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Mapping Potential Areas for Solar Power Sources In East Sumba Regency Based On Remote Sensing And Geographic Information System

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ABSTRACT

East Sumba Regency is an area with high solar radiation, which reaches 5.7 kWh/m² per day. Mapping of potential PLTS source areas is important to support the development of renewable energy in areas that are largely unreached by conventional energy infrastructure. This research aims to map the potential of PLTS in East Sumba Regency based on remote sensing and Geographic Information System (GIS) which is expected to be a reference for regional development in East Sumba Regency. The methods used are classification, overlapping, scoring, and weighting of each parameter. The parameters used are land surface temperature, slope, distance from the road, and land cover. The results of the analysis show that potential PLTS source areas can be classified into five categories, namely very potential, potential, quite potential, not potential, and very not potential. Each class has a diverse area of 13% for very potential areas, 19% for potential areas, 41% for moderately potential areas, 18% for non-potential areas, and 9% for very non-potential areas. These results show that East Sumba Regency is quite potential as a source of solar power plants. In order to accelerate the national agenda in increasing the proportion of renewable energy and reducing dependence on fossil fuels, it is hoped that this research can be a reference for the development of sustainable energy policies in the area.

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1. INTRODUCTION

Energy consumption in Indonesia has increased along with the increasing population (Al Hakim, 2020). According to the Central Bureau of Statistics, by 2023, Indonesia's population is estimated to reach 278 million, making it the fourth most populous country in the world. This increase in population directly impacts energy consumption, which continues to increase, both for domestic needs, the industrial sector, transportation, and the commercial sector. On the other hand, the availability of energy is dwindling, especially fossil fuels such as oil, coal and natural gas, which are the main sources of electricity generation in Indonesia because these energy sources are limited and non-renewable natural resources. Energy must be utilised to the greatest extent for the prosperity of society and its management must refer to the principles of sustainable development. According to Law Number 30 Year 2007 Article 2, energy is regulated based on benefits, equitable efficiency, social welfare, greater added value, sustainability, prudence, preservation of environmental functions, integration by prioritising capabilities, and national resilience. Furthermore, Article 3 states that the objectives of energy management must be directed towards self-sufficiency, the process of supplying, managing, using energy, the energy industry, the environment, and public access. As the fourth most populous country in the world, Indonesia has started using renewable energy as a national energy source to fulfil national energy needs (Hakim, 2020). Indonesia has potential renewable energy sources to develop, such as hydropower, biofuels, biomass, solar energy, wind power, nuclear, and geothermal (Hartono et al, 2020).

Indonesia is located between 6°N to 11°N and crossed by the equator. This location causes Indonesia to receive more sunlight, almost throughout the year with a relatively stable and high intensity with an average solar radiation intensity per day of ± 4.8 kWh/m² (Alim, et al., 2023). Indonesia also has two seasons, namely dry and rainy and has a tropical climate. These conditions make Indonesia the country with the largest solar power uptake in ASEAN. However, the relative installed capacity is still very low at 147 MW or 0.05% of the total potential of 208 GW. This large potential of solar energy is being massively utilised so that it can make a significant contribution in achieving the EBT mix target (Ministry of Energy and Mineral Resources, 2020).

East Sumba Regency, located in the province of East Nusa Tenggara (NTT), has geographical conditions that are very supportive for the development of renewable energy, especially Solar Power Plants (PLTS). The potential of solar energy owned by this region is very large with the highest solar radiation intensity in Indonesia, namely 5.7 kWh/m² per day and the availability of very large land that allows the construction of PLTS up to 50 GW. In addition, the availability of this vast land allows the development of large-scale PLTS to get the selling price of electricity from PLTS which will certainly be very cheap (Ministry of Energy and Mineral Resources, 2020).

The existence of solar power potential in East Sumba Regency is a good step in encouraging the development of solar energy so that it can not only be utilised by people in East Nusa Tenggara province, but can potentially be transmitted to surrounding areas. However, in realising effective development, mapping of potential solar energy areas is required. Remote sensing and Geographic Information Systems are among the technologies that can be used for site selection studies, especially in energy planning (Tunc et al, 2019). Remote sensing and GIS are considered to be less time-consuming and low cost, which can facilitate measurement and optimise planning.

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Some of the parameters that can be used in research on solar PV potential include *Land Surface Temperature* (LST), slope, land use, and road *buffering*. The method used in the analysis can be scoring or weighting. Based on research related to the use of scoring and weighting methods in the identification of renewable energy potential in Indonesia, the use of scoring methods in research related to the energy sector is still limited (Jumansa et al, 2024). Through this method, the parameters used are weighted according to their level of importance or urgency in determining potential areas for solar power plant development. The results of this study are expected to contribute to accelerating the national agenda to increase the proportion of renewable energy in the national energy mix and reduce dependence on fossil fuels.

2. METHODS

2.1 Research Location

The research location for mapping potential solar power plant areas was conducted in East Sumba Regency, East Nusa Tenggara Province. Geographically, East Sumba Regency is located at the coordinates 119°45'-120°52' East Longitude (East) and 9°16'-10°20' South Latitude (LS). The area of East Sumba Regency is 7,000.5 km2 or 700,050 Ha. To the north, East Sumba Regency is bordered by the Sumba Strait, to the east by the Sabu Sea, to the south by the Indian Ocean, and to the west by Central Sumba Regency.

East Sumba Regency was chosen as the research location because this region has low rainfall levels and high solar radiation throughout the year so it is very potential regarding the source of solar power plants. However, most of the area is still not fully covered by conventional energy infrastructure. The research location can be seen in the map image below.

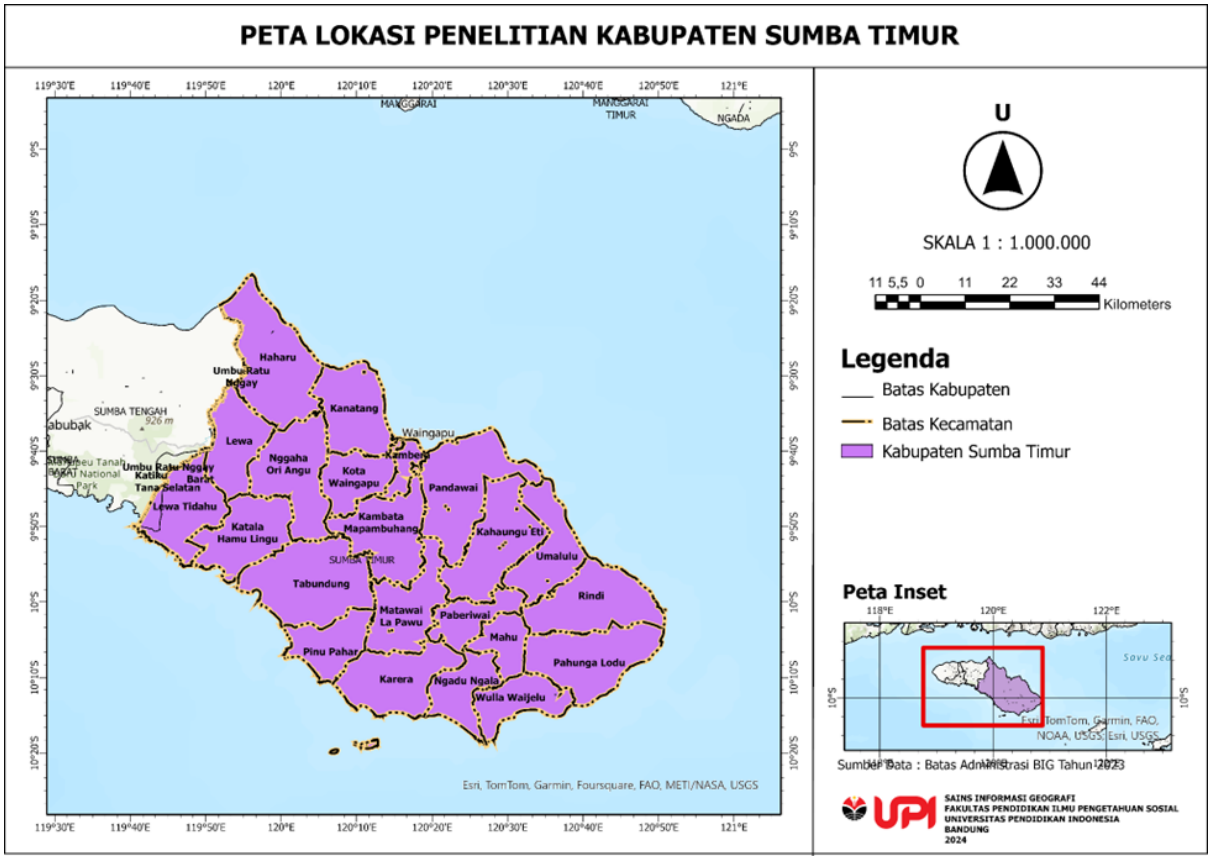

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Figure 1. Research Location

2.2 Tools and Materials

The tools used to support this research are laptop, mouse, and other supporting hardware. The software used in processing this research is QGIS 3.32, ArcGIS Pro, and ArcMap 10.8. Meanwhile, the materials used for mapping potential PLTS source areas in East Sumba Regency are Landsat 8 images recorded in 2023 sourced from USGS through the page https://earthexplorer.usgs.gov/, DEMNAS images, and road vector data both sourced from BIG through the page https://tanahair.indonesia.go.id/.

2.3 Theory

Solar Power Plant (PLTS)

Solar power plants are power plants that use sunlight through solar cells to convert solar photon radiation into electrical energy. PLTS systems can be classified into several types. Based on the application and configuration, in general, PLTS can be divided into two, namely on-grid PV systems and off-grid PV systems or stand-alone PLTS. Off-grid PV systems can operate independently, and can also be supported by other resources such as wind power, generator sets, or hydropower and micro- hydro power, which are referred to as hybrid PV systems (Kumara et al., 2018).

Remote Sensing

According to Lilesand and Kiefer (1979), remote sensing is the art and science of obtaining information about objects, areas, or phenomena through analysis of data obtained using tools without direct contact with the objects, areas, or phenomena being studied. The tool in question is a sensor that is generally carried by a vehicle in the form of an aircraft, hot air balloon, satellite, or other type of vehicle. The recording results are then called remote sensing data. Remote sensing is a technique developed for the acquisition and analysis of information about the earth.

Geographic Information System (GIS)

A geographic information system is a type of mapping information system designed to input, store, process, analyse, and generate relevant geographic or spatial information to support decision- making about the management and planning of cultivation, natural resources, and public services such as environment, transportation, urban planning, and others.

2.4 Flowchart

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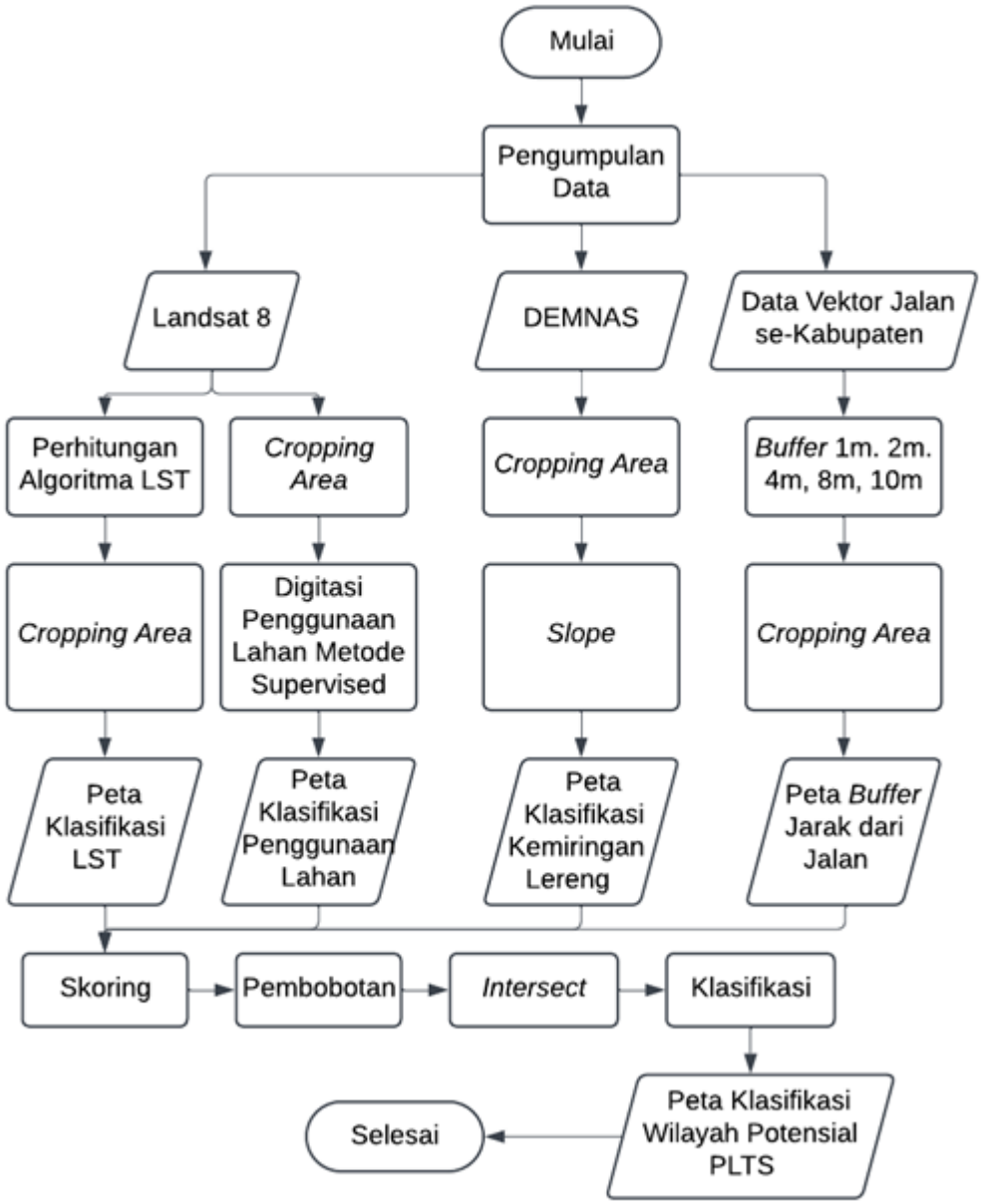

Figure 2. Flowchart

2.5 How to analyse data

The creation of the PLTS Potential Area Map in East Sumba Regency is determined by combining several parameters that affect the determination of potential PLTS source areas. The parameters used refer to the research of Md. Rabiul Islam et al (2023), namely Land Surface Temperature, Slope, Distance from Road, and Land Use. Each parameter is given a class, score, and weight based on the table below.

Table 1. Score and Weighting of Each Parameter

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Parameters	Magnitude	Class	Score	Weight
Land Surface Temperature (°C)	18 - 26	Low	2	0,6
	27 - 34	Medium	4	
	35 - 43	High	6	
Slope (°)	52,93	Very Low	1	0,16
	20,13	Low	2	
	11,83	Medium	3	
	5,6	High	4	
	1,66	Very High	5	
Land Use	Forest	Very Low	4	0,10
	Mangroves	Low	5	
	Agricultural Fields	Medium	6	
	Open Land	High	7	
	Settlements	Very High	8	
Distance from Road (Km)	10	Very Low	3	0,14
	8	Low	4	
	4	Medium	5	
	2	High	6	
	1	Very High	7	

Source: Md. Rabiul Islam et al., 2023

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3. RESULTS AND DISCUSSION

3.1. Parameter Map

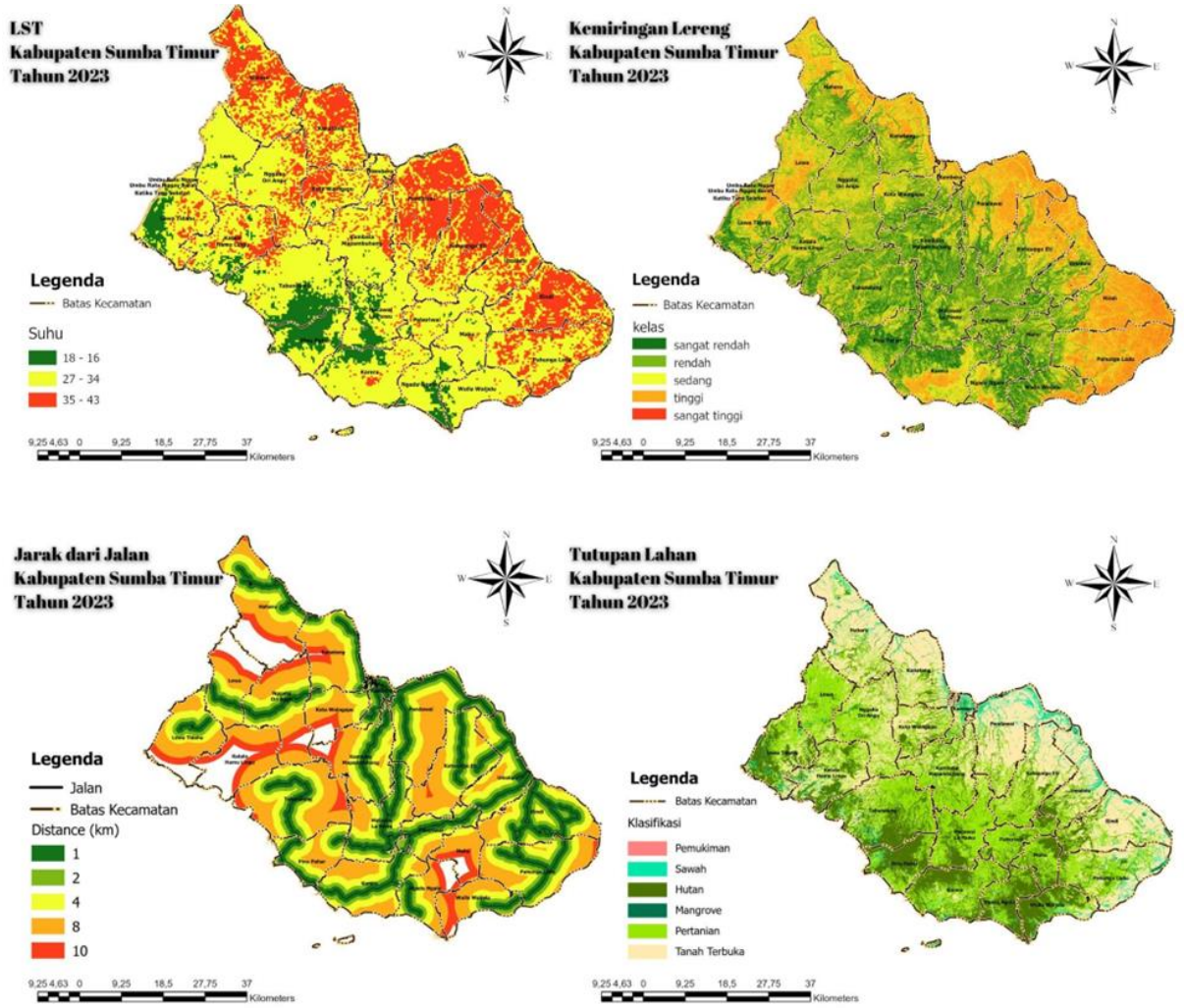

Figure 3. LST Map, Slope Map, Distance from Road Map, Land Cover Map.

The map above is a map of each parameter that affects the determination of potential PLTS source areas in East Sumba Regency. The map consists of maps of *Land Surface Temperature,* Slope, Distance from Road, and Land Use. Each map is classified according to the guidelines proposed by Md. (Rabiul Islam et al, 2023).

In determining potential areas for solar PV, distance from roads plays an important role in identifying locations that are easily accessible and have good infrastructure connectivity. Locations that are closer to the main road will be easier to reach for the construction, operation and maintenance of PLTS infrastructure. Therefore, the distance from the road map is used as one of the parameters in assessing potential PLTS areas. Based on the distance from the road map above, there are five classifications, namely 1 km, 2 km, 4 km, 8 km, and 10 km from the road. The closer the area is to the road, the higher the potential for PLTS placement. Although there needs to be consideration of other supporting parameters.

In addition to distance, slope is also very important in determining the potential of solar power plants (PLTS) because the efficiency of solar panels is affected by the angle at which

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sunlight is received. A slope of 1.66° to 5.6° (very high to high) or almost flat slope is ideal for solar power plants especially for areas that receive a lot of solar radiation. On the other hand, areas that are too flat can increase the accumulation of dust or water so a slight slope is needed to allow rainwater flow to clean the panels properly. Areas with such slopes tend to be in the eastern and southeastern regions. Meanwhile, steep slopes of 20.13° to 52.93° (low to very low) have very low potential for solar power plants because extreme slopes may block solar radiation by shadows from the slope or neighbouring objects. In addition, there is also the difficulty of installation in locations with steep slopes. These locations are in the western to southern regions.

The placement of solar panel locations must also be adjusted to the land cover in the area. The classification of potential solar panel placement is divided into five classes: very high, high, medium, low, and very low. The reason settlements are classified into the very high class is because the placement of solar panels can optimise the use of rooftops thus reducing the need for additional land. Then open land is classified into the high class due to its high flexibility for solar power plant installation. However, relevant EIAs need to be planned to minimise negative impacts on the environment. There are two land covers that are classified as medium class, namely paddy fields and agriculture. Rice fields and agriculture have relatively stable land cover. However, the installation of PLTS in rice fields must consider irrigation patterns and harvest seasons. Land cover in the form of forests is classified as low potential, namely mangrove forests which are classified as low, and forests which are classified as very low. Mangrove forests have very sensitive environmental conditions. Installing solar power plants in this area is likely to potentially damage mangrove habitats and ecosystems. Just like mangroves, forests also have very high ecological values and complex vegetation structures. The installation of PLTS in this area can damage the habitat of the flora and fauna in it. If it is forced to be built in a forest area like this, it will cause damage and other negative impacts such as deforestation.

The last parameter is *Land Surface Temperature* (LST) which is also one of the important factors in regulating most of the earth's chemical, biological, and physical processes that can be controlled by the balance of surface, atmosphere, surface, and subsurface temperatures. LST is also an important indicator in the energy balance on the earth's surface. In solar power systems, the ground surface temperature can affect the efficiency of solar panels. Based on the data processing, the LST temperature was obtained with three classifications, 16-18 C, 27-34 C, and 35 - 43 C. High LST often indicates that an area has strong solar radiation. The higher LST can be an indicator of sufficient solar energy availability.

3.2. Map of Recommended Potential Locations for Solar Power Plant Development in East Sumba Regency in 2023

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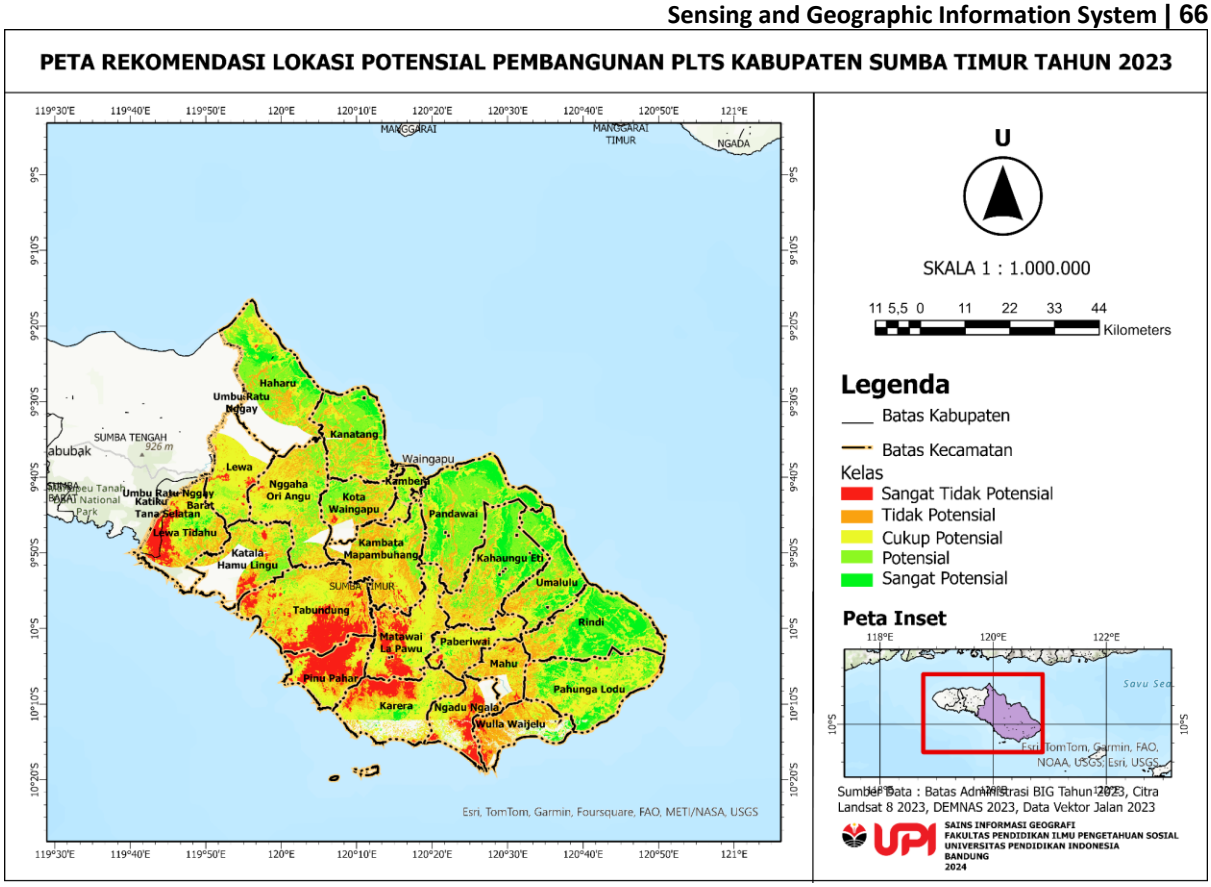

Figure 4. Map of Recommended Potential Locations for Solar Power Plant Development in East Sumba Regency in 2023

The map above is the result of *overlaying* the previously described parameter map, namely the East Sumba Regency PLTS Development Potential Location Recommendation Map in 2023 with a scale of 1:1,000,000. Based on these results, the area is divided into five classifications, namely very not **potential** (coloured red) scattered in parts of Lewa Tidahu, Tabundung, Mantawaila Pawu, Karera, Lewa, and Ngadu Ngala sub-districts; not potential (coloured dark orange) scattered in parts of Wulla Waijelu and Kambata Mapambuhang sub-districts; quite potential (coloured yellow) scattered in almost all East Sumba sub-districts; potential (light green in colour) scattered in parts of Rindi, Umalulu, Pandawai, Kambata Mapambuhang, Waingapu City, Kanatang, Nggaha Ori Angu, Lewa, Laala Hamu Lngu, Lewa Tidahu, and Haharu sub-districts; and very potential (bright green in colour) scattered in parts of Karera, Wulla Waijelu, Pahunga Lodu, Umalulu, Kahaungu Eti, Pandawai, Kambera, Kanatang, and Haharu sub-districts. These classifications can be described by percentage of area as follows:

1. Highly unpotential areas have a percentage of 9% with an area of 57477.6651 ha.
2. The non-potential area has a percentage of 18% with an area of 115291.2270 ha.
3. Moderately potential areas have a percentage of 41% with an area of 270067.5312 ha.
4. The potential area has a percentage of 19% with an area of 124259.0180 ha.

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5. High potential areas have a percentage of 13% with an area of 84271.8960 ha.

4. CONCLUSION

From this research, it can be concluded that East Sumba Regency has enormous potential for the development of Solar Power Plants (PLTS) thanks to the high intensity of solar radiation, which reaches 5.7 kWh/m² per day, as well as the availability of large tracts of land. Through remote sensing and Geographic Information System (GIS) methods, this research successfully mapped potential solar power plant areas by considering various parameters such as *land surface* temperature, slope, distance from roads, and land cover. Based on the results, the area of each potential PLTS development area classification is 13% for very potential areas, 19% for potential areas, 41% for moderately potential areas, 18% for non-potential areas, and 9% for very non-potential areas. This research emphasises the importance of planning in renewable energy development and contributes significantly to national efforts to increase the proportion of renewable energy in Indonesia and reduce dependence on fossil fuels.

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Hopefully this work can be a form of appreciation for all our efforts together and provide benefits to many people.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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