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Geographic Information System for Mapping Solar Power Plants in Lolo Wano Village

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Abstract —The use of renewable energy, particularly solar power plants (SPPs), is one of the strategic solutions to overcome limited access to electricity in rural areas. Lolo Wano Village, as one of the villages with high solar radiation intensity, has great potential for SPP development. However, the planning of SPP construction is often hampered by a lack of integrated spatial data related to residential locations, public facilities, and land availability. This study aims to design a Geographic Information System (GIS) capable of mapping the potential and determining strategic coordinates for SPP construction in Lolo Wano Village. The research method was conducted by collecting primary data in the form of GPS coordinates of residents' houses, schools, village offices, and vacant land with potential for use. Secondary data included administrative maps, topographic maps, and solar radiation data from BMKG and global sources. The data was processed using QGIS/ArcGIS software through the stages of map digitization, spatial overlay, and land suitability analysis based on criteria of solar radiation, accessibility, land area, and proximity to residential areas. The results of the study show that the use of GIS can produce digital maps of the distribution of existing solar power plant locations as well as recommendations for new locations suitable for development. This system not only assists village governments in making decisions on renewable energy development, but also supports equitable access to electricity for the community. Thus, the application of GIS in mapping solar power plants in Lolo Wano Village plays an important role in supporting sustainable development and improving the quality of life of the local community.

Keywords—Geographic Information System, Solar Power Plant, Renewable Energy, Mapping, Lolo Wano Village

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I. INTRODUCTION

The availability of electrical energy is one of the important factors in improving people's welfare and supporting sustainable development. However, not all regions in Indonesia, especially rural and remote areas, have equal access to electricity. Lolo Wano Village is one of the villages that still faces limitations in access to electrical energy, while the community's need for electricity is increasing in line with the development of social, educational, and economic activities [1]-[3]

The use of renewable energy, particularly solar power plants (PLTS), is one potential alternative solution to overcome this problem. This is supported by the geographical conditions of Lolo Wano Village, which has high solar radiation intensity throughout the year, making it suitable for solar energy development. However, the planning of SPP construction is often constrained by limited integrated spatial data, such as the location of residents' houses, public facilities, and vacant land suitable for the installation of solar panels.[4]-[6]

To address this issue, a system is needed that can map the potential and strategic locations for solar power plant development. Geographic Information Systems (GIS) are effective tools for managing and analyzing spatial data to support decision-making[7]-[9]. Through GIS, the coordinates of residential locations, public facilities, and potential land can be processed into digital maps that provide a comprehensive overview of electricity demand distribution.

The absence of a map-based information system makes planning and decision-making in solar power plant development less effective. As a result, the determination of solar panel installation locations is often suboptimal, leading to uneven electricity distribution and underutilization of solar energy potential [10].

Research by Pablo Benalcazar, Aleksandra Komorowska, Jacek Kamiński entitled A GIS-based method for assessing the economics of utility-scale photovoltaic systems. The research results are to build a GIS-based

information system to estimate PV generation capacity and potential, as well as to determine the average LCOE of utility-scale photovoltaic systems at a spatial resolution of 100 m. The total area of Poland is suitable for the installation of utility-scale solar PV systems. Installing PV systems in these areas would generate solar capacity ranging from 394.64 to 563.77 GW. In addition, the case study findings show that the LCOE would range from €0.043/kWh to €0.049/kWh, with a national average of €0.045/kWh[11].

Baoling Gui, LIdya Sam. Anshuman, Bhardwaj research title From roofs to renewables: Deep learning and geographic information systems insights into a comprehensive urban solar photovoltaic assessment for Stonehaven, the research results introduce a mature, detailed, and accurate assessment process, using Stonehaven as an example, aiming to utilize limited data to extract useful geographic data and information to guide urban PV planning. Initially, existing Digital Surface Model (DSM) data and optical imagery were utilized, combined with deep learning techniques and PV potential assessment models, to comprehensively assess the PV power generation potential in the Stonehaven area. Our results show that DSM integration significantly improves roof segmentation accuracy. Additionally, compared to DeeplabV3, U-Net demonstrates better performance in roof segmentation. Furthermore, the Solar Radiation Potential (SRP) map generated by DSM highlights better solar radiation reception capacity on south-facing roofs and flat roofs. Our investment return period (IRP) analysis shows that most roofs in Stonehaven have an IRP between 8.1 and 11.3 years. Future maps include improved data quality, refined segmentation algorithms, and exploration of urban energy planning analysis to support smarter urban planning[12].

Abdulaziz Alhammad, Qian (Chayn) Sun, and Yaguang Tao titled their research Optimal Solar Plant Site Identification Using GIS and Remote Sensing: Framework and Case Study. The result of the research is to build a solar power plant with a carbon system based on GIS and PHP spatial MCDA framework tailored to the characteristics of the Al-Qassim region. This framework adopts several tools used in Geographic Information Systems (GIS), such as Random Forest (RF) raster classification and model builder. This framework aims to determine the ideal location for solar power plants in the Al-Qassim region based on the potential photovoltaic electricity production (PVOUT)[13].

Tarek A. Eldamaty, Ayman G. Ahmed, Medhat M. Helal GIS-Based Multi Criteria Analysis for Solar Power Plant Site Selection Support in Mecca, the results of the study are to develop renewable energy using water based on GIS with multi-criteria solar in the Administrative District of Mecca. The best location for the construction of a solar power plant is determined using a series of factors and criteria, including planning and environmental criteria, as well as topographic calibrators. These criteria are defined through a comprehensive literature review. This information was then used to create a digital geographic database, which was integrated into an integrated GIS system to produce a spatial suitability model. Based on the suitability data, most of the Mecca region is ideal for solar energy projects, with suitability percentages ranging from 30% to 80%. These findings are promising and encouraging for Mecca's renewable energy industry and should be taken into consideration[14]

Ana Therese A. Levosada, Renz Paolo T. Ogena , Jan Ray V. Santos and Louis Angelo M. Danao, judul penelitian Mapping of Suitable Sites for Concentrated Solar Power Plants in the Philippines Using Geographic Information System and Analytic Hierarchy Process hasil penelitian adalah untuk membangun energi surya terkoneksi dengan matahari dengan metode yang digunakan adalah Gis dan AHP dengan menentukan lomkasi berbasis kriteria penyingkiran untuk ini: kawasan terlindungi, kemiringan, intensitas sinar matahari normal langsung (DNI), badan air, dan jenis penutup lahan, Lokasi yang sesuai ditemukan di provinsi-provinsi berikut: Ilocos Sur, Pampanga, Mindoro, Masbate, dan Maguindanao.Wilayah-wilayah ini memiliki luas total 27,9 km² dan kapasitas daya total yang diproyeksikan sebesar 733 MW[15].

and areas suitable for solar power plant installation. With GIS-based mapping, it is hoped that the village government and related parties can plan the construction of solar power plants in a more targeted, efficient, and sustainable manner, thereby improving energy equity and the quality of life of the people of Lolo Wano Village.

II. METHODOLOGY

This study is a descriptive study with a quantitative and spatial approach. The focus is to describe the existing conditions of electricity access in Lolo Wano Village, map solar energy potential, and determine strategic locations for solar power plant construction using Geographic Information Systems (GIS).

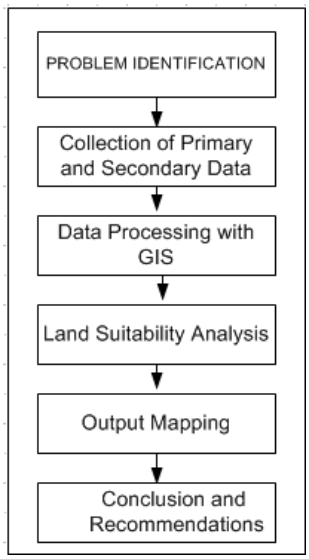

Fig. 1. Research Methodology

Problem Identification

Problem identification is the initial stage of research to discover the main issues that need to be addressed and resolved. In the context of Lolo Wano Village: Limited Access to Electricity, Untapped Solar Energy Potential, Lack of Integrated Spatial Data, Difficulties in Decision Making.

Collection Of Primary and Secondary Data

Primary data is data obtained directly from the field through observation, measurement, and interviews. In this study, the primary data collected included: Primary data focused on location, land conditions, energy needs, and visual evidence as the basis for spatial analysis in determining strategic locations for solar power plants. This secondary data provides spatial, statistical, and scientific support that complements primary data in determining strategic locations for solar power plant development.

Data Processing with GIS

GIS data processing is carried out through input, overlay, analysis, and visualization to obtain digital maps as a basis for decision-making in PLTS development.

Land Suitability Analysis

Suitability analysis was conducted using GIS-based overlay and criteria classification methods, enabling the best location for the solar power plant to be determined objectively and based on spatial data.

Output Mapping

Output mapping is the final stage of the spatial data analysis process, in which all processing and analysis results are displayed in the form of digital thematic maps. The aim is to visually display areas that have a certain level of suitability as potential locations for the construction of solar power plants (PLTS).

Conclusion and Recommendation

Researchers recommend that village governments conduct further field verification in priority areas, regularly update spatial data, and develop a WebGIS system so that mapping results can be accessed by the public. In addition, community involvement and the development of similar studies in other areas of Southwest Sumba are expected to accelerate the realization of renewable energy at the village level.

III. RESULT AND DISCUSSION

The Geographic Information System (GIS) for PLTS Mapping in Lolo Wano Village is designed to assist in the planning and determination of optimal locations for solar power plants by utilizing spatial data and attributes of houses, land, and solar energy potential. This system facilitates decision-making by village officials or technical planners through the presentation of interactive maps, reports, and accurate graphics, so that the implementation of solar power plants can be carried out efficiently, on target, and based on valid information.

System Design

Context Diagram

The administrator is responsible for inputting various PLTS data in the villages of Lolo Wano in Southwest Sumba Regency, including sub-district data, village data, PLTS type, and PLTS location. The system then processes this data to provide complete information about the sub-district, village, PLTS type, and distribution of PLTS locations. Users can access PLTS location information and search for their desired location.

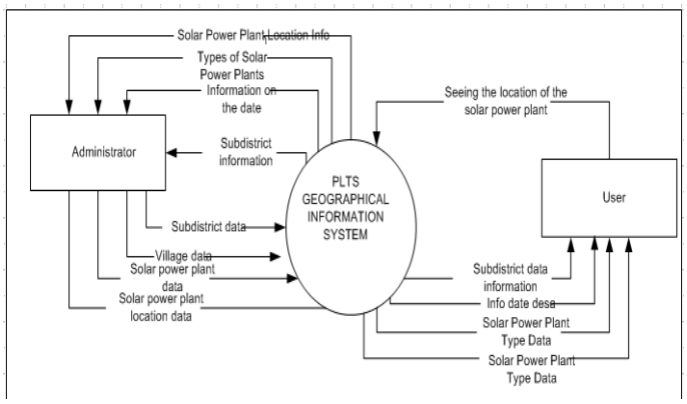

Fig. 2. Context Diagram

Data Flow Diagram

Data flow diagrams discuss the description of the system to be designed based on the design in the context of the diagram. The design can be seen in the following figure.

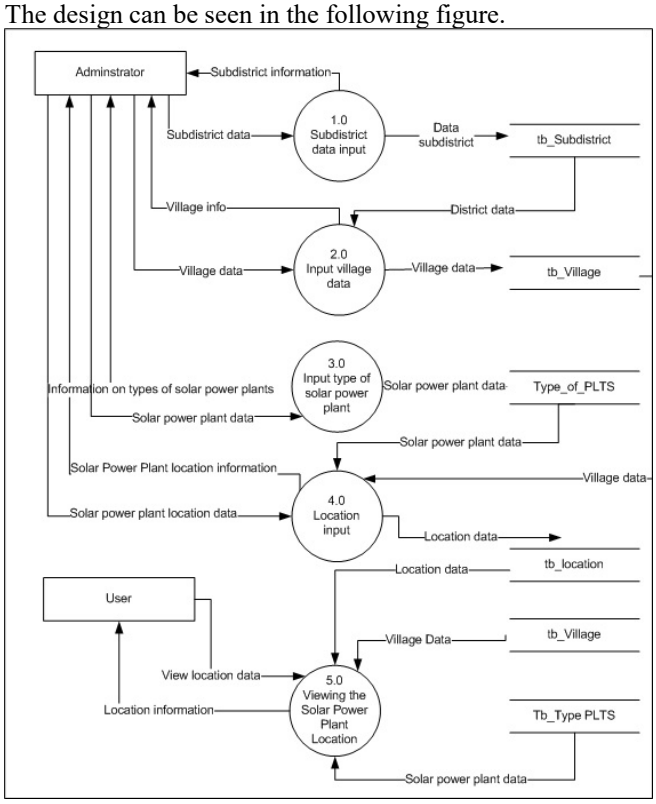

Fig. 3. Data Flow Diagram

Determination of Coordinate Points

Determining the coordinates of the solar power plant location in Lolo Wano Village is usually done with a GPS survey or using satellite imagery (Google Earth / ArcGIS / QGIS). These coordinates are used as the basis for mapping in the Geographic Information System (GIS).

Important locations for which coordinates need to be taken: Residential areas: so that the solar power plant is close to the beneficiaries. Public facilities: schools, churches, village offices, health centers. Vacant land / open land: potential locations for solar panel installation. Existing infrastructure: existing solar power plants, electricity networks (if any). Example of fictitious coordinates for Lolo Wano Village.

TABLE I. EXAMPLE OF FICTITIOUS COORDINATES FOR LOLO WANO VILLAGE

Location	Latitude (S)	Longitude (E)
Village Office Lolo Wano	-9.456789	119.876543
Elementary School	-9.458900	119.874321
Church	-9.460120	119.872450
Vacant Land (Solar Power Plant Candidates)	-9.462500	119.878900
Residents House (point 1)	-9.463200	119.877700
Residents House (point 2)	-9.464100	119.876200

Implementation and Discussion

The main page will appear when the website is accessed, displaying map information from Google Maps API. This page contains a header panel that displays application information, below which is a data panel that contains PLTS location data and a location search function. The content section is located to the right of the data panel and contains all the geographical information about the location of PLTS distribution in Lolo Wano village. The display can be seen in the following image.

Main Menu

The main menu is the initial display on the PLTS Mapping Geographic Information System (GIS) application, which serves as the navigation center for users. Its function is to facilitate access to various system features according to user (user and admin) needs.

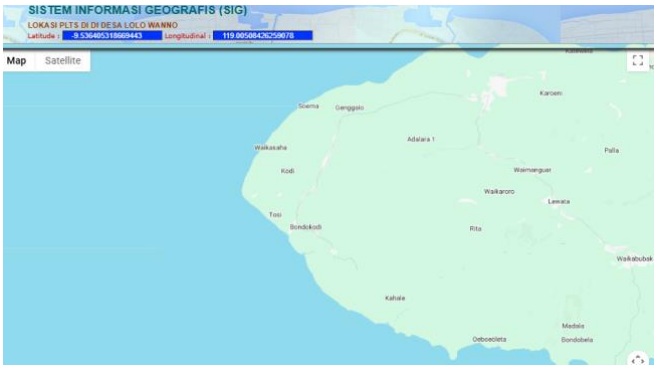

Fig. 4. Main Menu

Admin Login

The Admin Login feature is an authentication page used by administrators to access the system. Admins have full access rights to manage data, perform analyses, and generate reports.

Fig. 5.Admin Login

Subdistrict Data Input Form

The subdistrict data input form is a feature in the system used to enter information about the administrative area that covers Lolo Wano Village. This subdistrict data is important as a basis for compiling administrative maps and as a link between village data.

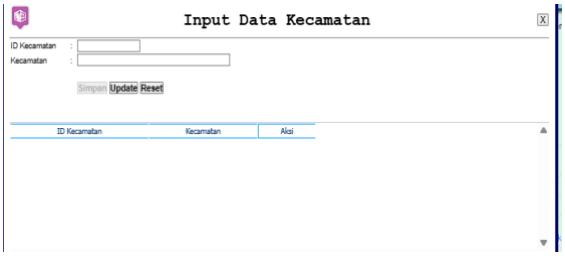

Fig. 6. Subdistrict Data Input Form

Village Data Input Form

The village data input form is a feature in the system used to enter and store administrative information about villages, particularly Lolo Wano Village. This village data is important because it is the main territorial unit in mapping the location of solar power plants.

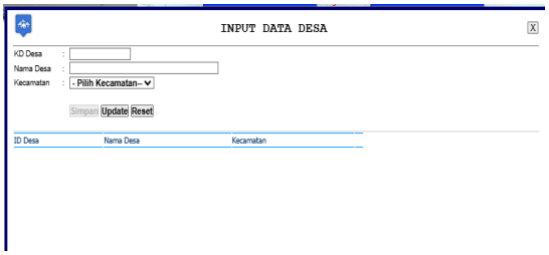

Fig. 7. Village Data Input Form

PLTS Type Input Form

The PLTS type input form is a feature used to enter data related to the type or category of Solar Power Plant (PLTS) to be mapped. This data is important for determining the characteristics, capacity, and scale of the PLTS that suits the needs of the Lolo Wano Village community.

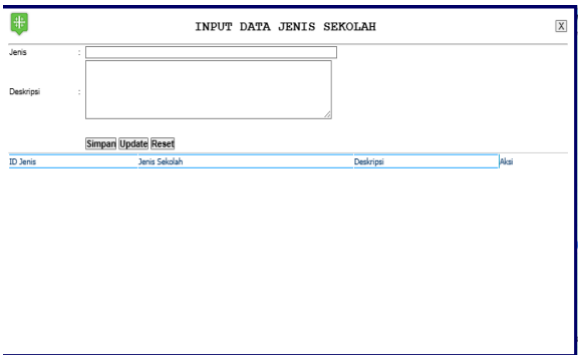

Fig. 8. PLTS Type Input Form

Location Data Input Form

The location data input form is a feature used to enter information related to points or areas that are candidates for solar power plant development. This data includes coordinates, land descriptions, and supporting conditions around the location.

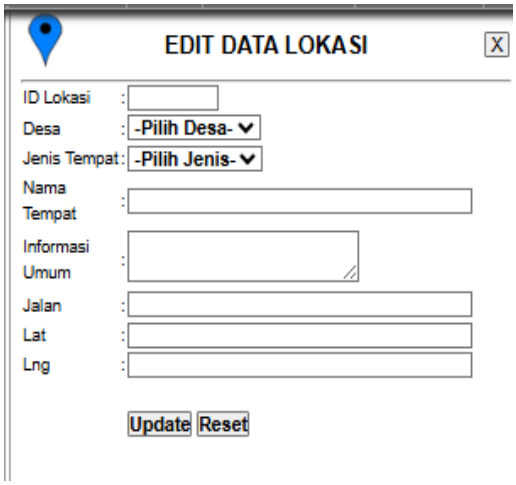

Fig. 9. Location Data Input Form

System Testing

System testing is a stage to ensure that the PLTS Mapping Geographic Information System application runs as required, is free from major errors, and can be used optimally by administrators and users.

TABLE II. SYSTEM TESTING

No	Function	Output	Result
1	Subdistrict Data	Can be run from data input to display normally and as needed	√
2	Village Data	Can be run from data input to display normally and as needed	√
3	Solar Power Plant Type Data	Can be run from data input to display normally and as needed	√
4	Location Data	Can be run from data input to display normally and as needed	√
5	Report Data	Can be run from data input to display normally and as needed	√

TABLE III. USER TESTING

No	Assessment Indicators	Respondents (Test Subjects)	Average Score (Scale 1–5)	Description
1	Ease of login, menu navigation, and data input	Village Administrator, Field Officer	4.6	Very Easy
2	Easy-to-read visual quality of maps, symbols, and colors	Village apparatus	4.5	Clear and Informative
3	Response time when displaying maps and analysis data	Technical Officer	4.3	Fast and Stable
4	Accuracy of potential solar power plant locations based on spatial data	Village Government	4.7	Highly Accurate
5	Relevance of features to village planning needs	Village Government & Community	4.8	Very Suitable
6	Neat design, easy to read information	All Users	4.4	Interesting and Easy to Understand
7	Overall assessment of the system	All Stakeholders	4.6	Very Satisfactory

IV. CONCLUSION

Based on the results of the research and implementation of the system, it can be concluded that:

1. The Geographic Information System (GIS) that was developed is capable of mapping the potential locations for solar power plant construction in Lolo Wano Village in a more structured and measurable manner through the use of primary data (GPS coordinates, topography, community energy needs) and secondary data (administrative maps, topographic maps, solar radiation data, and population data).
2. The use of GIS-based land suitability analysis has proven to be effective in assisting the decision-making process, particularly in determining strategic locations for solar power plants by considering factors such as topography, accessibility, population distribution, and solar energy potential.
3. The application, which was developed with various menus (admin login, village data input, PLTS type input, location data input, and analysis result mapping), has been tested using the black box testing method and functions properly, thereby supporting renewable energy planning needs at the village level.

4. This research can serve as a basis for further development in renewable energy planning, especially in rural areas with limited access to electricity, and is expected to become a decision support system for village governments and related agencies in realizing energy independence based on local resources.

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3. Relevant agencies such as the district government that have provided secondary data for analysis
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