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Development of Precision Agriculture Models for Medium and Small-Scale Agriculture in Indonesia

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Abstract. The purpose of this research is to build a model of precision agriculture to increase the productivity of medium and small-scale agriculture in Indonesia. This research used a descriptive method by conducting a literature study on the concept of precision agriculture and analysis of data related to agriculture in Indonesia. Extreme weather changes in Indonesia have an impact on the decline in agricultural production. While an understanding of environmental conditions is the primary key to agriculture, this research explained what data is needed in precision agriculture, how to obtain and process data, also explained how to visualize information through geographic information systems. This research also conducted an assessment of the built model. The assessment process is implemented by analysing the suitability of the model based on farmers' needs. The results of this study concluded that the model can be developed in the implementation phase. This research is expected to provide a clear explanation of the system requirements and also can reduce risk at the system development and implementation stage.

1. Introduction

Agriculture in Indonesia is dominate with medium and small-scale agriculture[1] because most of the farmers in Indonesia have been farming individually in traditional methods[2]. It is tough for Indonesia to meet domestic food needs. It is proven that until 2018 Indonesia still imports agricultural products from other countries[3]. Increasing the population in Indonesia makes the need for food increases. In order to meet food needs, the evolution of the agricultural sector is needed. Evolution requires not only better farming methods but also an understanding of ecosystems[4]. Precision agriculture is management concepts by using accurate agricultural land data by using IT technology[5]. The land management process in precision agriculture is done by measuring and observing the variables that exist in the agricultural field. Precision agriculture includes the use of global positioning systems (GPS), Geographic Information systems (GIS), remote sensing devices, sensors, and other technologies that can retrieve data directly from the agricultural land[6]–[10]. Precision agriculture is very closely related to the use of GPS and GIS for agriculture. Precision agriculture requires accurate agricultural land positioning[11]. By knowing the accurate position of the agricultural land, farmers will get accurate data about land conditions, weather conditions, and the latest soil conditions through images taken from satellites.

To help farmers, a precision agriculture system is developed based on geographical information systems. In this study, a precision agriculture model is proposed to increase the productivity of medium and small-scale agriculture in Indonesia. Understanding the environment is a significant factor for agriculture[4]. In the past, farmers could estimate the weather, also can determine when the planting season begins with conventional methods. Now, it is complicated to predict the weather using such a method because of global warming. Global warming makes it difficult for farmers to predict the weather. The developed system has been able to monitor the actual condition of agricultural land. The land condition can be monitored using sensors connected to the microcontroller. The user can get data in real-time[12]. There are some researches about the use of technology in the agriculture field. One of the previous studies was conducted by Foughali et al. [13]. In this study, farmers can monitor soil conditions while simultaneously being able to adjust the irrigation level in the soil precisely. Other studies conducted by Nandukar et al. [14], in this study, a precision agriculture system design was carried out by optimizing the wireless sensor network as a medium for sending data. There are also other studies focusing on one part of precision agriculture as data processing conducted by Bendre et al. [15] and camilli at all[16]. There is no specific research that implements all the parameters required by plants. Different from previous research, the model that was built for agricultural precision in Indonesia combines GPS, Remote sensing devices, and IoT devices. First, the farmer will mark the location of their agriculture area in polygons shape. Then the remote sensing device will take periodic land pictures and save it as time-series data. The monitoring process uses sensors to find out real-time of the condition of the agricultural area. The collected data will be stored in a database. Data will be processed and used as input in decision making.

The application of precision agriculture will be able to produce accurate and relevant information. The information is used for consideration of when to start the planting season and a reference in managing agricultural land. Also, with accurate information, the time spent on managing agricultural land can be reduced. This system can map the condition of plants, and the distribution of pests so that the use of fertilizers and Pesticides becomes more efficient. This system is expected to be able to increase Indonesia's agricultural productivity.

2. Method

The method used in developing this precision agriculture model is descriptive [17], [18]. This study consists of 4 stages. The first stage is to formulate the problem. In this stage, this study has a clear scope. In the second stage, data collection and analysis are carried out. In this stage, it is defined what data is needed on a precision agriculture system, as well as an analysis of the collected data. In the third stage, a system model based on the software engineering concept is developed. In the final stage, the assessment of the model using ISO 9126 is carried out. Figure 1 explains the stages of the method used.

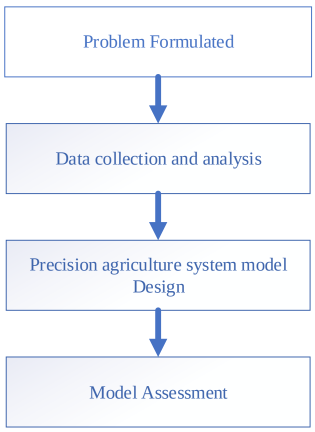

Figure 1. Research Methodology

3. Results and Discussion

The developed system has several inputs, land mapping using GPS, land image using a remote sensing device also uses a microcontroller that is connected to the sensor to retrieve data in real-time. The stored data consists of 3 types of data. The three types of data are spatial data, time-series data, and attribute data stored in the table. Spatial data is data that have a georeferenced, usually used to store data that include location or area information related to its coordinates on earth[19]–[22]. The second type of data is time-series data. Time series data is obtained from sensor monitoring results in real-time. The last type is in the form of attribute data. The attribute data used is agricultural data taken from the Indonesian open data site.

Data that has been stored and then analyzed and processed using the statistical method or data mining method[13], [20], [23]. This section can be said to have intelligence so that it can perform data processing and provide expected information for farmers. The last part is output. In this system, an easy-to-use and easy learning interface are designed because most of the farmer in Indonesia is not familiar with complex Computer system[24]. Figure 2 explains the details of precision agriculture system components.

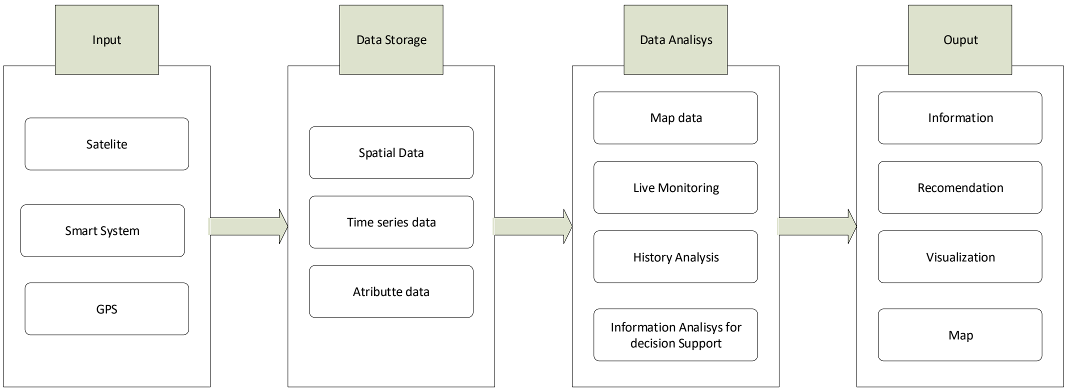

Figure 2. Precision agriculture system component

Business process modeling describes existing activities in the system[25], [26]. Business process modeling can also describe the flow of procedures on the implemented system. Figure 3 explains the flow of precision agriculture system activities.

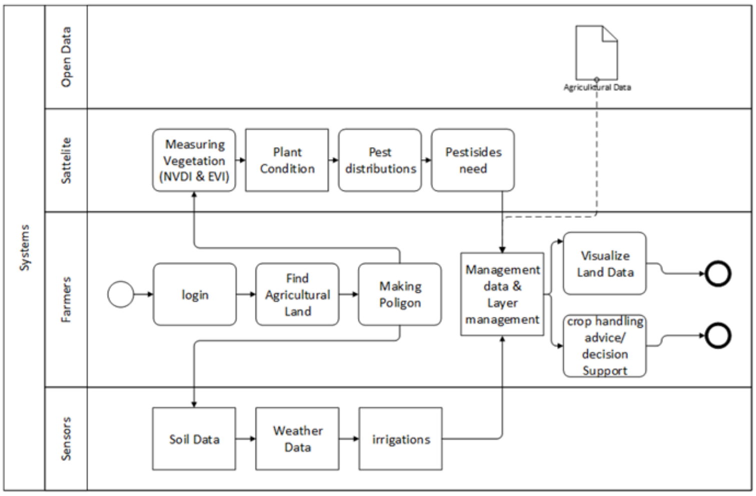

Figure 3. Flow of precision agriculture system activities

This precision agriculture system was built on a web-based system to maximize the visualization of information and also have the advantage of distributing information[27]. Web-based systems can receive data from the field more accessible and faster. The web-based system also supports integration with the APIs needed in precision agriculture systems. Figure 4 explains the architecture of a precision agriculture system that was built.

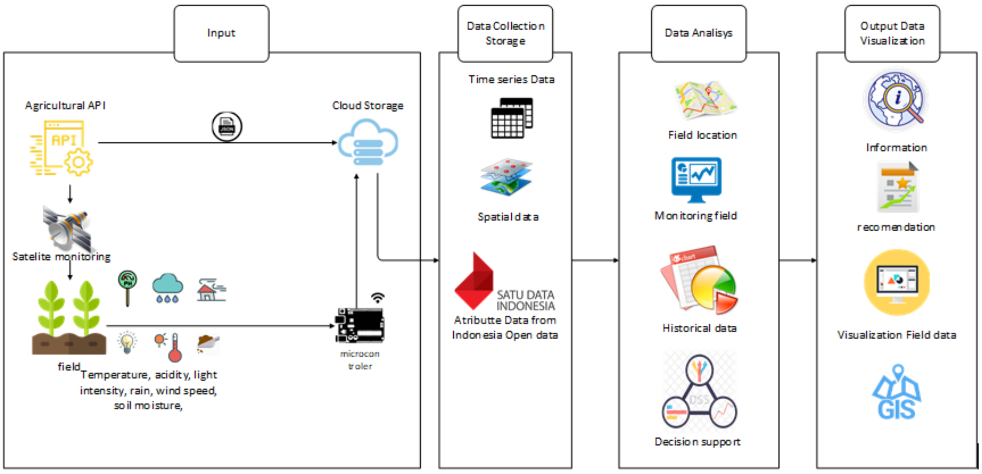

Figure 4. Architecture of precision agriculture system

The system helps farmers managing agricultural land. Good interface design is needed for farmers because farmers have the weak ability to operate computer equipment[28]. Therefore, the system is designed based on the needs of farmers. In order to meet the farmer's needs, a software requirements Specification analysis was conducted[29]–[31]. Software requirements specifications consist of Functional Software Requirements Specifications (F-SRS) and Non-Functional Software Requirements Specifications (NF-SRS). Table 1 and Table 2 explain the Software Requirements Specifications for the implemented system.

Table 1. Functional Software Requirements Specifications

Code	Requirement Description
SRS-F-01	Software can share access rights
SRS-F-02	Retrieve data from remote sensing device and sensors
SRS-F-03	Managing data in storage/ database
SRS-F-04	Marking and managing user agricultural field
SRS-F-05	Managing map of agriculture
SRS-F-06	Visualize plant data
SRS-F-07	Visualize climate data
SRS-F-08	Visualize potential area of agriculture
SRS-F-09	Providing data analysis function
SRS-F-10	Providing advice for commodity selection
SRS –F-11	Providing recommendation for field handling

Table 2. Non-Functional Software Requirements Specifications

Code	Requirement Description
SRS-NF-01	Web- based system
SRS-NF-02	Requires a good internet connection
SRS-NF-03	Using sensors and connected with microcontroller
SRS-NF-04	The user is farmer
SRS-NF-05	Using agriculture API to Retrieve data from remote sensing device

Non-Functional Software Requirements Specifications are related to components needed in the system[29]. This includes hardware, software, and user requirements. Table 3 explains the results of the hardware requirements analysis.

Table 3. Hardware requirement analysis

1	Processor	Quad Core Processor
2	Memory	Min. 4 GB
3	Storage	Min. 1 GB free space
4	Display/ screen resolution	1366 x 768 pixel

Understanding software requirements is as important as understanding hardware requirements[29]. Software is used as a bridge to connect hardware and users through the user interface. Software is also used as a tool for data management. Software requirements analysis is divided into two parts. One is the software requirements to build a system. Another is software requirements for users. On the user side, the precision agriculture system only requires a web browser. Table 4 explains the software requirements analysis to build a system.

Table 4. The Software Requirements Analysis To Build A System.

No	Software Name	Function
1	Sublime Text	Source code editor
2	QGIS	Map editor
3	PostgreSQL	Database Management System

Users of the system built are farmers. For understanding users, a user analysis is performed to build the User Specification requirements. Table 5 explains the User Specification Requirement system that was built.

Table 5. User Specification Requirement

No	Specification	Requirement
1	User	Farmers
2	Privilege	Manage agricultural data
3	User Experience	User have the ability to use the website, have low-moderate system experience, have none - moderate computer literacy
4	User Jobs & Task	Discretionary type of system use, occasionally frequency of use, predictability of task being automated
5	User Physical Characteristic	have good eyesight, has no disability
6	User Psychological Characteristics	Have Neutral-Positive attitude, have moderate-high Motivation.

Use Case diagrams are used to describe interactions between actors and systems. The use case diagram also explains what functions exist in a system as well as which actors have access to use these functions. Figure 5 explains the use case of the implemented precision agriculture system.

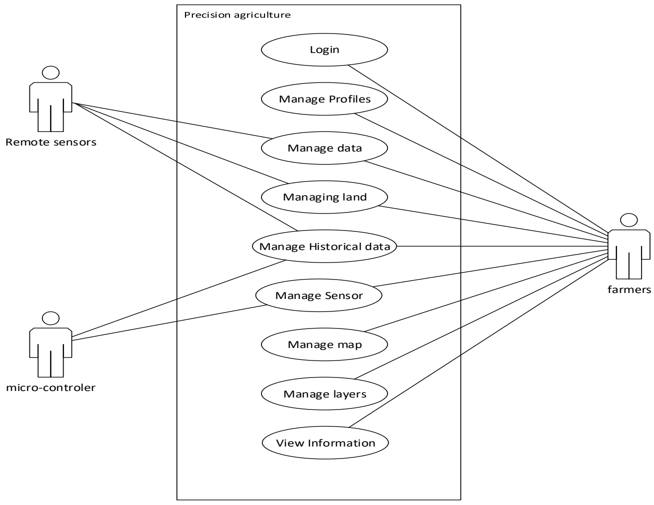

Figure 5. Use Case Diagram

Assessment of the model is needed to ensure the quality of software. [30], [32]. The assessment is based on the software quality model on ISO / IEC 9126 [33], [34]. Model assessment is done by analyzing aspects that exist in ISO 9126. The indicators contained in ISO / IEC 9126 are functionality, reliability, usability, efficiency, maintainability, and portability. In the model testing phase, the test is conducted by carrying out two stages. The first stage is the validation stage. The validation process is carried out to ensure that all requirements are written in the software requirements specification. The second stage is verification. This stage ensures that the requirements written in the software requirements specification are correct. Farmers, as users are involved in the assessment process. Based on the results of validation and verification, it can be concluded that the built model has fulfilled the needs of the user and can be developed in the implementation phase.

4. Conclusion

This study provides an overview of precision agriculture for medium and small-scale farmers in Indonesia. The developed model allows farmers to make polygons to mark the location of their agricultural land. After that, the farmer can find out the actual condition of the farmland based on input from the micro-controller as well as from the remote sensing device. In this model, it is explained how to obtain data, process data into information then visualize the information to farmers. The assessment of the model is done by validating and verifying the model by involving farmers as users. Based on the results of the assessment, an implemented model was under the farmer's needs and can be continued to the next stage. The next stage is a software development and system implementation. With this model, the risk in software development can be minimized.

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