

Development of Spatial Database System Based on Cloud Computing Remote Sensing for Monitoring of Oil Palm Plantation in Indonesia

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Abstract

Oil palm plantations provide the highest amount of foreign exchange earnings for the Indonesian government. However, according to the Indonesian Ministry of Agriculture, the foreign exchange has dropped to 20%. Therefore, to increase oil palm productivity, the President Republic of Indonesia issued Instruction No. 6 of 2019 regarding National Action Plan for Sustainable Oil Palm Plantation 2019–2024, one of the actions to increase national oil palm productivity is strengthening data infrastructure. Considering that the oil palm plantations in Indonesia are highly extensive and spread across almost all parts of Indonesia, cloud computing remote sensing technology is a satisfactory solution for monitoring oil palm plantations. This study aims to develop a spatial database system for monitoring oil palm plantation in Indonesia based on cloud computing remote sensing data. The methodology includes user needs and spatial data identification as Indonesian regulations, combined with focus group discussions, normalized geographic data normalization, and spatial database development using conceptual, logical, and physical models and system design and data visualization. The resulting spatial database system for monitoring oil palm plantations in Indonesia based on cloud computing remote sensing has been constructed by leveraging data saved in the cloud on ArcGIS Living Atlas of The World. The data recorded in ArcGIS Online are then linked to a visualization system created using the ArcGIS operation dashboard. The dashboard has been developed based on user needs and displays information about oil palm plantation age, administration boundaries, rainfall, terrestrial ecosystems, hot spots, and weather conditions.

Keywords: Cloud Computing, GIS, Oil Palm, Remote Sensing, Spatial Database

1. Introduction

The oil palm (*Elaeis Guineensis*) is a palm tree often cultivated throughout Southeast Asia, particularly in Malaysia, Indonesia, and Thailand. It is used for producing cooking oil, mechanical oil, and fuel, all of which are widely used in everyday life and business [1] and [2]. Palm oil derived from seeds or parts of a hard mesocarp shell yields approximately 80% saturated fat, which may be used as a raw material in the *oleochemical* industry to create soaps, cleansers, and various other products [3] [4] and [5]. Moreover, oil palm has a high potential for future usage as a biofuel [6]. Commercial plantation firms are encouraged to grow oil palm plants on a large scale owing to high yields and low production costs

associated with oil palm [7]. Oil palm agriculture has tremendously expanded on account of the rising global need for food and fuel [8], making palm oil one of the most consumed vegetable oils worldwide [9].

In Indonesia, a large area is under oil palm plantation (approximately 16.8 million ha) and provides the highest foreign exchange for the government [10]. However, the Indonesian Ministry of Agriculture (2019) reported that the foreign exchange earned from oil palm has dropped to 20%. This is because of the large area under old plants, which are less productive, and many diseased plants.

Therefore, to increase oil palm productivity, the President of the Republic of Indonesia issued Instruction No. 6 of 2019 regarding National Action Plan for Sustainable Oil Palm Plantation 2019–2024, in which one of the actions to increase national oil palm productivity is through strengthening data and infrastructure [11]. According to Presidential Instruction No. 6 of 2019, oil palm productivity must be supported by components of strengthening data and infrastructure for effective oil palm management [11]. This is necessary in terms of strengthening data and information on oil palm plantations, referring to the One Map Policy as an effort to realize a map with one reference and one standard as per Presidential Regulation Number 8 of 2016 issued on February 2, 2016. Therefore, to support Presidential Instruction No. 6 of 2019 regarding oil palm management and Presidential Regulation Number 8 of 2016 regarding the One Map Policy, needed technology for collecting and using national oil palm data.

Since 1990, remote sensing satellite imagery data has been used to monitor oil palms [12] [13] and [14]. According to [15], remote sensing technologies have now entered the era of big data. Remote sensing big data have been attracting increasing interest from governments, businesses, and academic sectors [15] and [16], commonly referring to the 3Vs, i.e., extraordinary growth in data Volume, Velocity, and Variety [17] and [18]. However, three prevalent challenges, namely, big data computing, big data cooperation, and big data methodology, have been described in accordance with the trinity of understanding big data in remote sensing [16]. According to [19], big data technologies, geo-artificial intelligence, and cloud computing can be used with the precision agriculture approach to make right management decisions aimed at increasing oil palm production. Furthermore, precision agriculture uses AI to assist in the identification of pests, insufficient plant nutrition in farms, among others. It uses data recorders, yield monitors, GPS, geographical information system (GIS), Internet of Things (IoT) capabilities, sensors, and other devices. These devices are attached to aerial equipment for data collection [9].

Recently, cloud computing and remote sensing data have emerged as transformative tools for monitoring extensive agricultural areas, showing significant potential in enhancing the efficiency and precision of agricultural practices [15] and [16]. In a notable study, researchers [20] delved into the smart farming concept by integrating Internet of Things (IoT), mobile, and cloud technologies, harnessing the power of big data analytics to optimize farming operations. This approach has opened new avenues

for real-time data collection and analysis, significantly boosting productivity and sustainability in agriculture. Further advancements have been made as detailed in [21], which explored the burgeoning role of IoT in enhancing smart agricultural practices. This research also highlighted the innovative application of digital twins in agriculture, providing detailed simulations that aid in decision-making and yield prediction, thereby enhancing harvest strategies [22]. Concurrently, researchers in [23] introduced GeoFarmer, a bespoke monitoring system designed to streamline agricultural project development. This system leverages geo-spatial data to provide actionable insights, improving crop management and resource allocation. Additionally, the study [24] investigated the use of IoT technologies to develop automated irrigation systems, demonstrating how connectivity and automation can lead to more precise water management, reducing waste and ensuring optimal growth conditions. Meanwhile, [25] examined the potential of green IoT technologies for intelligent agricultural monitoring. This research focused on using predictive intelligence tools, powered by machine learning algorithms and prototype analysis, to forecast agricultural outcomes, thereby enabling proactive management of farming operations. The study also surveyed the latest technological developments, indicating a growing trend towards more interconnected and intelligent agricultural ecosystems.

Although there have been significant advancements in technology, the implementation of these technologies in many agricultural areas has brought prominence to specific challenges, especially in the monitoring of oil palm. For example, [26] detailed the creation of an oil palm database utilizing high-resolution images from Google Earth, the Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR), and Landsat optical images. This database aims to enhance the precision and scope of monitoring, yet the development of information systems that cater to specific user needs and effectively harness the capabilities of big data and remote sensing in oil palm cultivation still encounters notable limitations. These challenges include integrating vast amounts of data, ensuring data accuracy, and customizing applications to suit specific agricultural conditions and user requirements. Transitioning from the broader technological challenges to specific factors affecting production, the age of the oil palm emerges as a critical determinant. Several studies [1] [3] [27] and [28] have identified oil palm age as a significant influencer of fruit bunch yield.

Information on oil palm age is an effective yield indicator because it affects the quality and quantity of fresh fruit bunches [28]. Additionally, age information is crucial in precision agriculture for identifying anomalies within specific oil palm age groups, planning counteractive management strategies, and optimizing management resources [29]. In other contexts, oil palm age information is necessary for tax estimation, replanting time estimation, and disease diagnosis [1].

Moreover, a major issue impacting oil palm productivity in Indonesia, as noted by the Indonesian Ministry of Agriculture, is the 20% drop in foreign exchange earnings. This significant decline underscores the importance of management support and the availability of relevant data to enhance oil palm productivity [30]. Addressing these challenges is essential for bolstering the sector's economic resilience and sustainability. In response to these challenges, this study aims to develop a spatial database system for monitoring oil palm plantations in Indonesia based on cloud computing and remote sensing data. The spatial database system will support Instruction No. 6 of 2019 issued by the President of the Republic of Indonesia regarding the National Action Plan for Sustainable Oil Palm Plantations 2019–2024. This initiative aims to make oil palm plantation management in Indonesia more efficient, effective, and productive."

2. Method

The methodology incorporates user needs and spatial data identification as Indonesian regulations, combined with focus group discussions, spatial data normalization, development of spatial databases using conceptual, logical, and physical models, and then system design and data visualization (see Figure 1).

2.1 User Needs and Spatial Data Identification

The process of assessing user needs is designed to ensure that the information built for oil palm plantations is based on user needs. This process has several stages [31] and [32]:

a. Identification of User Needs on Indonesian Oil Palm Laws and Regulations.

Data on oil palm plantations were identified by analyzing the regulations and standards on oil palm plantations. The following list presents the amount of data points that may be determined based on a review of the statute.

- Law Number 39 of 2014 concerning Plantations.
- Government Regulation of the Republic of Indonesia Number 23 of 2021 concerning Forestry Administration.

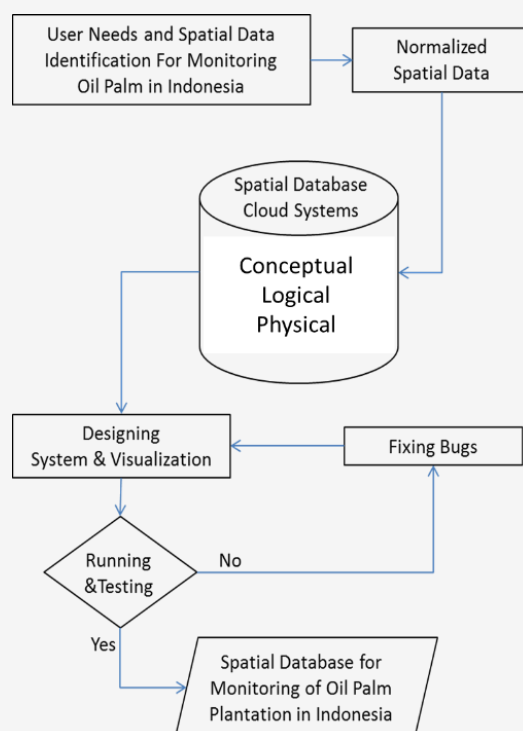


Figure 1: Development of spatial database design using conceptual, logical, physical stages, and visualization

- Government Regulation of the Republic of Indonesia Number 26 of 2021 concerning Implementation of the Agricultural Sector.
- Regulation of the Minister of Agriculture Number 18 of 2016 concerning Guidelines for Rejuvenating Oil Palm Plantations.
- Regulation of the Minister of Forestry Number P.56 Minister of Forestry of 2006 concerning Zoning Guidelines for National Parks.
- Regulation of the Minister of Home Affairs Number 76 of 2012 concerning Guidelines for Confirming Regional Boundaries.

b. Identification of User Needs on Focus Group

Discussion

User needs for this monitoring application were discussed in a group discussion forum (FGD) with the Indonesian Oil Palm Research Center (IOPRI) and an agriculture office. The discussion was conducted by inquiring about the information needed for oil palm plantation management in Indonesia, such as information on climate, land, and harvest management. The necessary data will be later provided on a monitoring program dashboard [31]. The process of identifying data from laws and regulations and research results produced 20 of data categories.

2.2 Data Normalization

Data normalization is performed by checking each piece of information that came from analyzing the laws and rules and the results of the earlier study. If the same data are found, they will be considered only once to avoid data duplication [33]. The 20 data are produced after identifying data from laws, rules, and research findings. However, duplicates still exist; consequently, the data normalization method must be used to eliminate the duplicates and create 7 data categories.

2.3 Spatial Database

The oil palm plantation data structure is created by grouping the data into tables based on layers that correspond to data type. The data structure in this study divides data into three categories: basic data, thematic data, and additional data [32] and [34], and the spatial databases are developed based on a conceptual model, logical model and physical model. The conceptual model is designed by determining the relationship between entities, The conceptual model is designed by determining the relationship between entities by determining the primary key and foreign

key to produce a conceptual spatial database model [35] and [36].

The logical model is developed by describing the relationships between entities while constructing the spatial database for oil palm farms in Indonesia. Relationships between spatial databases can be one-to-one (1:1), one-to-many (1:N), or many-to-many (M:N) [36]. The physical model database is designed by identifying the data attributes using an attribute table and the contents of the attributes [31] and [37]. The attribute table contains Name, Format, Length, and Description. The field name contains the name of the attribute in a spatial database. The format specifies field format. Text, integer/long integer, double, geometry, or object id can be used as field formats.

2.4 Design Systems and Visualization

This application was developed using a customized ArcGIS process with a prototype approach, where modifications must be made periodically, specifically by means of requirements analysis, application design, and application testing (see Figure 2) [38] and [39]. The suggested system was built to facilitate the collection, storage, processing, and analysis of geographical data using a web interface [40]. Although Esri's commercial products have been used for implementation, open-source solutions may provide the same outcomes.

3. Results

3.1 Spatial Data Identification

The data used in this investigation and submitted to the spatial data repository are presented in Table 1. The development of the IoT is providing plantations with copious amounts of data that can be accessed in batches in real time [41]. The oil palm data used in the application dashboard include:

3.1.1 Oil palm age

Oil palm age data are based on Landsat 8 satellite images and are grouped into 3 categories: 0-4 years (young), 5-25 years (mature), and >26 years (old) [1]. These data may be used to provide information on the age distribution of oil palm trees in each region of Indonesia.

3.1.2 Administration boundary

The administrative boundary data collected from the Geospatial Information Agency can be used to define oil palm plantation borders in each Indonesian region/province. These data could be used to determine the spread of oil palm in each province.

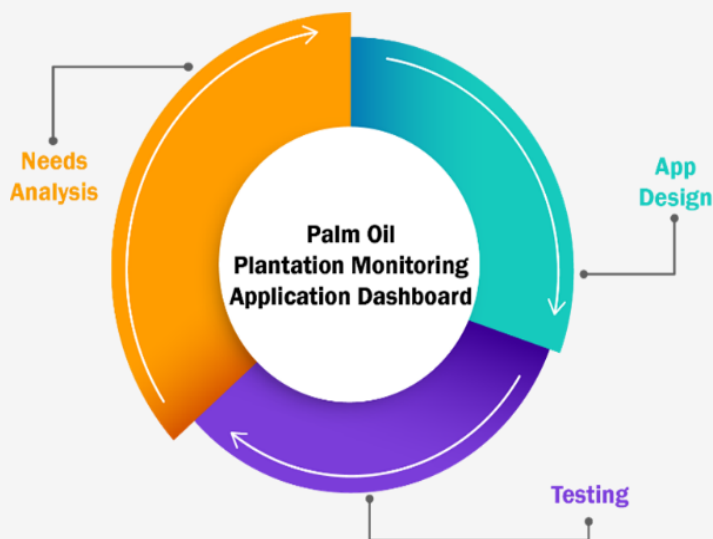


Figure 2: Design system and visualization

Table 1: Data source

| No. | Type of Data | Source |
|-----|-------------------------|---|
| 1. | Oil palm age | Oil palm Phenology Model Based on Remote Sensing [1]. |
| 2. | Administration boundary | The Geospatial Information Agency: https://tanahair.indonesia.go . |
| 3. | Rainfall | The Meteorology, Climatology, and Geophysics Agency: https://dataonline.bmkg.go.id |
| 4. | Terrestrial ecosystem | <i>ArcGIS Living Atlas of the World:</i> https://landscape12.arcgis.com/arcgis/rest/services/World_Terrestrial_Ecosystems/Imag_Server |
| 5. | Weather station | <i>ArcGIS Living Atlas of the World:</i> https://services9.arcgis.com/RHVPKKiFTONKtxq3/arcgis/rest/services/NOAA_METAR_current_wind_speed_direction_v1/FeatureServer |
| 6. | Hotspot | <i>ArcGIS Living Atlas of the World:</i> https://services9.arcgis.com/RHVPKKiFTONKxq3/arcgis/rest/services/MODIS_Thermal_v1/FeatureServer |
| 7. | Weather imagery | <i>ArcGIS Living Atlas of the World:</i> https://earthlive.maptiles.arcgis.com/arcgis/rest/services/GOES/GOES31D/MapServr |

3.1.3 Rainfall

On an average, the rainfall data obtained from Meteorology, Climatology, and Geophysics Agency are taken every week. These data can be used to estimate rainfall in oil palm plantations every week, and hence oil palm farmers can use these data as a reference for determining the fluctuations of water discharge in drainage in an oil palm plantation [42]. Water discharge in an oil palm plantation may affect soil fertility, which in turn can also affect production of fresh fruit bunches.

3.1.4 Terrestrial Ecosystem

The terrestrial ecosystem data were collected from ArcGIS Living Atlas of the World, which was

created by many international organizations such as the United States Geological Survey, The Nature Conservancy, and Esri. These data can be automated and updated in real time over a period of approximately a year, and may clearly illustrate surface conditions with a resolution of 250 meters. The three categories are climate, landform, and land cover. The use of terrestrial ecosystem data can assist the public in understanding the ecosystems prevalent in each location. For example, while planning to establish an oil palm plantation, one must understand the circumstances of the location for ensuring favorable conditions for the plantation.

3.1.5 Weather station

The weather station data were collected from ArcGIS Living Atlas of the World; these data are provided by National Oceanic and Atmospheric Administration (NOAA) and are updated in real time every 1 hour. These data are displayed on the dashboard application as information, which ranges from surface temperature to rainfall in a certain location. According to [43], several techniques are available for increasing crop and agricultural system resilience to climate change. However, technological requirements, as well as extension and training approaches, must be thoroughly examined to completely understand the role of a technology in adaptability [44]. Accordingly, agricultural big data are crucial for developing climate change adaptation methods [45].

3.1.6 Hotspot

The hotspot data were collected from ArcGIS Living Atlas of The World and were created by NASA's Earth Observing System Data and Information System. These data were collected using the satellites Aqua and Terra, which monitor thermal activity on the earth's surface. Thermal activity recorded will considered a hotspot or fire location. Within 2-4 hours, these data will be updated in real time. Although the satellite detects significant thermal signals, not all reported thermal activity represents a hotspot. This information is used to track hotspots or fires that occur in a certain area. This information is also valuable for monitoring oil palm farms in Indonesia, such as in terms of frequency of fires,

which destroy oil palm plantations and renders them permanently unproductive.

3.1.7 Weather imagery

The weather satellite imagery data were collected from the ArcGIS Living Atlas of the World and were created by NOAA's Visualization Laboratory. These data were obtained by merging data from the NOAA satellites GOES-East and GOES-West, as well as the Japan Meteorological Agency's satellite Himawari, with a resolution of 1.5 kilometers per pixel. These data may be automatically updated in real time throughout the 24-hour period. These data are displayed as information on the application dashboard to monitor local weather conditions.

3.2 Spatial Database

Spatial database is a data management method that accommodates a collection of geospatial information in the form of spatial data (see Figure 3) [31]. Most geographic data consist of multiple data categories that are too complex for conventional databases to efficiently manage [32]. In this study, seven spatial data will be stored in a GIS database. Generally, GIS database processing involves storing the data entered in the database, manipulating the data as needed, and retrieving data to be presented as the output of the application [35]. WebGIS, similar to the GIS desktop program, requires database support for graphical data, including vector and raster, and attributes such as tables that link to graphical databases. Database management systems (DBMS) are now used to manage databases for GIS applications [32] and [35].

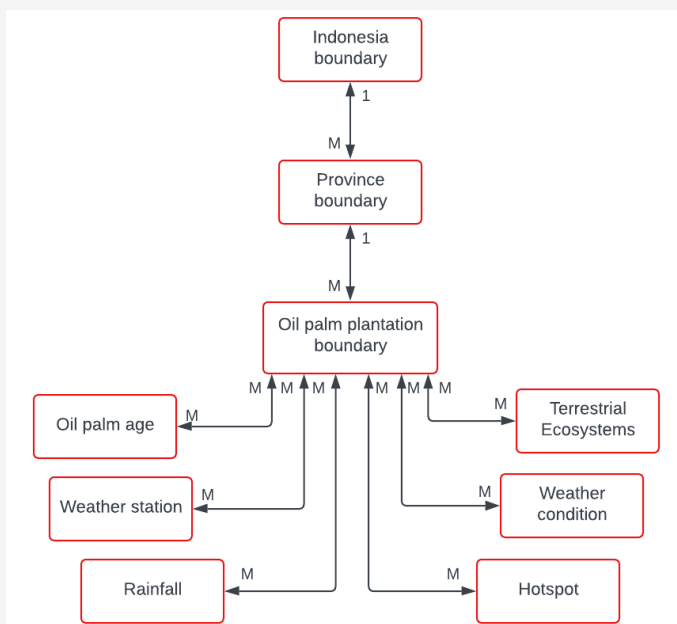


Figure 3: Conceptual-Logical database model

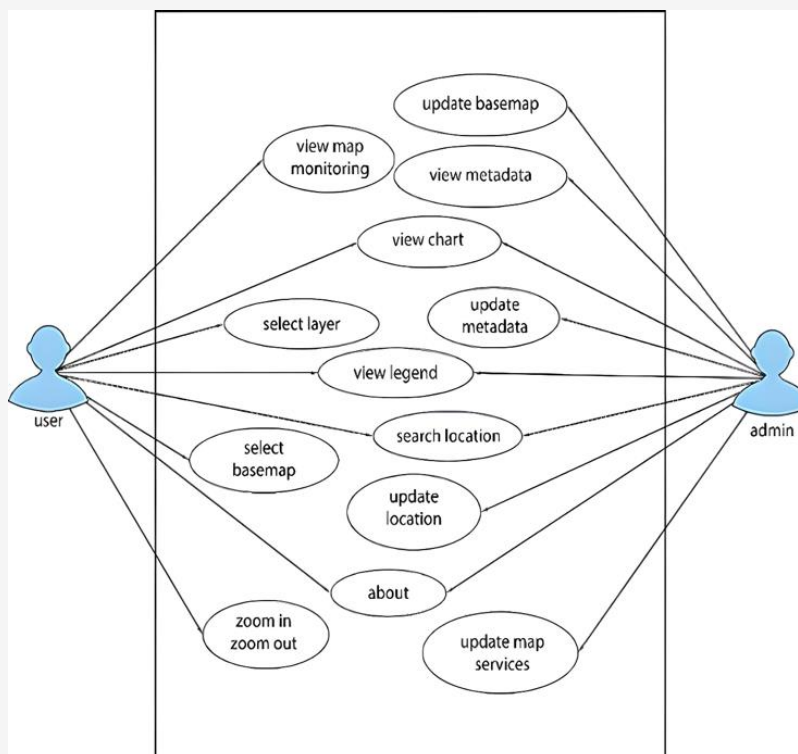


Figure 4: Use case

A DBMS has three data model description layers. At the highest level, it contains a conceptual model, a direct model of the real world in terms of the data model, a logical/view model that interprets the conceptual model in terms of database mechanisms, and a physical model that applies the logical model in a specific DBMS implementation [32].

3.3 Design Systems and Application

3.3.1 Use case

Use cases are employed in conducting system analysis to identify, clarify, and manage the needs of a system (see Figure 4) [31]. Discussions with stakeholders regarding the required system have been performed with IOPRI and the agriculture office.

3.3.2 Business Process and Architecture

The Business Process System is a useful instrument for assisting utilities in increasing their efficiency and making better use of their information technology [46]. Business process management is a discipline that encompasses techniques, ideas, and tools that not only identify but also record, analyze, monitor, and optimize processes within a company to maximize the value for stakeholders [47]. A business process has a lifecycle that structures the principles, methods, strategies, and tools of Business Process discipline and provides a sequential order of tasks to be

completed to manage and provide value to the process [46] and [47]. We developed the system in this study using the ArcGIS environment. There are two bounding boxes, one of which is red and the other is blue. The blue bounding box indicates the extent of this study, which begins with data collection, system building, and visualization [46] (see Figure 5). The system architecture comprises three layers: spatial database, middleware, and application layers. The spatial database layer stores data; the middleware layer publishes data into a service; the application layer is used by GIS systems (see Figure 6) [48]. The system architecture comprises three layers: spatial database, middleware, and application layers. The spatial database layer stores data; the middleware layer publishes data into a service; the application layer is used by GIS systems (see Figure 6) [48]. The website for the system was constructed as an application dashboard, which can be used to monitor oil palm plantations in Indonesia to identify occurrences or circumstances that involve oil palm plantation (see Figure 7). Figure 7 shows a web-based dashboard using a customized ArcGIS Environment process with a prototype approach. A web-based dashboard that has been designed to monitor several elements of oil palm production and related environmental factors.

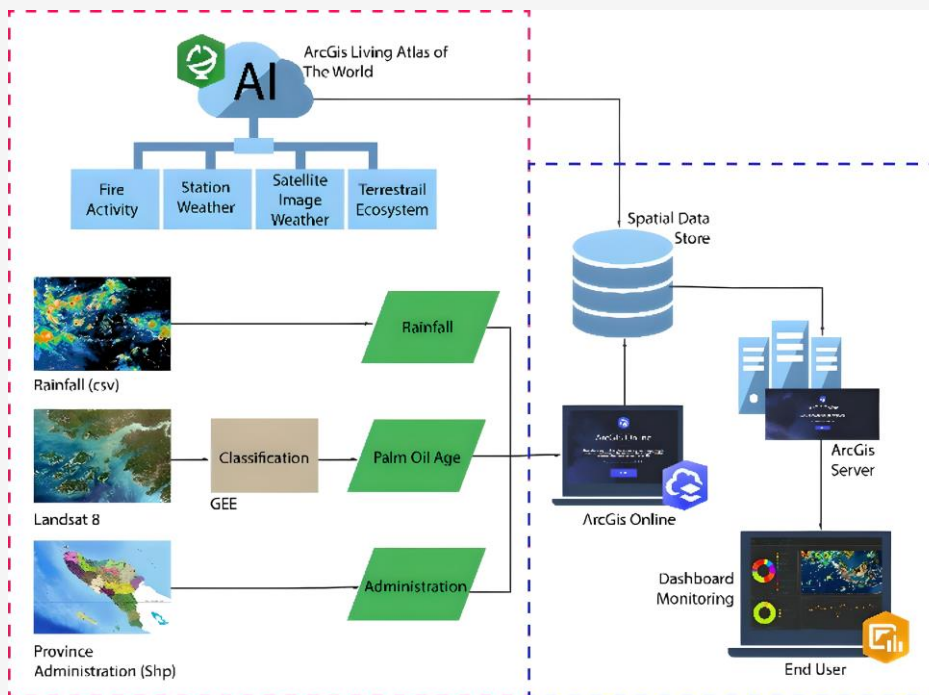


Figure 5: Business process

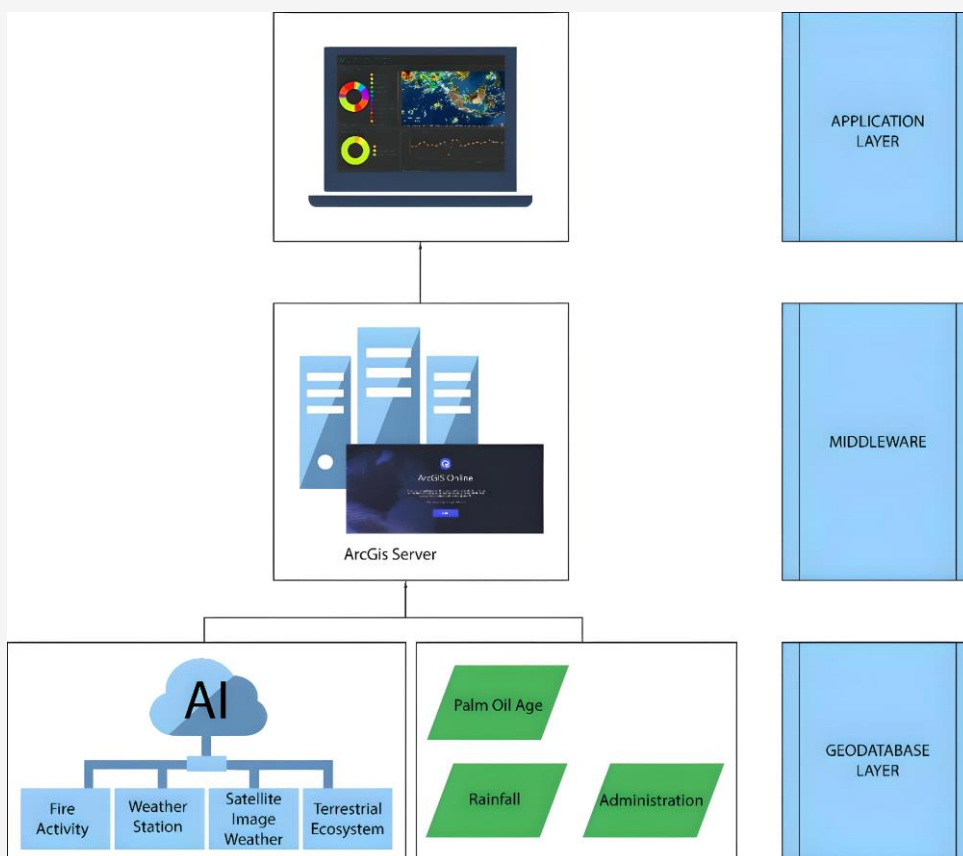


Figure 6: System architecture

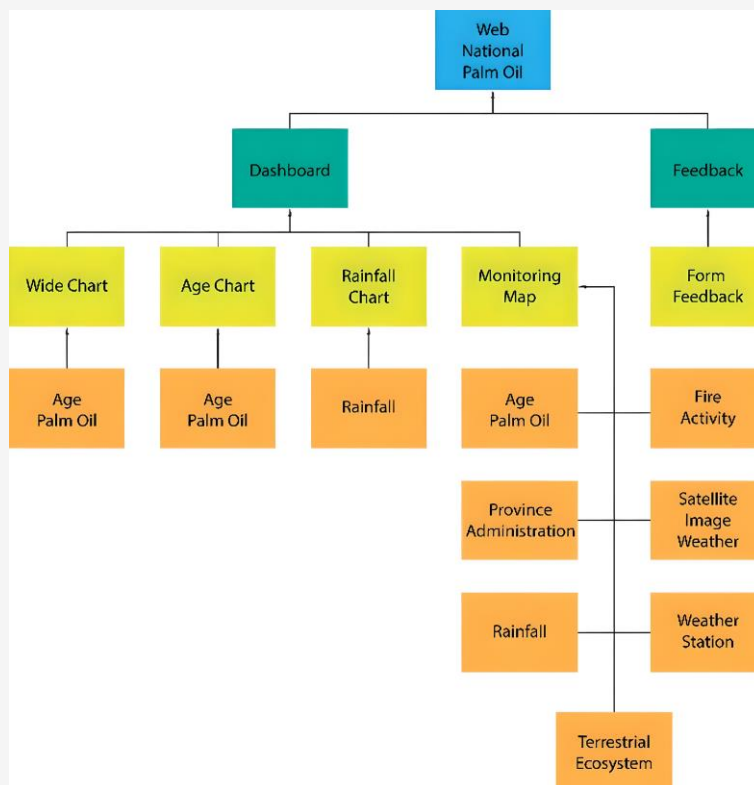


Figure 7: Sitemap of the system of web-based dashboard

The primary dashboard provides as a center for integrating several data visualizations, such as demographic data on the age of vegetation, distribution maps showing the growth of oil palm plantations on wide chart, and graphs show rainfall patterns on rainfall chart. These designs are important for understanding the dynamics of oil palm agriculture and its environmental impacts. The dashboard also includes a monitoring map that likely offers up-to-date geographical information on the locations of plantations, processing facilities, and places impacted by environmental changes. The platform includes feedback tools, such as the Feedback and Form Feedback sections, which enable stakeholders to provide views and report issues about oil palm production or environmental concerns. In addition, the platform incorporates environmental monitoring capabilities such as fire activity tracking, satellite image weather analysis, and weather station data.

These technologies are crucial for monitoring environmental factors that impact oil palm production, including cases of fire and weather patterns. Furthermore, the flowchart demonstrates validation for local governance through the province administration category, which enables the management of regional data and decision-making. The terrestrial ecosystem component of the

evaluation places special focus on the ecological impact of oil palm farming, on biodiversity, soil health, and other ecological indicators. However, web-based dashboard for monitoring sustainability and productivity in Indonesia's oil palm sector. In other circumstances, oil palm age information is necessary for tax estimation, replanting time estimation, and disease analysis.

3.3.3 Implementation

Based on the data obtained through discussions with IOPRI and the agriculture service in the FGD forum for this application, monitoring data is needed including climate, land and harvest management in the management of Indonesian oil palm plantations. In this application, the required data are obtained by using existing information in the ArcGIS Living Atlas of the World cloud storage. These data are then linked to the established system, i.e., the oil palm plantation monitoring application dashboard. The application can be found at <https://bit.ly/KelapaSawitNasional>. The application dashboard (Figure 8) provides various geographic data that are automatically updated in real time. These informational resources contain statistics on fire activity, meteorological data, weather satellites images, and terrestrial ecosystems information.



Figure 8: Dashboard application

The information obtained from these data define a situation or occurrence, particularly that relating to Indonesian oil palm plantations. The application dashboard contains several features, including the following:

- *Visualization of Spatial Data*

This feature, which displays data in the spatial form, can show an incident or the state of Indonesian oil palm plantations. There are several basic maps, including picture maps, road maps, and others, in the visualization of spatial data. The visualization of spatial data features displays data from several sources (Figure 9(a)).

- *Large Area*

This feature provides information on the area of oil palm plantations in various Indonesian regions, and the information is displayed in graphical form. The area unit used in this graph is Ha (hectare) (Figure 9(b)).

- *Oil Palm Age*

Oil palm age is one of the user-required data points, and it is displayed as a graph. The oil palm age is split into 3 categories: 0 to 4 years, 5 to 25 years, and over 26 years. In the three sections, oil palm age is paired with area, so that total area based on oil palm age can be determined (Figure 9(c)).

- *Legends*

The legend feature displays conventional symbols or signs used in the application dashboard. The symbols will appear on the application dashboard when a certain layer is activated (Figure 9(d)).

- *Layer*

This feature displays all data that have been processed and compiled from several sources to form a layer. This functionality can be accessed by activating the relevant layer. Activatable layers include weather stations, fire activity, oil palm age, precipitation, administrative borders, weather satellite images, and land cover (Figure 9(e)).

ArcGIS and its JavaScript API were used for spatial analysis and dataset visualizations. Using the platform, certain geospatial analysis scenarios were carried out as ArcGIS maps. In order to create a large-scale geographic database for spatiotemporal analysis, imported datasets were abstracted as layers in ArcGIS [48]. The application has already been tested for seeing the quality of a website application made, both in the quality of the website to the quality of the information provided. Testing using the ISO 9126 standard approach, because ISO 9126 is a software quality benchmark which can later be assessed through certain measures and methods [49]. There are 3 application testing results, including the following, Usability, Functionality, and Reliability. The overall test results get a “Good” interpretation with an average percentage of 81%.

However mapping the distribution of oil palm is essential for managing and organizing the sustainable operations of oil palm plantations [50]. A database management system using GIS and visualization can assist solve the issue since the data produced by the system can make it easier to monitor and analyze plant growth, according to [51] and [52].

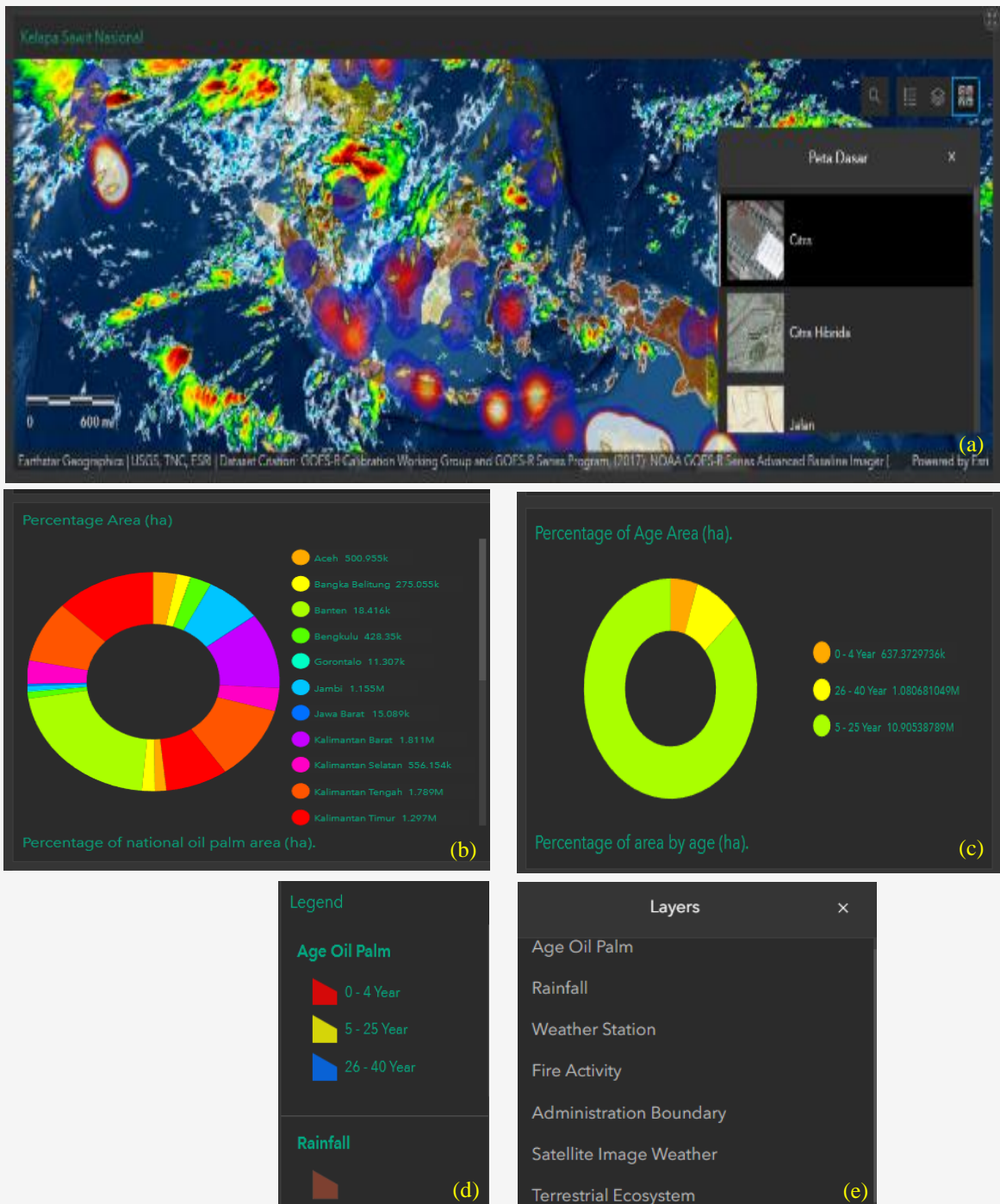


Figure 9: (a) Visualization of spatial data; (b) Information of large area; (c) Information of oil palm age; (d) Legends; (e) Layer

Plantation management information requirements, including GIS integration, comprise infrastructure, production planning, mapping, and control analysis for several plantations at different phases of growth [1]. Unmanned aerial vehicles (UAVs) and Geographical Information Systems (GIS) for base-

remote sensing are promising tools to help with environmental conservation in oil palm plantations and to improve crop quality and productivity [53]. Satellite images can be used to monitor palm oil plantations effectively and sustain the sustainability of palm oil in Malaysia [54].

Therefore, in order to manage oil palm, it is necessary to look into six factors that affect oil palm yield: elevation [42] mean annual minimum and maximum temperatures, mean annual rainfall, average number of rainy days per year, average annual relative humidity, and environmental conditions and oil palm varieties [2] and [55]. For the upcoming study, a geodatabase system will be used to speed up the identification and transmission of data regarding the quantity of oil palm plants, as well as any dead or sick plants. Additionally, an android application will be developed to help insertion officers with maintenance tasks related to unhealthy palm trees or insertion.

4. Conclusions

The development of a spatial database system to monitor oil palm fields is a significant improvement for oil palm management in Indonesia. This method including development spatial database using conceptual, logical, physical stages, and visualization. Spatial data base utilizes cloud computing and remote sensing data stored in ArcGIS Living Atlas of the World to provide a thorough analysis of significant variables that influence oil palm sustainability. Once the data is collected in ArcGIS Online, it is simply integrated into the visualization system built with the ArcGIS operating dashboard. This specifically designed dashboard has been customized to fit the unique requirements of users and provides significant insights into several elements including the age of oil palm plantations, administrative borders, rainfall patterns, terrestrial ecosystems, hotspots, and meteorological conditions. This detailed information correlates with the purposes of Instruction No. 6 of 2019, issued by the President of Indonesia, which aims to improve the management of oil palm plantations as part of the National Action Plan for Sustainable Oil Palm Plantations 2019–2024. The strategy aims to improve the efficiency, effectiveness, and productivity of plantation management.

Despite these technological developments, the effective management of oil palm plantation needs the accessibility of up-to-date remote sensing data that can accurately measure environmental variables such as temperature, precipitation, humidity, and particular conditions of oil palm's various types and elevation. To achieve these requirements, the next improvements will include the development of a geodatabase system. This system will simplify the process of discovering and transmitting data on the amount of oil palm trees, including those that are deceased or afflicted with diseases. Additionally, an Android application will be designed to help field officers in maintaining diseased palm palms.

This application will simplify the fast execution of maintenance tasks and upgrades, ensuring timely actions that are essential for maintaining the health and productivity of the plantations.

Finally, the spatial database system has provided a framework for improved management practices. However, continuing integration of real-time data and user-friendly applications will be crucial in effectively addressing the changing challenges of oil palm management. These developments will not only improve the efficiency of plantation management but also contribute to the larger objectives of sustainability and productivity in Indonesia's oil palm sector. In other circumstances, oil palm age information is necessary for tax estimation, replanting time estimation, and disease analysis.

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