

Development of the Backend Module of the Agroecological Land Suitability Assessment System for Garlic

Annisa, A.,^{1*} Reyhan, M.,¹ Sitanggang, I. S.,¹ Agmalaro, M. A.,¹ Sobir, S.,² Semadi, I. P. D.,¹ Noormandiri, F. I.¹ and Mustafidah, H.¹

¹Department of Computer Science, IPB University, Indonesia, E-mail: annisa@apps.ipb.ac.id,* cryptbrnreyhan@apps.ipb.ac.id, imas.sitanggang@apps.ipb.ac.id, agmalaro@apps.ipb.ac.id, dewasemadi@apps.ipb.ac.id, ilhamfaris@apps.ipb.ac.id, hilyatulmustafidah@apps.ipb.ac.id

²Department of Agronomy, IPB University, Indonesia, E-mail: sobir@apps.ipb.ac.id

*Corresponding Author

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Abstract

Garlic is one of the horticultural commodities with diverse benefits and high consumption. The challenge in improving the quality and production of garlic is the difficulty in determining suitable land, as garlic cannot thrive in just any location. The assessment of land suitability for garlic production is required to support the government's self-sufficiency program for garlic from 2030 to 2045. This study aims to develop the backend module of the Agro-ecological Land Suitability Assessment System for Garlic. The result of land assessment from this backend system will be visualized using mobile and web-based GIS applications. Different from other previous land suitability assessment systems, the determination of garlic land suitability in this system is based on twelve primary garlic growth requirements grouped into three factors: factors that are uncontrollable and uncorrectable, factors that can be corrected, and factors that can be controlled. The use cases implemented in this system include user registration, land suitability assessment, viewing land suitability assessment results on the map, viewing a list of previously assessed lands, viewing all lands assessed by users, viewing the history of a land's class, reading the glossary of garlic growth requirement's terms, viewing user profiles, logging in and out. The backend system resulted in a database with 16 tables and 37 Application Programming Interfaces, along with 1 scheduler, which has been successfully tested using black box testing methodology.

Keywords: Backend, Database, Garlic Productivity, Land Suitability, Spatial Decision Support System

1. Introduction

Garlic (*Allium sativum*) belongs to the "relatives" of the Liliaceae family and has various health benefits in addition to its culinary uses. In addition to being used as a spice and food ingredient, garlic bulbs also possess antimicrobial abilities derived from the presence of organosulfur compounds in garlic as stated in [1]. As the population of Indonesia increases, garlic consumption has risen due to the inclusion of garlic in many Indonesian recipes. However, garlic productivity in Indonesia experienced a decline of approximately 7.78% from 7.84 tons/ha in 2018 to 7.23 tons/ha in 2019, as mentioned in [2]. The Directorate General of Horticulture of the Ministry of Agriculture has implemented a development program to increase garlic production in Indonesia [3]. The government

has also created a roadmap program from 2016 to 2045, intending to achieve self-sufficiency by 2030-2045, as mentioned in [2]. The development program was established in 2015, and potential garlic cultivation center locations were designated between 2016 and 2019 through import regulations. Garlic cultivation centers are planned to be established between 2020 and 2024 in several provinces, including East Java, Bali, West Nusa Tenggara, East Nusa Tenggara, North Sulawesi, South Sulawesi, Central Sulawesi, Maluku, and Papua.

The issue faced when planting in new land is that garlic plants cannot grow just anywhere. Although garlic can grow in less suitable land, it will result in suboptimal plant growth and can lead to productivity that does not match the land's production area.

Therefore, land suitability assessment becomes crucial because information about land suitability classes is needed by agricultural sector development planners to recommend the most suitable land for garlic cultivation.

Land suitability is the degree of compatibility of a specific land area for a particular purpose [4]. Land suitability can be assessed based on the quality of soil and its environmental characteristics, which include climate, soil, topography, hydrology, and drainage suitable for specific agricultural commodities [4]. Based on the FAO framework (1976), the land suitability classification structure includes highly/very suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). S1 (very suitable) indicates that the land either has no significant limiting factors for sustainable use or the limiting factors are minor and will not significantly reduce land productivity. S2 (fairly suitable) indicates that the land has limiting factors that will affect land productivity in sustainable use. Additional input or resources are required. Typically, farmers can address these limitations themselves. S3 (marginally suitable) indicates that the land has severe limiting factors that will impact land productivity. Addressing these limiting factors in S3 requires more resources compared to S2. It involves higher capital and assistance or intervention from the government or the private sector are necessary. Without such assistance, farmers may not overcome these limitations. N (not suitable) indicates that the land is classified as not suitable because it has very severe limiting factors that are challenging to overcome. A limiting factor refers to a specific environmental or soil condition that restricts or limits the potential use or productivity of a particular land area for a given purpose, such as agricultural production. Limiting factors can include various elements, such as soil quality, drainage, topography, climate, and other site-specific characteristics. These factors can significantly affect the suitability of land for a particular land use or crop cultivation.

Although there have been numerous previous studies examining the potential of garlic cultivation land based on land characteristics and suitability as discussed in [5][6][7] and [8], considering agroecosystem and agro economic suitability in [6][9][10] and [11], investigating the relationship between weather aspects, rainfall, and temperature with garlic productivity in [12] and [13], as well as conducting land suitability evaluation using machine learning algorithms in [14][15] and [16], there hasn't been specific research directed towards farmers, land assessors, and agricultural planners to consider limiting factors for determining whether a specific

land area is suitable for garlic cultivation and how to overcome these limitations. However, identifying and addressing these limiting factors is crucial for optimizing land use and improving agricultural productivity. Grouping these factors is also important for formulating recommendations in land management for garlic cultivation. Additionally, previous research used weather factors over specific periods without considering the daily weather data changes. Mobile and web-based GIS is also not available for assessing garlic land suitability based on these three groups of factors and dynamic changes in weather factors.

The Agroecological Land Suitability Assessment System for Garlic to be developed in this research consists of three main components: first, the development of a backend module; second, a mobile application for on-site land suitability assessment; and third, a web application for land suitability assessment based on agroecological factors managed within the database and user input. The proposed solution for garlic land suitability assessment includes modeling land suitability based on three groups of factors: factors that cannot be controlled or corrected, factors that can be corrected, and factors that can be controlled. Factors that cannot be controlled and corrected include weather factors such as temperature ($^{\circ}\text{C}/\text{month}$), rainfall (mm/month), sunlight duration (hours per day), and relief factor (%). Factors that can be corrected include soil mineral depth (cm), base saturation (%), and soil acidity (pH). Factors that can be controlled include drainage, soil texture, and cation exchange capacity (cmol). According to the study conducted by [17], the low growth and productivity of garlic in Indonesia are attributed to the insufficient duration of sunlight exposure, leading to a reduction in the time available for the photosynthesis process.

The evaluation model of garlic land suitability based on these three groups of factors will be implemented in a web and mobile-based Geographic Information System (GIS), allowing easy access for garlic cultivation planners. Consistent with the purpose of the decision support system, this system aims to assist in decision-making for spatial issues [18], manage and analyze spatial data, provide data visualization in the form of images or maps, and generate reports [19]. The GIS will be designed to dynamically manage weather data, enabling land suitability assessments to be based on the latest weather conditions, considering limiting factors for determining whether a specific land area is suitable for garlic cultivation and giving recommendations on how to overcome the limitation.

In this research, the focus is on building the backend module of the system. The structure of this paper will proceed as follows: section two will describe the methodology to develop the backend module of the system, followed by the results and discussion in section three, and it will conclude with future research plans and conclusions in section four.

2. Material and Methods

2.1 Research Objectives and Design

The Agroecological Land Suitability Assessment System for Garlic is a spatial decision support system based on GIS aimed at assisting farmers, agricultural extension officers, and land assessors in evaluating the suitability of agricultural land for planting garlic. The system's inputs include twelve growth requirements for garlic on the assessed land, which will be automatically inputted into the system. Garlic growth requirements are categorized into three groups of factors: uncontrollable or uncorrectable factors, correctable factors, and controllable factors. Uncontrollable factors include weather elements such as temperature ($^{\circ}\text{C}/\text{month}$), rainfall (mm/month), sunlight duration (hours per day), and

relief factor (%). Correctable factors include soil mineral depth (cm), base saturation (%), and soil acidity (pH). Controllable factors include drainage, soil texture, and cation exchange capacity (cmol). The system then calculates land suitability based on these inputs, producing output in the form of suitability classes for the land. The resulting land suitability class could be one of the following: suitable (S1), moderately suitable (S2), marginally suitable (S3), or not suitable (N). The assessment results can be reviewed and displayed on a map.

The actors in the system are general users, registered users, including researchers and landowners, and finally, the admin. The use case diagram in Figure 1 shows the features accessible by these actors. All actors can view the land suitability map and general information in the "About" menu. Registered users and admins can access information in the glossary, which includes explanations about growing conditions and the functions of garlic barriers, conduct land suitability assessments, and download land suitability files within the system. Basic map input can only be performed by the admin.

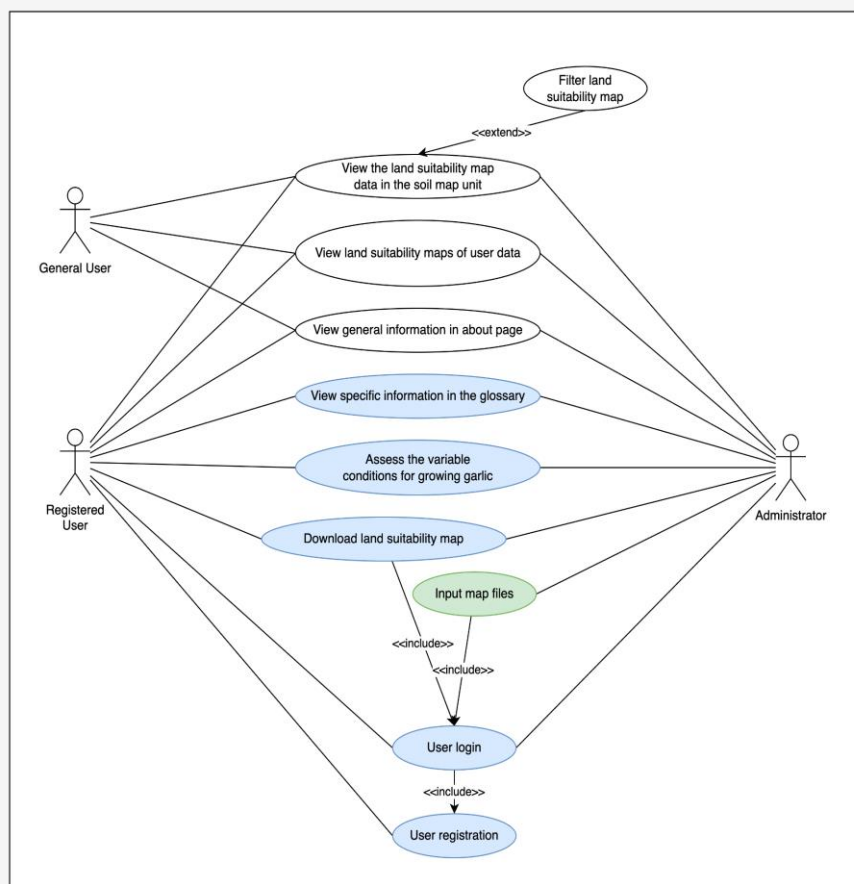


Figure 1: Unified modeling language (UML) use case diagram

2.2 Data Used

The data used in the development of this system are based on consultations with experts and consist of twelve main garlic growing requirements adapted to geographical conditions in Indonesia, along with the availability of data for each variable. The twelve variable data were obtained from various sources, such as data on soil properties and characteristics consisting of information on soil mineral depth, drainage, soil acidity, cation exchange capacity, base saturation, soil texture, and relief. The seven data were provided by the Center for Agricultural Land Resources (BBSDLP) Ministry of Agriculture of the Republic of Indonesia, with non-spatial format in the form of soil characteristic values as attributes of spatial data in the form of maps packaged in a shape file (*.shp). This data is referred to as the Soil Map Unit (SPT/SMU). SPT is the identity of a row of data that is a variable and soil characteristic trait associated with a spatial object, where an SPT can represent several polygon-shaped spatial objects. The SPT data used in this research is a database processing with a combination of tabular data (soil characteristics) and spatial data (soil map polygons) [20]. The other four are climate data, such as rainfall precipitation, temperature, Duration of Sunlight and Solar radiation, which were provided from Visual Crossing data services and the Meteorology, Climatology, and Geophysics Agency (BMKG). Lastly, elevation data was obtained from the United States Geological Survey (USGS).

The complete list of variables, descriptions, formats, and sources used is provided in Table 1.

Generally, garlic can grow at various altitudes depending on the cultivated variety. However, garlic tends to grow in highland areas with a tropical climate. There are several considerations to keep in mind when planting garlic, including:

1. The planting site should be suitable for the chosen garlic variety. This includes considering factors such as soil type, irrigation, altitude, temperature, humidity, and rainfall.
2. Soil preparation should involve loosening the soil, liming if the soil is too acidic, creating drainage ditches, and applying fertilizers.
3. The planting time, or planting season, should be at the beginning of the dry season. This is because garlic struggles to thrive in waterlogged conditions. Garlic cannot be planted at any time; it requires specific timing. Generally, garlic has specific growing conditions as presented in Table 2.

Day length and temperature are crucial factors for garlic bulbs, according to [21]. Table 2 provides a detailed overview of the essential land characteristics crucial for successful garlic cultivation. These characteristics play a pivotal role in assessing the suitability of land for garlic farming. The table categorizes land suitability into four classes: S1, S2, S3, and N, based on specific attributes.

Table 1: List of garlic growth variables

Variable	Description	Format	Source
Rainfall	Average rainfall per month	Numeric	Visual Crossing API
Temperature	Average temperature per month	Numeric	Visual Crossing API
Duration of sunlight exposure	Total duration of sunlight exposure per month (hour per day)	Numeric	Data Online BMKG
Solar radiation	Average solar radiation per month (W/m ²)	Numeric	Visual Crossing API
Elevation	Elevation states the height of land from sea level based on a digital elevation model (DEM)	Numeric	Open Topo Data API
Soil depth	Soil depth states the depth of the soil layer	Tabular	BBSDLP
Drainage	Drainage is the influence of the rate of water allocation into the soil on air aeration in the soil	Tabular	BBSDLP
Soil texture	Soil texture expresses the term in terms of the distribution of fine soil particles with a size of < 2 mm	Tabular	BBSDLP
Soil acidity (pH)	Soil acidity is the pH value of the soil in the field	Tabular	BBSDLP
Cation exchange capacity (CEC)	Cation exchange capacity represents the cation exchange capacity of the clay fraction	Tabular	BBSDLP
Base saturation (BS)	Base saturation is the number of bases (NH ₄ OAc) present in 100g of soil sample	Tabular	BBSDLP
Relief	Relief states the slope of the land measured in %	Vektor	BBSDLP

Table 2: Garlic growing condition classification [4]

Land characteristics requirements	Land suitability class			
	S1	S2	S3	N
Temperature (tc)				
Temperature (c)	20 - 25	25 – 30, 18 – 20	30 – 35, 15 – 18	> 35, < 15
Water availability (wa)				
Rainfall (mm)	350 – 600	600 – 800, 300 – 350	800 – 1600, 230 – 500	< 1600, < 250
Oxygen availability (oa)				
Drainage	Good, a bit hampered	A bit fast, medium	Hampered	Very hampered, fast
Rooting medium				
Texture	Fine, a bit fine, medium	-	Rather rough	Rough
Rough material (%)	< 15	15 – 35	35 – 55	> 55
Soil depth (cm)	> 50	30 – 50	20 – 30	< 20
Peat				
Thickness (cm)	< 60	60 – 140	140 – 200	> 200
Thickness (cm), if there are mineral/enrichment material inserts	< 140	140 – 200	200 – 400	> 400
Maturity/ripeness	Sapric	Sapric, Hemic	Hemic, Fibric	Fibric
Nutrient Retention (nr)				
Cation exchange capacity of clay (cmol)	> 16	≤ 16		
Base saturation (%)	> 35	20 – 35	< 20	
pH H ₂ O	6 – 7,8	5,8 – 6,0 7,8 – 8,0	< 5,8 > 8,0	
C-organic (%)	> 1,2	0,8 – 1,2	< 0,8	
Sodicity (xn)				
Alkalinity/ESP (%)	< 20	20 – 30	35 – 50	> 50
Sulfic hazard (xs)				
sulfidic depth (cm)	> 75	50 – 75	30 – 50	< 30
Erosion hazard (eh)				
Slope (%), erosion hazard	< 8, very low	8 – 16, low – medium	16 – 30, heavy	> 30 very heavy
Flood hazard(fh)				
Puddle	F0	-	-	> F0
Land preparation (lp)				
Rocks on the surface (%)	< 5	5 – 15	15 – 40	> 40
Rock outcrops (%)	< 5	5 – 15	15 – 25	> 25

It outlines temperature ranges conducive to garlic cultivation within each suitability class, along with rainfall patterns and drainage conditions essential for optimal growth. Additionally, the table addresses soil texture, depth, and peat thickness necessary for successful cultivation. Maturity levels of the soil, soil fertility, and nutrient retention are also presented, along with factors such as alkalinity and sodicity. Hazards like sulfic material depth, erosion, and flood

risks are evaluated, providing insights into potential challenges. Lastly, the table includes information on land preparation, emphasizing the presence of rocks and their impact on cultivation practices. The information contained in Table 2 will be highly useful in determining the classification of land suitability for garlic. For further details, the classification calculation will be explained in section 3.1.

2.3 System Architecture

The system to be developed implements a client-server architecture. In general, the three main components of the system consist of the backend service, frontend service, and mobile app. These three components are connected through Rest API as mentioned in [22][23][24] and [25]. The On-Premises server serves as the location where the backend runs. The backend service runs on the on-premises server using a containerization system provided by Docker. In the backend, there is a relational database connected to PostGIS to store, process, and display spatial data [26]. The front end and mobile app function as applications for clients to interact with the system. The Rest API connects the backend, front end, and mobile app (client applications). Figure 2 illustrates the overall system architecture.

In Figure 2, the yellow-colored section represents the scope of the backend service, which is connected to several external services, including the Visual Crossing API to obtain weather data (temperature, rainfall, and solar radiation), online BMKG data for obtaining weather data (duration of sunlight), OpenTopoData API for obtaining elevation data, and

Sendinblue for sending emails to users. All these external services are connected to the backend using a Rest API. The green and blue-colored sections are the web-based and mobile client applications, respectively. All traffic in the system's applications will pass through a reverse proxy owned by IPB University.

2.4 Prototyping Methods

The development of the backend module in this system uses the Prototyping method [27]. In the communication stage, Focus Group Discussions (FGD) are conducted with horticulture experts and stakeholders to define the system's requirements and functions. In this research, garlic growth requirement data is categorized into three groups of factors.

Modeling of the backend module begins with the identification of the most suitable options to meet the requirements of the features to be developed. Next, a conceptual design of the changes to be made is created. This conceptual design is then converted into a relational schema and further normalized. The results of this normalization are then transformed into an entity relationship diagram (ERD).

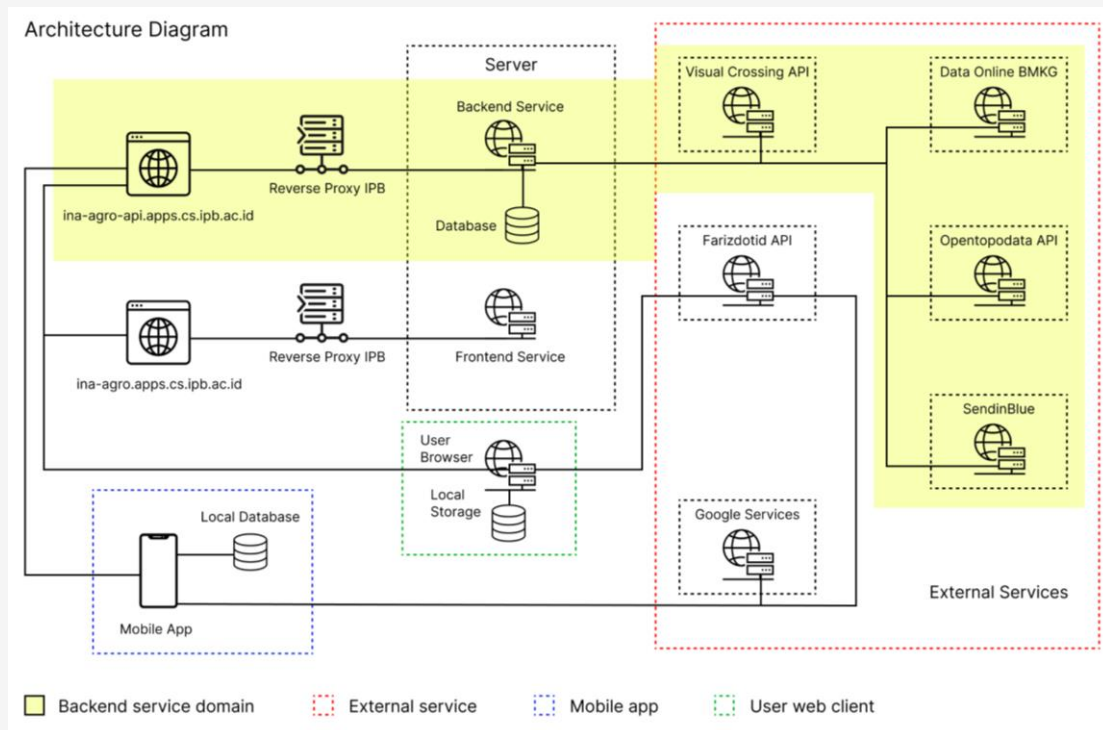


Figure 2: System architecture

An implementation system is then carried out for the features to be developed. The implementation is based on the designs and models created in the previous subsection. Testing is conducted using the

black box testing method [28]. Testing is performed in two environments, namely, the development environment and the production environment [29]. Testing in the development environment is carried

out by the backend developer while testing in the production environment is performed by the frontend and mobile developers. First, testing is conducted in the development environment. Afterward, the backend module is uploaded and installed on a new server with full access to the operating system, allowing all features, including file uploading, to be used. Following the upload and installation of the backend module on the server, further testing is carried out by stakeholders. If any errors occur during this stage, iterations are made to the preceding sections according to the identified errors.

3. Result and Discussion

3.1 Land Suitability Assessment

Based on the communication result, Figure 3 shows the activity diagrams illustrating the workflow of conducting land suitability assessment and viewing land suitability assessment results. Inputting location data in the form of coordinates (latitude and longitude) can be done automatically if connected to the internet by pressing the automatic fill button. Conversely, without requiring an internet connection, automatic input can also be performed for date and time observation data.

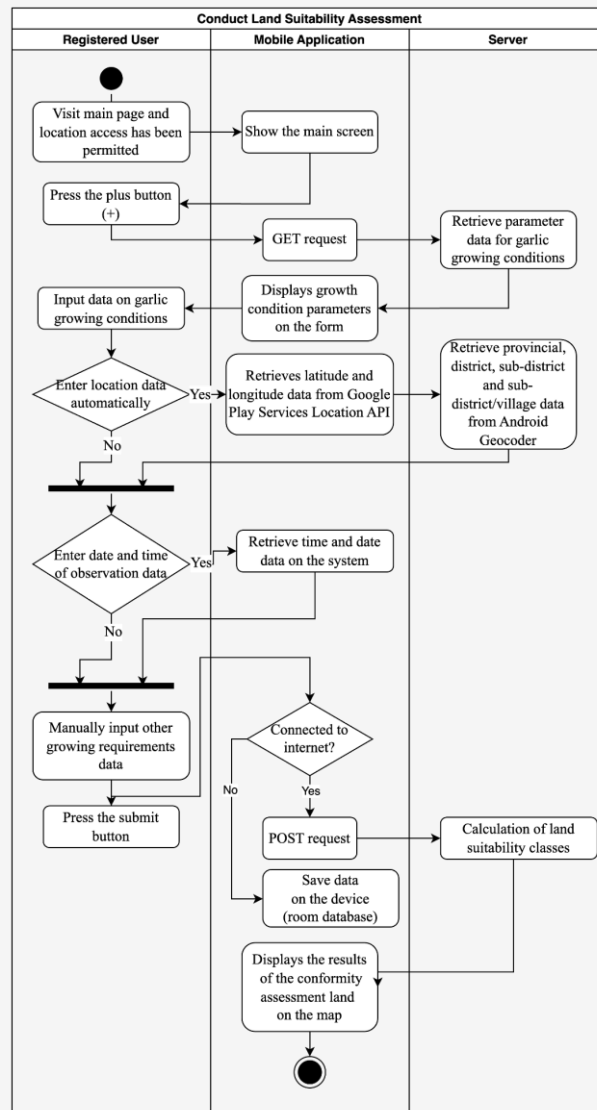


Figure 3: Activity diagram

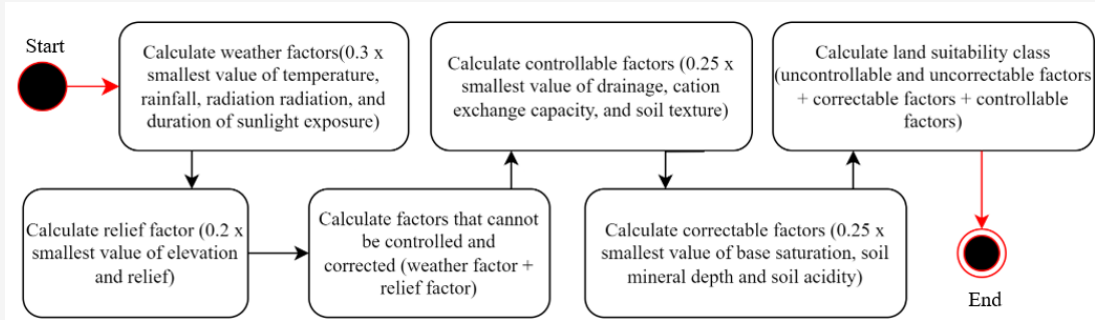


Figure 4: Calculation of garlic land suitability classification

Table 3: Limitation Factors

Category	Member of Category
Weather factor	Temperature, rainfall, sunshine time, and solar radiation
Relief factor	Elevation and relief
Correctable factor	Base saturation, soil mineral depth, and soil acidity
Controllable factor	Drainage, cation exchange capacity, and soil texture

Land suitability assessment is conducted using calculations as illustrated in Figure 4. Each weight, multiplied by the growth factor, is obtained from discussions with horticulture experts. To calculate land suitability classes, first, each class is assigned a weight as follows: class S1 = 4, S2 = 3, S3 = 2, and N = 1. The growth requirements with class N in each category will be used to calculate the suitability class results. The types of limitation factors and categories used in this study can be seen in Table 3.

The calculation of the final class results uses the weighted overlay method, as shown in Equation 1:

$$S = \sum_{i=1}^n W_i X_i$$

Equation 1

Where: S = The overall class value
 W_i = The weight of the i -th factor
 X_i = The class score on the sub-criteria

The weight for each factor is determined by experts.

The results of the calculation in Equation 1 will be converted into classes based on FAO (1976) [30], namely S1, S2, S3, and N, with intervals for each class as determined by experts, namely S1 (3.6-4), S2 (2.6-3.5), S3 (1.6-2.5), N (1-1.5). This study refers to the guide for land suitability proposed by FAO (<https://www.fao.org/3/x5310e/x5310e00.htm>). There are four classes for land suitability: Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), and Not Suitable (N). The criteria of each class is presented in Table 4.

Next, the determination of the least suitable class for each factor will be carried out. The result of determining the least suitable factor (or the smallest) is then converted using alternative class values, and then the class values will be calculated using the formula in equation 1 for each factor. The results of the calculation for each factor are then summed up. The outcome of this calculation can be seen in Table 6. The total calculation of all factors is then converted based on the intervals specified by experts. According to Table 5, the result of the total land suitability value is 3.5, which falls into the Suitable class (S2). In general, the assessment process can be seen in Figure 4.

3.2 Modeling the Database

The database design begins with the creation of a conceptual design, followed by logical and physical design [31]. First, entity identification is performed based on the created use case diagram [32]. There are three entities required: user entity, land entity, and growth conditions entity. The user entity is needed to store user data, which is used for user management. The land and growth conditions entities are needed to store data related to land and growth conditions, which will be used to assess land suitability.

After obtaining the three main entities to be used, further analysis is carried out on each entity. Starting with the land entity, based on the existing use case diagram, there are two types of land to be stored in the system: user-entered land (user land) and land obtained from the soil map units obtained from BBSDLP (geometry land).

Table 4: Criteria for land suitability classes [30]

Class	Criteria
Highly Suitable (S1)	The land has no significant or minor limitations for growing the crops. The minor limitations will not significantly reduce the productivity of crops and will not raise inputs above an acceptable level.
Moderately Suitable (S2)	The land has moderately severe aggregate limitations. In this class, crop productivity will be reduced, and required inputs will increase.
Marginally Suitable (S3)	The land has severe aggregate limitations. In this class, crop productivity will be reduced, and required inputs will increase.
Not Suitable (N)	The land has qualities that appear to preclude sustained use for growing crops.

Table 5: Input data for calculating garlic land suitability

Factor	Input value	Class	Class grades
Weather factor			
Temperature	27	S2	3
Rainfall	350	S2	3
Sunshine duration	9	S2	3
Solar radiation	22	S1	4
Relief factor			
Elevation	1100	S1	4
Relief	16	S2	3
Correctable factor			
Base saturation	40	S2	3
Soil mineral depth	60	S1	4
Soil acidity	7	S2	3
Controllable factor			
Drainage	Good	S1	4
Cation exchange capacity	20	S1	4
Soil texture	Medium	S1	4

Table 6: Results of determining and calculating land suitability classes

Factor	Smallest class	Class grades	Value [%]	Result
Weather factor	S2	3	30	0.9
Relief factor	S2	3	20	0.6
Correctable factor	S1	4	25	1.0
Controllable factor	S1	4	25	1.0
Total land suitability value			3.5	

For each type of land, a new entity will be created as a specialization of the land entity, where these two new entities are disjoint. Then, because a piece of land can be assessed multiple times, a new entity is needed, named the observation entity. This observation entity will have a many-to-one relationship with the land location entity and a many-to-many relationship with the growth conditions entity. The many-to-many relationship is used between the observation entity and the growth conditions entity because one observation can have many different growth conditions, and vice versa,

one growth condition value can be owned by many different observations. Furthermore, since a piece of land requires two types of locations, namely point locations and administrative location divisions (area locations), one entity is needed for each type of location. The relationship between the land entity and the point location entity and area location entity is one-to-one and many-to-many, respectively. The many-to-many relationship is used because one piece of land can have many area locations (provinces, cities, etc.).

In the geometry land entity, two new entities are derived from further analysis, namely the geometry entity and the soil characteristics entity. The geometry entity and soil characteristics entity are each required to store geometry data and soil characteristic data from soil map units. The geometry entity has a one-to-many relationship with the geometry land entity because one geometry can potentially encompass many parcels of land, while the soil characteristics entity has a one-to-one relationship with the geometry entity. This is because the soil characteristic data obtained from BBSDLP is unit data for each piece of land. Furthermore, an additional entity is derived from the development of the soil characteristics entity, namely the proportion entity. The proportion entity has a one-to-many relationship with the soil characteristics entity. This is because the same proportion can have many soil characteristics. Then, from the analysis of the observation entity, a new entity is obtained, namely the land suitability class entity, which has a one-to-one relationship with the observation entity. This entity is created to break down the complexity of the observation entity and to facilitate data retrieval. After that, to store data from automatic weather data collection, a new entity is required, namely the daily weather entity. This entity has a many-to-one relationship with the point location entity because the data required for weather data collection is point data, and one point data can have many daily weather data.

In general, all growth conditions are placed in one entity, which is a "growth variable." An entity named "area location" is created to manage location data from the land, such as province, district/city, sub-district, and village. Within this entity, there is an attribute called "bpsCode" used to store the area code data from the Central Statistics Agency (BPS). Storing the BPS area codes is necessary because the frontend and mobile modules implement a third-party API for location data, and this API relies on data from BPS.

Furthermore, all the data related to land suitability classes is stored in the "land suitability class" entity. This allows the backend module to determine land suitability classes for each combination of growth conditions only once. Additionally, the conceptual design includes an "observation" entity, which serves to link the "land location" entity with the growth conditions and land suitability classes. With the presence of the "observation" entity, users only need to input growth condition data without the need for land location data to conduct land suitability assessments at the same location. After creating the conceptual design, it is then converted into a relational form. The purpose of this conversion is to normalize the database design to eliminate redundancy. The Entity Relationship schema for the database can be seen in Figure 5.

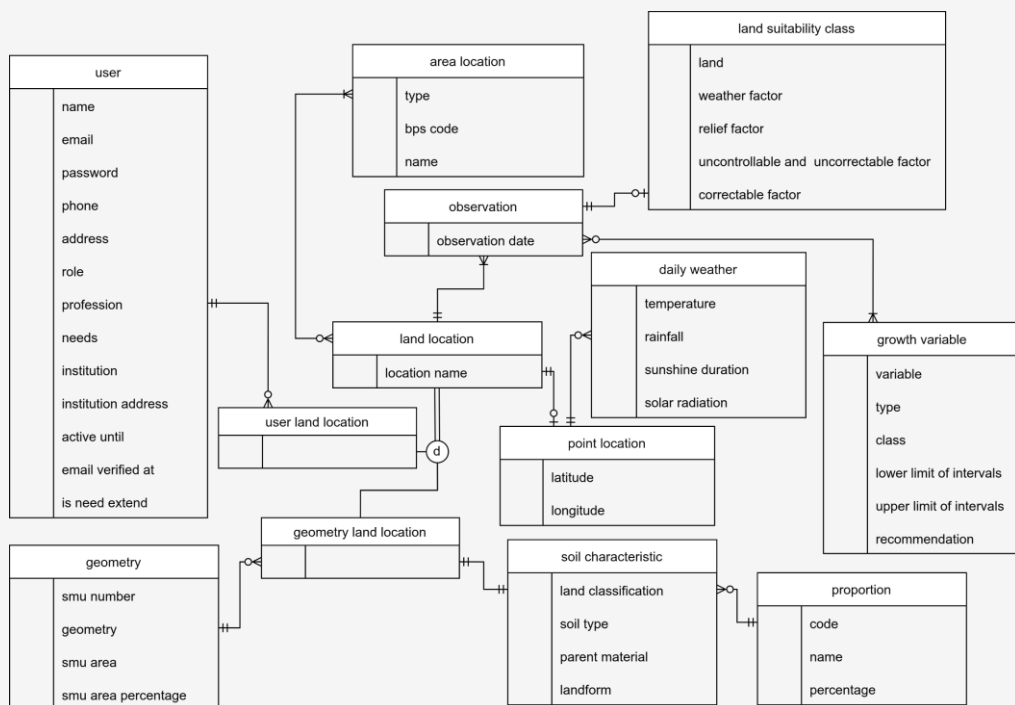


Figure 5: The entity relationship schema

Table 7: API Groups

No	Groups of API	Number of Method	Functionality	Endpoint API
1	Location Area	Get (2), Put (1), Post (1), Delete (1)	Provides information on the location of land that has a relationship with land planted with garlic.	/area-location/
2	Growth Conditions	Get (2), Put (1), Post (1), Delete (1)	Provides information related to data aggregation and processing of garlic plant growth requirements based on 12 factors.	/growth-variable/
3	Land Location	Get (6), Put (2), Post (3), Delete (3)	Provides information about land that has received aggregation results based on the growth requirements evaluated with input in the form of SPT data or data entered by the user.	/land-location /geometry/
4	Users	Get (4), Put (1), Post (8), Delete (0)	In this API group there are all APIs related to user data in the system. The main function of this API group is to process user data.	/Users/

3.3 Development of Backend Module

In the development of the backend module, the implementation of the previously created database design is carried out. This part begins with preparing the program code structure of the backend module to group related program files. The development of the backend module resulted in 37 APIs and 1 scheduler. The APIs are categorized into four groups: location area, growth conditions, land location, and users. Each group has a different focus in terms of functionality as mentioned in Table 7. Separating these functions simplifies the integration process for frontend and mobile developers because each group has a common prefix.

3.3.1 API group for location

This API group consists of all APIs related to location data within the system. The primary purpose of this API group is to process location data from the land. All APIs in this group can only be accessed by users with the admin role. To add and update location data, users must send a request body. The request body contains several fields, including type, name, and bpsCode. The "type" field represents the type of location to be added, where users can input "province" for provinces, "district" for districts or cities, "sub_district" for sub-districts, and "urban_village" for urban or rural villages. The "name" field is the name of the area to be added, while the "bpsCode" field is the BPS area code for the location to be included.

There are two APIs for retrieving location data. These APIs will return a response in the form of

JavaScript Object Notation (JSON) containing location data. In addition to location data, these APIs will also return a "success" field as an indicator of the requested user operation.

3.3.2 API group for growth requirement

This group contains all the APIs related to growth requirement data within the system. The main function of this group of APIs is to process growth requirement data. Furthermore, to add or modify growth requirement data, users need to send a request body. The request body includes several fields, such as type, class, lower_limit_interval, upper_limit_interval, and recommendation. However, users do not need to send all these fields to add a new growth requirement. The fields that must be sent are only variable, type, and class, while other fields should only be sent if the specific growth requirement being added includes those fields. There are two APIs to retrieve growth requirement data. Both APIs will return a JSON response containing growth requirement data.

3.3.3 API group for land location

This API group contains all APIs related to land data within the system. Generally, this API group is divided into two subgroups: the user subgroup and the geometry subgroup. The user subgroup includes APIs that focus on processing user-inputted land data, while the geometry subgroup consists of APIs that focus on processing land data from the SPT.

3.3.4 User subgroup

In the user subgroup, there are all APIs related to land data entered by users. In general, this API subgroup has two main focuses. These primary focuses include processing users' land data and processing observation data of users' land. The processing involves addition, modification, or deletion. Furthermore, for the API that retrieves all user-input land data along with all observations and their suitability classes, no authorization is required. This API does not need authorization because it should be accessible to all users, including those who have not authenticated. The response from this API is a list of users' land data containing location data in the form of points (latitude and longitude) and area names and a list of observations that includes growth conditions and land suitability classes for each observation. To add new users' land location data and observations, authorization is required. This authorization mandates that the user accessing the API must be a registered user with a minimum role as a user. Users are also required to send a request body when using this API. In the request body, users must input location data so that the land data they intend to submit can be displayed on the map. Furthermore, when users make a call to the API to add users' land data, all requests sent by the users will be processed by first undergoing an authorization process, which involves checking the token sent according to the user's role. The data entered by users is not manually verified again by the admin. This is because only verified users can input data. Data entered by verified users is considered accurate, and the user is fully responsible for the accuracy of the data they enter.

To assess land suitability, the user-inputted growth conditions include factors such as weather, relief, uncontrollable and uncorrectable factors, controllable factors, and factors with correctable effects. The overall land suitability class will be determined based on these factors. To modify land location data, users are required to input a request body and the ID of the land they want to modify. Changes that can be made with this API are limited to modifications in the land name and land location data. Additionally, there is authorization in the API to ensure that the land data being modified belongs to the user initiating the change and not to another user. Next, to delete land location data, users are required to input the ID of the land they want to delete. The deletion process also includes removing all observations associated with that land. Consequently, all user-input land suitability calculations will also be deleted. This API also includes authorization, which functions similarly to the API for making changes to land location data. Subsequently, to add a new

observation, users must input the ID of the land to which the observation will be added. Users need to provide the observation date and all the growth condition data in the request body. If the user does not input the observation date, it will be filled with the timestamp at the time of the user's call. To make changes to users' land observation data, the same request body as the one used to add observation data is required. Changes that can be made with the API to modify observation data include altering the observation date along with modifying all growth condition data. If there are changes to the growth condition data, the backend module will reevaluate the land suitability for that observation data. This API also includes authorization, functioning similarly to the API for adding observation data.

Furthermore, to delete observation data, users are required to input the ID of the observation they want to delete. Like the API for modifying observation data, this API also includes authorization, functioning similarly to the API for modifying that observation data.

3.3.4.1 Geometry subgroup

This subgroup of APIs contains all APIs related to land data from the SPT (Surat Pemberitahuan Tanah or Land Notification Document). Similar to the user API subgroup, generally, this API subgroup also has two main focuses. These primary focuses include processing land data from the SPT and downloading specific parts of that land data. The API for obtaining all locations (provinces and regencies/cities) that differ in the SPT land data does not require a request body, and this API also does not have authorization, meaning all users, including those who have not authenticated, can use this API.

The API to retrieve all land data from the SPT, along with all observations and their suitability classes, also does not require a request body. However, this API includes queries that users can use to filter the data they want to obtain. These queries include filters for province, regency/city, and land ID. Additionally, this API does not require authorization.

To add land data from the SPT, users need to input several files, namely the shp, shx, dbf, prj, and xlsx files. Additionally, users also need to input location data in the form of province and regency/city codes. In general, the process of adding SPT land data is like adding users' land data, but the source of growth condition data when adding SPT land data comes from the Excel file provided by the user. Another difference is that SPT land data has some parts that are not present in users' land data. These parts include geometry and soil characteristics.

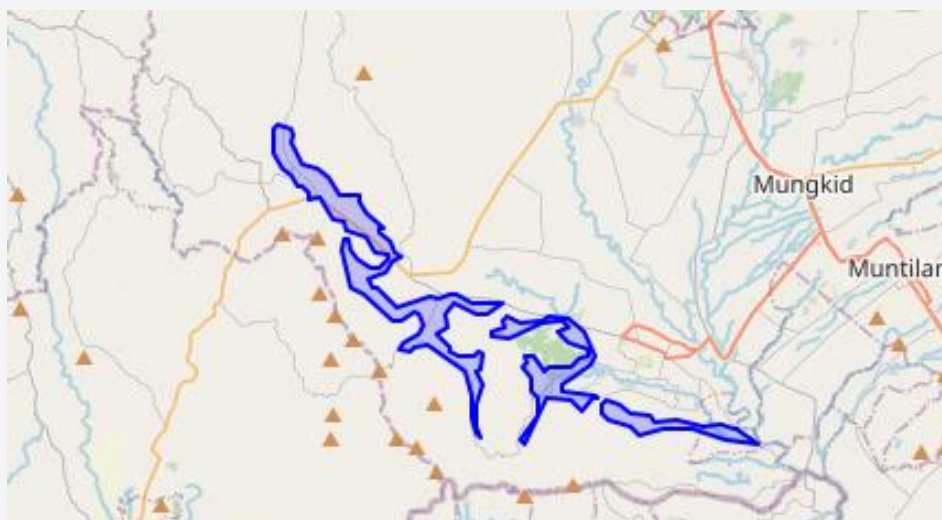


Figure 6: Visualization of geometry in one of the SPT data

When adding SPT land data, the suitability class of the land is not immediately determined. This is because the weather data used to determine the land suitability class is either average data or cumulative data for a month. However, weather data obtainable from APIs such as Visual Crossing or other weather APIs is usually daily data. Therefore, it is necessary to fetch weather data for that land over the next month before the suitability class of the land data can be determined.

In this section, there is a process for separating geometry data that has more than one polygon. The separation is done using the `ST_GeometryN` function from PostGIS. This separation results in each polygon having one record in the database to facilitate the determination of the centroid of that polygon. Figure 6 displays the visualization of geometry for SPT number three, showing three polygons present in the SPT data. If this data is not separated, the determination of the centroid in the next step will result in incorrect values.

To perform the separation of the geometry data, the `ST_GeometryN` function from PostGIS is used. This function returns the geometry of the first shape (polygon, point, line, etc.) from the input geometry data. In Image 30, SPT number three has three records because the separation process creates one record for each polygon in SPT number three. Next, to delete SPT land data, users need to input the region code of the SPT land they want to delete in the request body. The intended code is the BPS code entered when the user adds SPT land data. This API includes authorization, allowing only users with admin roles to delete SPT land data.

There are three APIs for downloading data, including an API for downloading daily weather data,

soil characteristic data, and a shapefile of SPT land data. The response from these APIs is not JSON but binary files that the user wants to download. This is designed to facilitate frontend developers, so they do not have to handle the response from the backend's file download, as the file will be automatically downloaded by the user.

3.3.5 API group for users

Generally, the APIs in this group serve to register and process user data. Before being recognized as a registered user, individuals must verify their email and wait for their account to be verified by an administrator before it can be used. Once the user's account is verified by the admin, the account will be active for one year. To register, users need to provide personal information and information about their institution. Users can choose to enter the institution's ID or enter the name and address of the institution. Meanwhile, other APIs handle essential user-related tasks, including extending the active period, resetting passwords, and changing passwords. Additionally, there are APIs for processing user data, such as activating users, resending verification emails, and retrieving all user data. APIs for processing user data are accessible only to users with admin roles.

3.3.6 Weather scheduler

The weather scheduler created in this research is used to retrieve daily weather data from two sources: Visual Crossing for temperature, precipitation, and solar radiation, and the BMKG data center for solar radiation data. To retrieve data from the BMKG data center, registration is required beforehand. The process for retrieving daily weather data is illustrated in Figure 7.

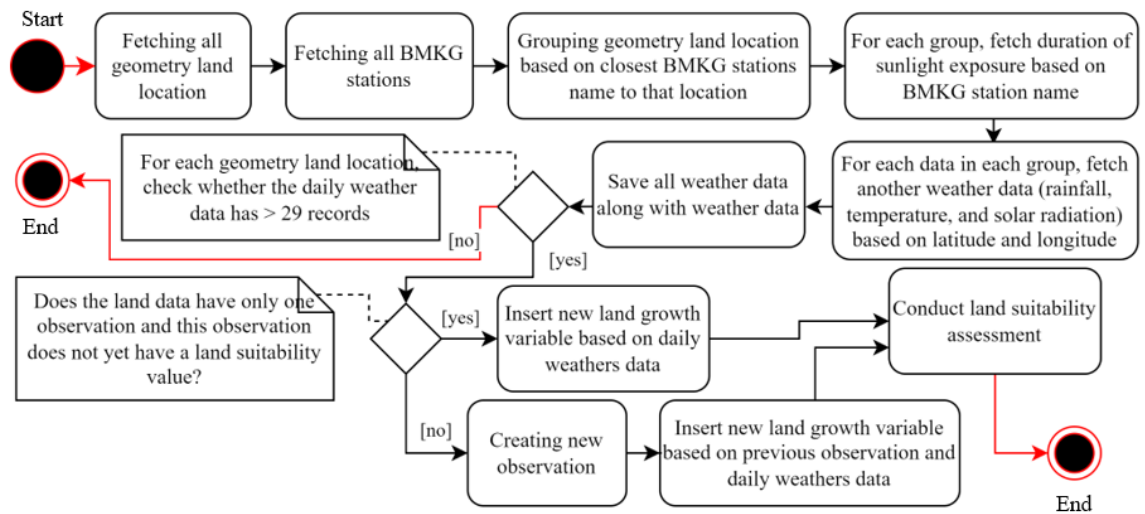


Figure 7: Activity Diagram for Daily Weather Scheduler

The flow depicted in Figure 7 will be executed every day at 23:00 WIB (Western Indonesian Time). Before retrieving solar radiation data from the BMKG data center, all available measurement stations are initially collected. The retrieval of BMKG measurement stations is done by requesting the BMKG data center site. Once all available stations are obtained, the data of SPT land is grouped based on the nearest station to that land. Subsequently, the retrieval of solar radiation data is conducted. Following that, weather data is obtained through the Visual Crossing API, and all this data is stored in the database. Then, if the weather data for a particular SPT land exceeds 29 entries, the suitability class for that SPT land is determined.

3.4 Testing and Deployment of Backend Modules

Testing was conducted for all APIs developed in this research, using the black box testing method. The testing occurred three times: first by the backend developer in the development environment and later by the frontend and mobile developers in the production environment. After testing in the production environment, the test data was removed to avoid interference with actual data.

Sixty-eight scenarios were utilized for testing. Within these scenarios, two test flows were examined: the positive flow and the negative flow. The positive flow is conducted to verify if an application performs as expected with valid input data. Conversely, the negative flow tests whether the application behaves appropriately when subjected to negative input, validating its response against invalid data. Among the 68 scenarios, 10 scenarios are designated for each of the area location and growth variable API groups.

Additionally, 26 scenarios are allocated for the land location API group, 24 scenarios for the user API group, and 1 scenario for the scheduler. The results showed that each scenario achieved the expected outcome (success). Deployment was done using containerization with Docker to an on-premises server owned by the research team. The use of Docker aims to avoid mixing various dependencies required by the backend modules. After deployment, domain name configuration was performed, including adjustments to the DNS records of the used domain name.

4. Conclusion and Future Research

This study has successfully developed features in the backend module for the garlic land suitability decision support system, considering uncontrollable and uncorrectable factors, correctable factors, and controllable factors. The research also implemented program code to separate SPT data with more than one polygon, facilitating the determination of the polygon's centroid. A scheduler was created to automatically fetch the latest solar radiation data from the BMKG data center for each SPT land in the backend module. The backend module was redeployed to an on-premises server, enabling the use of all features related to file storage. All features were tested using black box testing with 68 scenarios, and the results were as expected. Pagination has not been implemented for all existing APIs in this research, meaning all APIs for data retrieval return all available data. This could impose a burden and impact the speed of the backend module when handling a large amount of requested data. Pagination should be considered, especially if the database contains a substantial amount of data.

Additionally, not all regions in the BMKG data center have measurement stations, so the obtained historical solar radiation data may not be representative of the land's location. In future research, interpolation will be performed using historical solar radiation data from the nearest measurement stations in the land's region to obtain more accurate data for areas far from BMKG measurement stations.

Furthermore, in SPT data, there is a possibility that the polygon can be very large (across districts or regencies), resulting in centroid points with considerable distances from other locations within the polygon. In the next research, a check and determination of an upper limit for polygon size will be implemented. If a polygon exceeds this limit, it can be divided into smaller polygons or a grid can be created on the large polygon, enabling the determination of centroids in the grid squares. Additionally, alternative options need to be explored to obtain more accurate historical solar radiation data with better data availability than the BMKG data center.

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