

A Geographic Information System for Managing and Mapping Irrigation Infrastructure

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Abstract: Indonesia is one of the world's major agricultural nation which offers wide diversity of tropical products and agricultural commodities produced in substantial number of agricultural areas. Some of these areas are equipped with irrigation infrastructures which delivers water management throughout the land. Irrigation helps grow agricultural crops, maintain landscapes, and revegetation disturbed soils in dry areas. Water resources are finite while cyclic droughts on agricultural areas affecting the amount of water remains, thus creating unbalanced water demand and supply. Therefore, building an effective plan and management for irrigation infrastructure must be conducted using reliable information. The objective of this study is to develop a geographic information system to help managing and mapping process of irrigation infrastructure, such as flood gate and water ways. This system also helps to manage all the irrigation area and infrastructure data by providing geological information, search, and managing database function. We developed a web application for system interactivities. We also work together with Dinas Pekerjaan Umum dan Penataan Ruang of Kabupaten Kubu Raya, as they are managing nearest irrigation land which available to be inspected for research. The system has been tested in a real-life case study. As a result, the system enhances the efficient management of irrigation area and infrastructure data. Users stated that this geographic information system has many benefits to irrigation area management, i.e, ensuring data authorization with user information when data is recorded, real time image capture for each irrigation infrastructure, and digital maps to gain a wide overview of irrigation area information on Kabupaten Kubu Raya.

Keywords: irrigation area, irrigation infrastructure, geographic information system

INTRODUCTION

Irrigation area is a land comprises with water from irrigation network consist of canals and construction to serve, share, deliver, use, and disposal of water throughout the area. It requires irrigation network management, a sequence of procedures, e.g. actions, maintains, and rehabilitation. The main purpose of irrigation process is to increases farmer's productivities by enhancing agriculture commodities. The development of irrigation infrastructure periodically is a must. Therefore, a reliable information is important to conduct the effective plan and management processes. A visualization of entire area along with the infrastructure may reducing the adversity of managing the entire infrastructure.

Indonesia will become a nation with lack of rice supply if there are no solution for water deficiency on their irrigation areas. Development of irrigation infrastructure with proper and quick investigation could be an alternative. One of the most reasonable solution is to conduct development phase implements innovation in technology (Pasandaran, 2016).

A policy to encourage consolidation of diversification agricultural commodities to build a balance between improvements of farmer's productivity and agricultural efficiency is necessary. One of the possible approaches is the development of irrigation area around the fields (Siregar, 2016).

The objective of this study is to develop a geographic information system to help managing and mapping process of irrigation infrastructure, such as flood gate and water ways. Each infrastructure is located on specific coordinates which recorded on a database managed by Dinas Pekerjaan Umum dan Penataan Ruang of Kabupaten Kubu Raya.

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This system also helps to manage the irrigation area and infrastructure data by providing geological information, search function, and managing database function. We worked together with Dinas Pekerjaan Umum dan Penataan Ruang of Kabupaten Kubu Raya, as they are managing nearest irrigation area available to be inspected for research. The water quality on one of their irrigation area on Kecamatan Terentang is evidently appropriate for irrigation (Fitriadi, F., 2016). Also, agricultural commodities is one of their promising sector to be developed in future (Hajeri, H., et.al, 2015).

LITERATURE REVIEW

We reviewed a few previous works related to GIS. For example, an application of field mapping using remote sensing and GIS on an irrigation area in India (Nikam, B.R et.al, 2010), an Android application to map disaster-aware villages of Gorontalo District (Pakaya .A, 2020), and effectiveness examination of suitable GIS implementation on land administration in Kaduna (Shekarau, J.A. & Aliyu, M.A, 2019).

Furthermore, we also reviewed other works related to GIS of agricultural fields, such as development of monitoring system for environmental conditions of agricultural fields using Arduino and Wireless Sensor Network (Sushanth, G. & Sujatha, S, 2018), an information system of irrigation building on Rentang irrigation area (Ayuningtias, D. K, 2014), and a location reporting system for irrigation field officers using Android application (Sunaryo, B. et.al, 2019).

In addition to manages irrigation area information database, this system also serves as a Geographic Information System (GIS), a computer-based system capable of capturing, preparing, managing, saving, analyzing, manipulating, and presenting georeference data (Huissman & De By, 2009). The maps displayed on this system are built using Leaflet JS, an open source Javascript library for interactive digital map hosted on public server. It can be accessed using web browser. Leaflet uses World Geodetic System 1984 (WGS84) as the coordinate system consist of latitude and longitude variables (Derrough, 2013).

We developed a web application for system interactivities, using Rapid Application Development (RAD) methodology. It is a collection of techniques, procedures, and integrated device which supports and satisfy user requirements in a short period of time. The software changes continuously as more user feedbacks received during development (Daud et.al, 2010).

We collected irrigation infrastructure data from several irrigation area around Kabupaten Kubu Raya. This is a district located in western area of Provinsi Kalimantan Barat, Indonesia. It has 9 sub-districts along with 50 irrigation areas, each consist of irrigation infrastructures.

METHOD

This research focused on managing and mapping the irrigation infrastructure. We start collecting data of irrigation area, such as coordinates, area code, restoration date, district, sub-district, and authority. We also collect irrigation infrastructure data, e.g. flood gate type, conditions, coordinates, length of water ways, and photos of each infrastructure. The collected data subsequently analyzed to design the Entity Relationship Diagram (ERD). It is a conceptual level of database design and at a higher level of abstraction (Byrne, B. M., & Qureshi, Y. S., 2013). We aimed to develop a high-quality database design so it can easily be maintained and upgraded for future works. This diagram is depicted on Fig. 1.

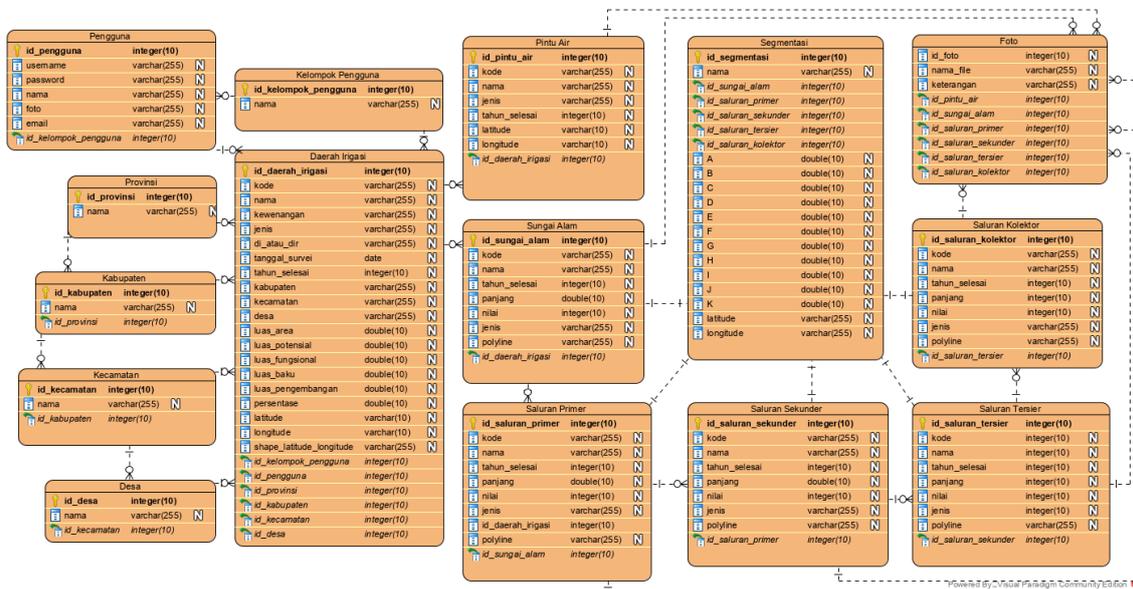


Fig. 1 Entity Relationship Diagram

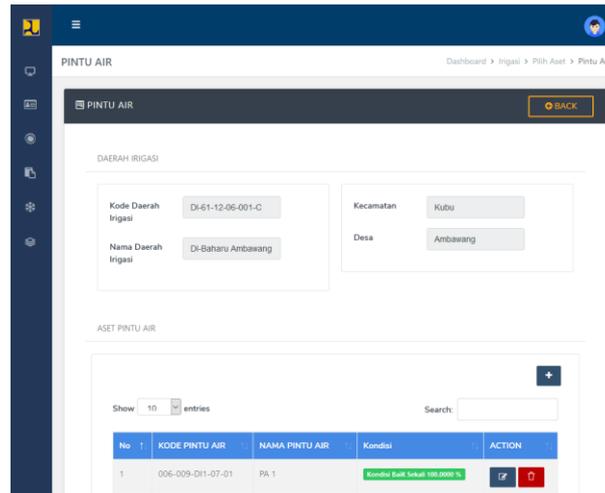


Fig. 4 Flood Gate Dashboard

Fig. 5 shows a map consist of polygons to indicate irrigation area, polylines for waterways, and a circle to denote flood gate. Users will be able to zoom in or out to show more details of the map, and search for certain irrigation infrastructures nearby.

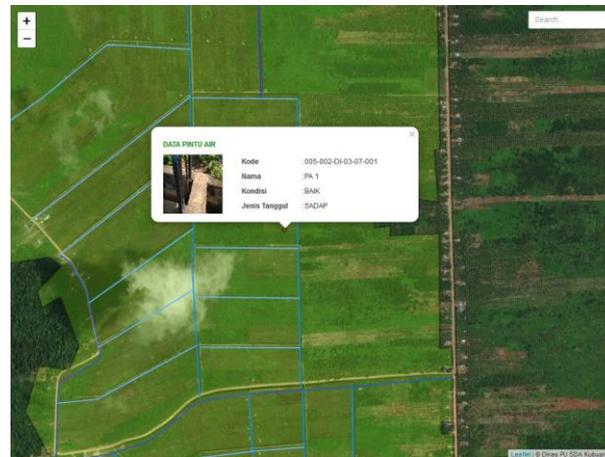


Fig. 5 Irrigation Area Map

Report shown on Fig. 5 are waterways informations, such as names, locations, codes, and conditions. Users may print this report as PDF files, if necessary.

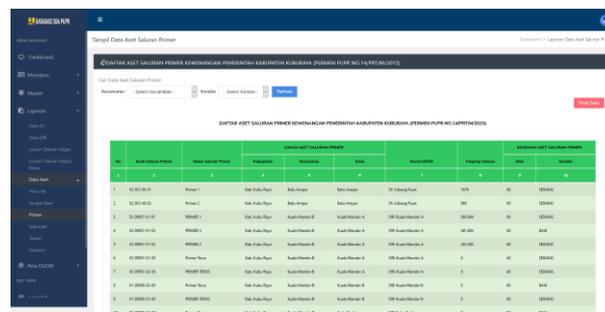


Fig. 5 Water Ways Report

To determine whether this system satisfies the user requirements, we used User Acceptance Test (UAS) method. The test is proposed to validate software against business requirements, which is the usability for managing and mapping of irrigation infrastructure by Dinas Pekerjaan Umum dan Penataan Ruang Kabupaten Kubu Raya. The choices for each statement on this test were structured using Likert format. There are five choices provided for every statements. The choices represents the degree of agreement, i.e. Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). The results are shown in Table 1. The test concluded that there is a high satisfaction of users for the functionalities on this system.

Table 1
User Acceptance Test

Description	SD	D	N	A	SA
Easy to navigate			7%	10%	83%
No missed data to managed			6%	6%	88%
Images load quickly			22%	22%	56%
Maps displayed correctly			8%	20%	72%
No authorized action occurred				7%	93%

DISCUSSION

Our work has several differences from previous works as our system are built based on requirements from Dinas Pekerjaan Umum dan Penataan Ruang Kabupaten Kubu Raya. In consequence, the whole functionalities are designed to fulfill the requirements. We build a report page for users if they have to print the irrigation area report in PDF format. The maps displayed on this system are using geolocation data with WGS84 coordinate system as the latest revision of World Geodetic System (WGS), a standard for use in cartography, geodesy, and satellite navigation. The three levels of users are set according to level of authority in Dinas Pekerjaan Umum dan Penataan Ruang Kabupaten Kubu Raya.

This research conducted to build a system that fully satisfy the user requirements. Therefore, a frequent visit to the irrigation area is required. As we permitted to conduct research on an irrigation area, which is a government property, it is necessary to follow the instruction from the authority. As a result, this research's system design is exemplary for other web developers who wants to build government apps in their project.

There are few limitations on this work, such as there are no functionality to track the operator's location when they send report. Also, the images captured using smartphone are stored without any compressing process. Hence, this system required a large storage space on the server. Also, we have to design an inelaborate user interface on our system since the users are immensely unfamiliar with technology.

Security is a crucial part on every application. In this research, we only used basic security system, i.e., XSS filtering security, which prevents any malicious Javascript code. Furthermore, this system requires a higher level of detection and prevention mechanism to prevent any access from unauthorized personnel in future.

CONCLUSION

Our goal is to develop a geographic information system to help managing and mapping process of irrigation infrastructure and also helps to manage all the irrigation area and infrastructure data by providing geological information, search, and managing database function. The result is a running web application which able to satisfy user requirements based on the results from UAT test. Maps displayed correctly using Leaflet JS on a web page, exposing brief information of irrigation infrastructures. Web application development process using RAD, sufficiently satisfy user requirements of this system. In order to build a running application for government, we found that one has to adjust the development process with the requirements discussed with the authority before starting the project. For example, in our matter, the authority are using Degrees Decimal Minutes (DDM) as the coordinate format on their database, while Leaflet JS requires Decimal Degrees (DD) as their input. The geographic information system are running satisfactory based on UAT test. It can manage irrigation infrastructure data while using digital maps to display geological information. Users also stated that this geographic information system has many benefits to irrigation area management., i.e, ensuring data authorization with user information when data is recorded, real time image capture for each irrigation infrastructure, and digital maps to gain a wide overview of irrigation area information on Kabupaten Kubu Raya. There is an opportunity to integrate this system with an Android application with an ability to monitor surveyor works and record data directly from devices.

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