant Group Data	Admins can add, edit, delete, search, activate, and deactivate plant group data, and view plant data organized by plant group.
SKPL.SIGKL.008	Managing Plant Data	Admins can add, edit, delete, search, activate, and deactivate plant data, filter by plant groups, and view knowledge rule data based on plants.
SKPL.SIGKL.009	Managing Data Knowledge Rules	Admins can add, edit, delete, search, activate, and deactivate data knowledge rules and filter based on plants.
SKPL.SIGKL.010	Managing Basemap Data	Admin can add, edit, delete, search, activate, and deactivate basemap data.
SKPL.SIGKL.011	Managing Data Layer Groups	Admins can add, edit, delete, search, activate, and deactivate layer group data, as well as view land data organized by layer groups.
SKPL.SIGKL.012	Managing Land Data	Admins can add, edit, delete, search for, activate, and deactivate land data, and filter it by layer groups.
SKPL.SIGKL.013	Managing Provincial Data	Admins can add, edit, delete, search for, activate, and deactivate provincial data, as well as view district/city data for each province.
SKPL.SIGKL.014	Managing Regency/City Data	Admins can add, edit, delete, search, activate, and deactivate district/city data, filter by province, and view sub-district data by district/city.
SKPL.SIGKL.015	Managing Sub-district Data	Admins can add, edit, delete, search, activate, and deactivate sub-district data, filter by district/city, and view village/sub-district data by sub-district.
SKPL.SIGKL.016	Managing Village/Sub-district Data	Admins can add, edit, delete, search, activate, and deactivate village/sub-district data and filter by sub-district.
SKPL.SIGKL.017	Managing Profile	Users can change their profile data and password.
SKPL.SIGKL.018	Sign Out	Users can log out of the system
SKPL.SIGKL.019	Displaying the Home Page	Guests can view summary statistics of the data and detailed information.
SKPL.SIGKL.020	Displaying Land Suitability Mapping	Guests can view detailed mapping and land information, including land suitability for various plants.

The FAO framework (1976) is structured into several levels: Order, Class, Subclass, and Unit. At the order level, land is classified as suitable land (S = *Suitable*) and unsuitable land (N = *Not Suitable*). Land in the suitability order (S) is divided into three classes, namely highly suitable land (S1),

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moderately suitable (S2), and marginally suitable (S3). Meanwhile, land in the unsuitability order (N) is not classified. Land quality is a complex identifying characteristic of a land area. Land quality has properties that have an influence on the suitability of use which consists of one or more land characteristics. Land quality and characteristics are presented in Table 2 below.

Table 2. Land Quality and Characteristics

Land Quality	Land Characteristics
Temperature (tc)	Average temperature (°C)
Water Availability (wa)	Rainfall (mm), Humidity (%), Length of dry month (months)
Oxygen Availability (oa)	Drainage
Rooting Media (rc)	Texture, Coarse Material (%), Soil Depth (cm)
Peat (g)	Thickness (cm), Thickness (cm) if there are mineral/enrichment inserts, Maturity
Nutrient Retention (nr)	Clay CEC (cmol/kg), Base saturation (%), pH H2O, C-organic (%)
Toxicity (xc)	Salinity (dS/m)
Sodicity (xn)	Alkalinity/ESP (%)
Sulfidic Hazard (xs)	Sulfidic depth (cm)
Danger of Erosion (eh)	Slope (%), Erosion hazard
Flood Hazard (fh)	Puddle
Land Preparation (lp)	Surface rocks (%), Rock outcrops (%)

The rules obtained during acquisition at the communication stage are implemented as IF-THEN rules. The number of rules for one plant can differ from another because the plant criteria also vary from one plant to another. For example, in wheat, there is no rule for the temperature criterion for the S3 class, whereas for the same criterion in another plant, rules for classes S1, S2, S3, and S4 are complete. The maximum limited factor identifies the primary limiting factor by comparing the order with the highest maximum value. For instance, if the temperature criterion for corn is Suitable (S1), but the rainfall criterion for corn is not suitable (N), then the land evaluation result is deemed unsuitable due to the limiting factor of water availability (N/wa).

3.3. *Quick Design Modeling*

The Unified Modeling Language (UML) is used to document and gather functional requirements [31]. At this stage, *use case diagrams* and *class diagrams* are designed.

3.3.1. *Use case Diagram*

Use case diagrams aim to show the various user roles and how they relate to the system [32]. *Use cases* are the primary driver for all UML diagramming techniques [31].

Figure 2 shows that there are two actors involved in SigKL: *Guest* and Admin. *Guests* are general users who can access SigKL features without registering. *Guests can access* the homepage, land mapping, information on its suitability for food crops and horticulture, and a sign-in page for users with accounts to access additional data management features. Admins are users who already have an account and can access the data management features. Data that can be managed include land quality, land characteristics, orders, classes, plant groups, plants, *knowledge rules, basemaps, layer groups*, land, provinces, districts/cities, sub-districts, and villages/sub-districts.

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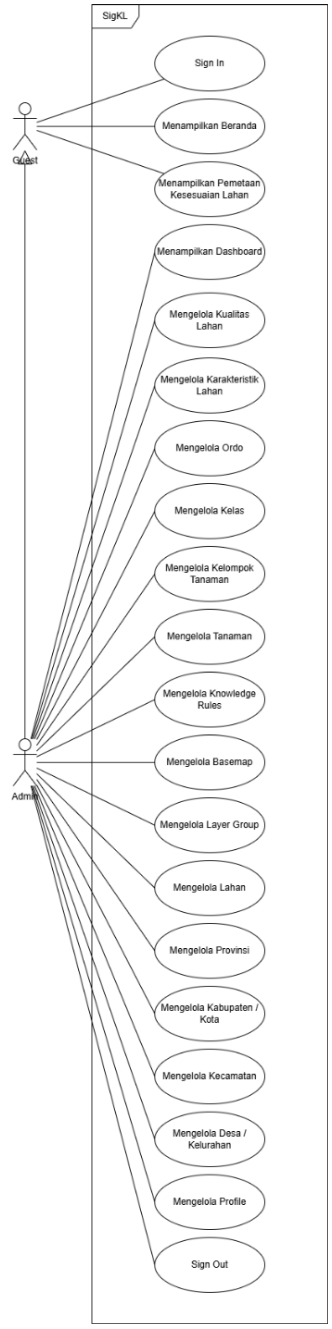

Figure 2. SigKL Usecase Diagram

3.3.2. *Class diagram*

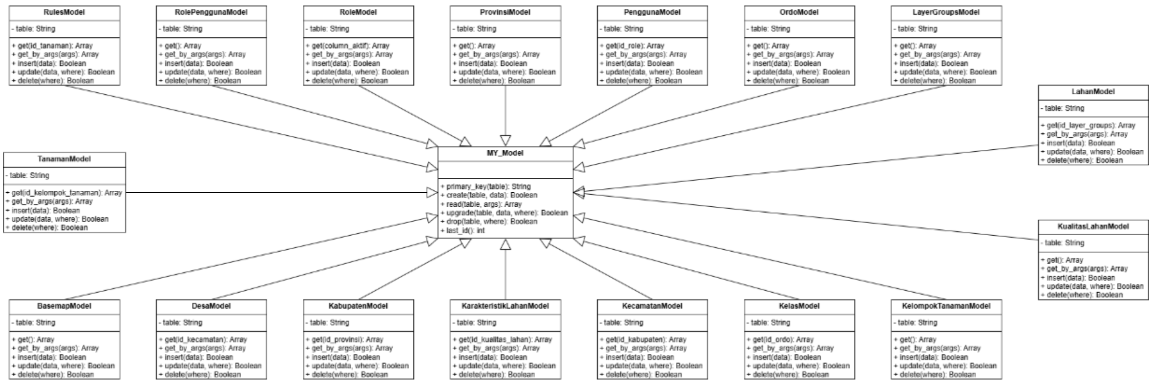

Figure 3. SigKL Class Diagram

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A Class Diagram is a graphical model used in an object-oriented approach to display the classes of objects in a system [32]. *A Class Diagram* is a static model that shows classes and their relationships, which remain constant in a system over time. *A Class Diagram* depicts classes, which include behavior and state, with relationships between classes [31]. A SigKL *Class Diagram* is shown in Figure 3.

3.4. *Construction of Prototype*

The result of this phase is the implementation of the design and requirements specifications established in the previous phase. The homepage, the initial system interface, displays statistical data that summarizes all data. Each data item can be viewed in detail by clicking "Next." The homepage display is shown in Figure 4.

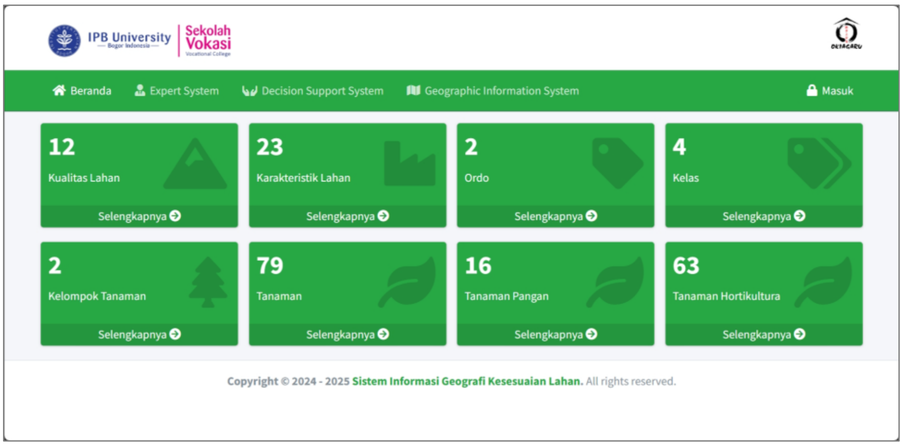

Figure 4. Home Page

Figure 5 shows land data presented on a map. When the system is first accessed, it will request permission to access your location. If granted, the map will focus on the location from which the system was accessed. The land data contained in SigKL can be expanded as needed.

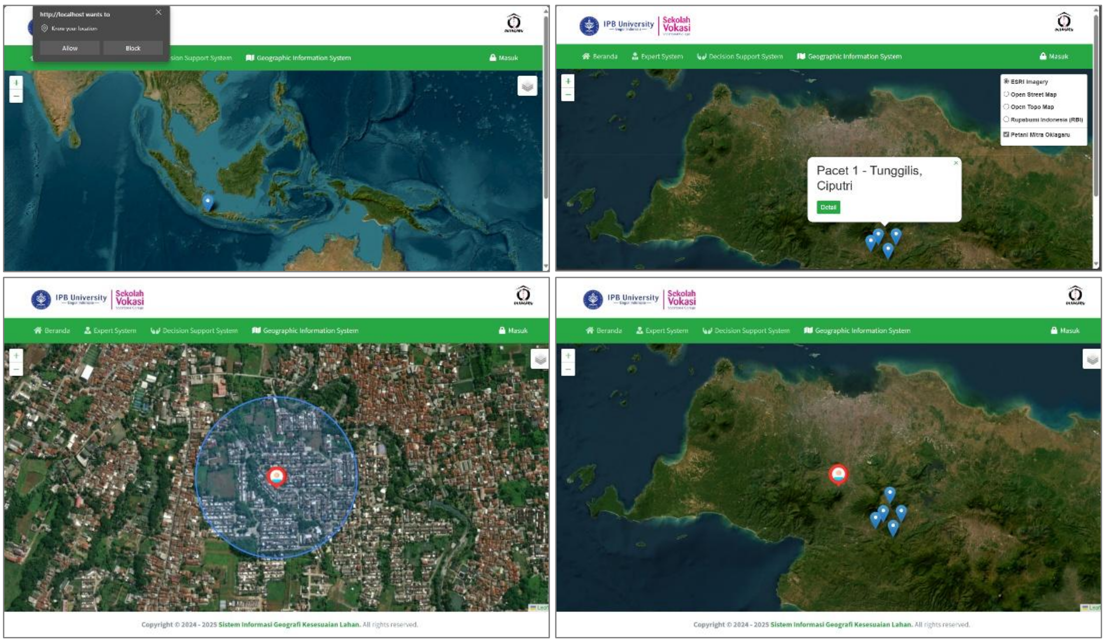

Figure 5. Land Mapping. (a) When requesting location access permission (b) Displaying a map according to the location access obtained (c) *Zooming out* the survey location point and access point (d) Accessing land location details

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Currently, there are only five locations for Okiagaru Indonesia Agricoop's partner farmer plots, located around Cianjur and Sukabumi. You can select *the basemap* based on your needs, and if new *services become available, the admin can add them to the basemap menu*. Detailed land information and crop suitability are illustrated in Figure 6.

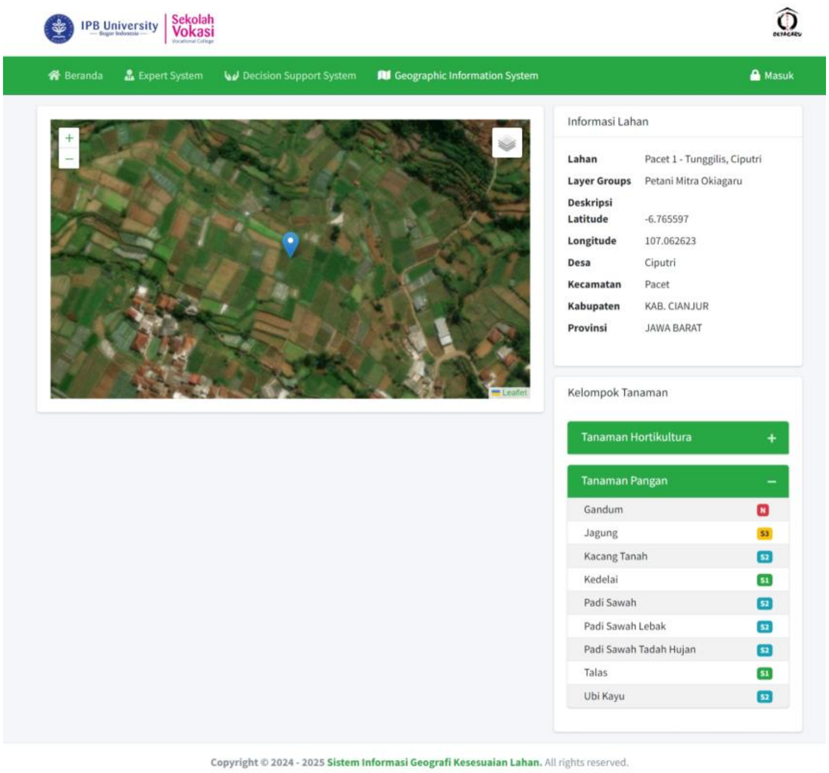

Figure 6. Land Suitability Information

On the *Sign In page*, users don't need to register first. User data is managed in the user management module. Users log in using their email address and password, as shown in Figure 7.

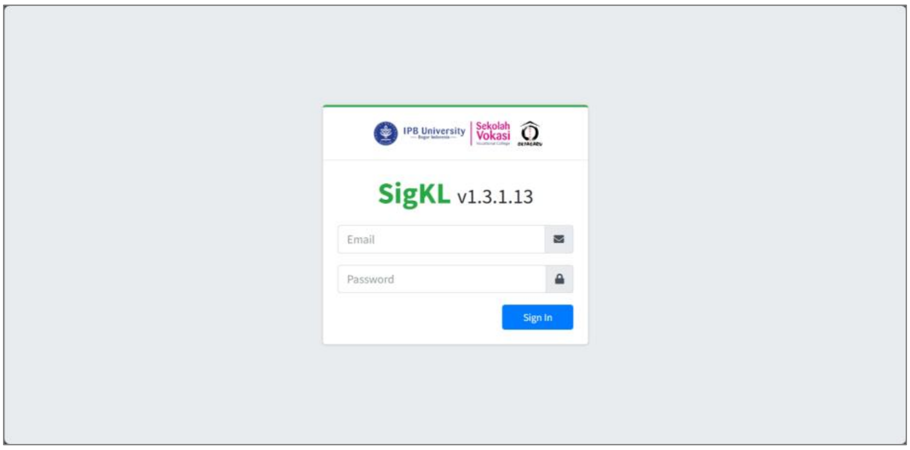

Figure 7. *Sign In* Page

After the user logs in, *the dashboard page* will appear, as shown in Figure 8. *The dashboard page* provides a statistical overview of the data in the system. This data includes information related to land quality, land characteristics, order, class, plant group, crop, layer groups, land, province, district/city, sub-district, and village/sub-district. This data can be managed through each menu.

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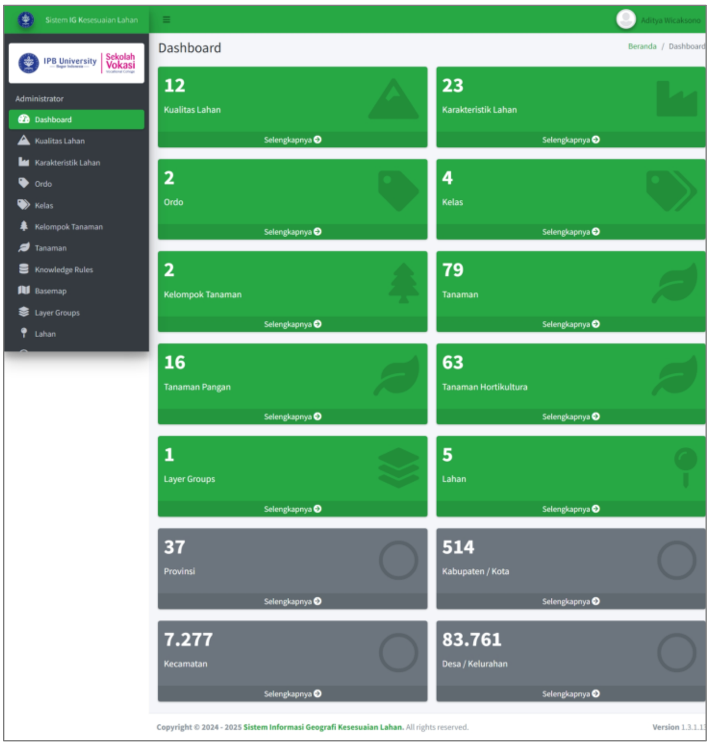

Figure 8. *Dashboard* Page

The features in each menu are relatively similar: adding, changing, deleting, searching, activating, and deactivating data. Some menus also include additional data filtering features. These features are illustrated in Figure 9.

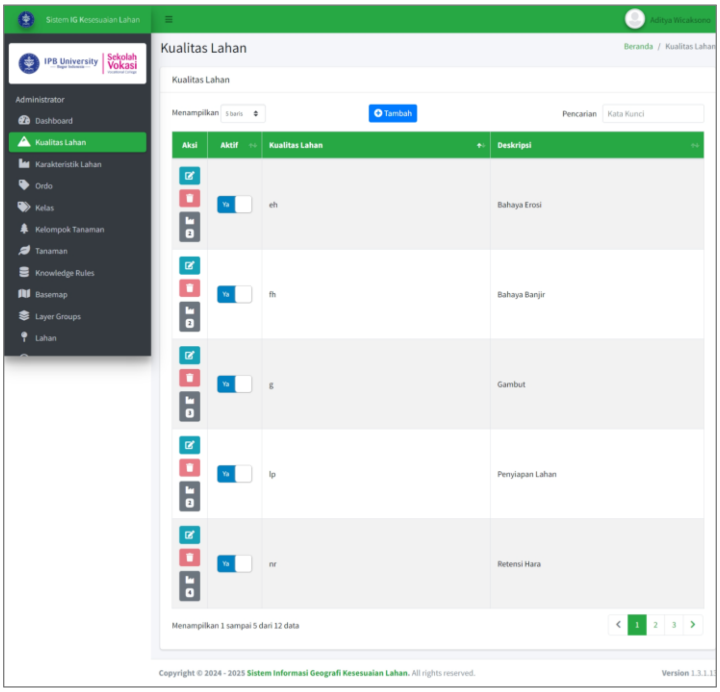

Figure 9. Land Quality Page

3.5. *Deployment Delivery & Feedback*

At this stage, the developed system is tested using a series of test scenarios known as *User Acceptance Testing* (UAT). Based on Black-Box Testing*, all features function as expected, achieving a*

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100% success rate. *Black Box Testing* is a software testing method in which the tester assesses the functionality of the software without examining the internal code structure, implementation details, or its internal paths. This method focuses on the software application's input and output and is entirely based on its requirements and specifications. *Black Box Testing* itself has been widely used for system testing, including financial information systems [33]. As well as ordering and inventory management systems [34].

4. DISCUSSIONS

Confirming the choice of the *prototyping method* by Sihombing (2024) [35], the results of the implementation of the Geographic Information System for Land Suitability (SigKL) showed that the *prototyping approach* was able to produce a system that suited the needs of users, especially the farmer partners of the Okiagaru Indonesia Agricoop Cooperative. This finding aligns with the research of Katili et al. and Razali et al. (2025), which demonstrated that combining the Analytical Hierarchy Process (AHP) with GIS enhances the accuracy of land suitability mapping [36] [37]. This finding aligns with the rule-based approach employed by SigKL, as both emphasize the importance of integrating biophysical parameters into decision-making. Similarly, Yang *et al.* (2025) emphasize the importance of integrating spatial and environmental parameters to support sustainable land-use planning in Ethiopia [38]. Similarly, Anuber *et al.* (2025) confirmed that the combination of GIS and remote sensing can identify optimal zones for crop production in the Philippines [39]. Thus, SigKL strengthens the evidence that rule-based *GIS* can be a strategic tool in agribusiness decision-making.

The main contribution of this research lies in the application of the FAO (1976) classification framework, integrated with knowledge rules based on land characteristics. This provides the system with the flexibility to tailor crop recommendations to local conditions. The implementation of a rule-based system integrated with a Geographic Information System (GIS) demonstrates how core concepts in informatics can be applied to solve complex multidisciplinary problems. Compared with the research by Utami *et al.* (2024) [17], which has developed a general land suitability system for food crops, SigKL adds an interactive digital mapping aspect that farmers and stakeholders can access directly. This feature enhances the transparency and accessibility of information, thereby supporting the *Sustainable Development Goals* (SDGs) related to food security and sustainable agriculture.

Although the system testing success rate reached 100% using the Black Box Testing method, certain limitations should be noted. The system's validity is highly dependent on the accuracy *of the knowledge rules* used. If land parameters are not updated regularly, the resulting recommendations may be less relevant to actual conditions. Therefore, the integration of *Internet of Things* (IoT) technology is an important development direction, so that land and environmental data can be obtained in *real-time* [40] [41]. With IoT sensors, the system can provide more precise recommendations on crop types and ideal planting times. This is in line with Saha *et al.* (2025), who emphasized the role of IoT sensors in land mapping and crop prediction [42]. In addition, Sadenova *et al.* (2024) and Aarthi *et al.* (2025) emphasized the need for integration of GIS, *remote sensing*, and artificial intelligence for sustainable land management, which can strengthen SigKL's ability to deal with environmental dynamics [43] [44].

Furthermore, the land data coverage, currently limited to five locations in Cianjur and Sukabumi, needs to be expanded to allow for broader use by farmer partners across the region. Further development could also incorporate multi-criteria *decision-making* (MCDM) analysis to account for socio-economic factors, such as production costs and market access, so that recommendations are not only biophysically based but also consider economic sustainability [45] [46] [23] [24].

Thus, SigKL serves not only as a land suitability mapping system but also as an innovative platform that can support the digital transformation of agriculture in Indonesia. Going forward, this

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research could serve as the foundation for developing an integrated agribusiness system that digitally connects land data, crop recommendations, and the agricultural supply chain.

5. CONCLUSION

The Geographic Information System for Land Suitability has been successfully implemented using the *Prototype method*. Based on Black-Box Testing, all features function as expected, achieving a 100% success rate. This indicates that the system can handle all tested scenarios without errors or malfunctions. However, this system relies heavily on the validity of *knowledge rules* for land characteristics for each crop. A significant contribution to the development of Informatics/Computer Science lies in the application of the rule-based system concept combined with interactive GIS, thereby expanding the scope of computer science applications from merely traditional information systems to spatial decision support systems. Thus, this research is not only relevant to the agricultural sector but also strengthens the position of Informatics/Computer Science as a discipline capable of addressing multidisciplinary challenges through technological innovation. This system can be enhanced by incorporating IoT technology, enabling the collection of land and environmental data in real time. This can further improve the precision of determining when crops are suitable for planting.

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