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IDENTIFICATION OF LANDSLIDE-PRONE AREAS IN CIANJUR REGENCY USING THE SMORPH MODEL

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ABSTRACT

Cianjur Regency has a high potential for landslides, as seen from the region's topographic parameters. This research aims to map landslide-prone areas in Cianjur Regency using the SMORPH (Slope Morphology) model. The results of landslide susceptibility mapping in Cianjur Regency using the SMORPH model show that 81.87% of the area is in the low susceptibility classification, 13.78% is in the medium classification, and 4.35% of the area is in the high susceptibility classification. Based on the Kappa accuracy test, the level of mapping accuracy with the SMORPH model has an overall accuracy value of 0.875, which means that the mapping results are almost in accordance with field conditions. It is hoped that the results of this research can be used as a reference model for more accurate landslide susceptibility mapping as a form of effort to increase landslide disaster capacity.

A. INTRODUCTION

Mountainous, hilly, and slopes are areas that are vulnerable to landslides throughout the world (Wang et al., 2022). The largest landslide event ever recorded occurred on Mount Huascaran, Peru, resulting in approximately 4,500 fatalities (Mergili et al., 2018). The landslide phenomenon is closely related to the conditions of soil binding capacity and stability (Guzzetti, 2006; Miswar et al., 2022).

As many as 54% of landslides in the world occur on the Asian continent, causing many casualties, especially in the Himalayan Mountain region (Alam et al., 2023). Landslide disasters can be caused by many causal parameters, especially intrinsic and trigger factors (Sim et al., 2023; Wachal & Hudak, 2000).

Indonesia as a tropical country with high rainfall and extreme temperature changes accompanied by lithological and topographic conditions means that Indonesia has the potential threat of landslides (Kaban et al., 2019). In Indonesia, the landslide disaster greatly impacted high material, non-material, and socio-cultural loss levels (Hardianto et al., 2020). Landslides themselves often occur in areas with slope conditions ranging from 15˚-45˚, weathered volcanic rock structures, rainfall intensity of more than 100 mm/day, and other intrinsic factors such as geological conditions and clay mineral

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content in the soil in the area (Hardianto et al., 2020; Prawiradisastra, 2013).

West Java Province is one of the provinces where landslides occur most frequently in Indonesia (Faizin & Azis Nur, 2018). This phenomenon is caused by the West Java Province region's many active volcanoes, which are dominated by areas with very steep slopes (Ramadhona & Susilo, 2019). The very dense anthropological activity in this province is also one of the causes of high vulnerability to landslides (Handayani & Singarimbun, 2016). A similar condition also occurs in Cianjur Regency, which is one of the districts in West Java.

Cianjur Regency is one of the areas with a high intensity of landslide incidents with data from 170 disasters that occurred, 66% were landslides (Bastiandy, 2020). This district is ranked 11th nationally in the category of areas with a high level of disaster risk (Puspita et al., 2014). Geographically, Cianjur Regency is at the foot of Mount Gede, which results in this district having topographic conditions dominated by hills, coupled with average rainfall in the range of 2,500-4,000 mm/year (Albaihaqi & Setiawan, 2024; Fadli, 2013). This condition causes Cianjur Regency to have a very high potential for being affected by landslides if seen from the rainfall parameters and topography of the area. Landslides are natural phenomena related to land adaptation efforts to changes that occur, but this phenomenon has turned into a disaster since human intervention occurred in the process (Fidan et al., 2024; Nugraha et al., 2015). The existence of susceptibility information itself can have an impact on human psychology and mental conditions regarding the disaster (Sim et al., 2023). However, detection of disaster-prone areas is still needed as an option for policymakers to carry out development planning as well as a form of mitigation for communities in these areas (Swain et al., 2023).

Geographic information system (GIS) based disaster susceptibility mapping is one of the best ways to increase the disaster capacity of a region (Ishola et al., 2023; Patil & Panhalkar, 2023; Rana et al., 2023). In mapping landslide disaster susceptibility, there are many mapping methods and models that can be used, one of which is the slope morphology model or what can be called the SMORPH model (Karfidova & Batrak, 2018). Mapping landslide susceptibility using the SMORPH model focuses on measuring and mapping the slope parameters and slope shape of the study area (Permadi et al., 2019; Whittaker & McShane, 2012).

From the background of the problem above, this study and research process was carried out to map the level of susceptibility to landslides in Cianjur Regency using the SMORPH model.

B. METHOD

In mapping landslide susceptibility using the SMORPH model, two main parameters are used, namely the slope parameter and the slope shape parameter. The use of these two parameters is by the provisions for applying the SMORPH model which has been established by (Shaw & Johnson, 1995) as the creators of this landslide susceptibility mapping model. The data source used is digital elevation model (DEM) data with a resolution level of 8.5 x 8.5 meters.

In the data processing process, several mapping techniques are used such as scoring, overlay, and intersect. In the next step, after the slope and slope shape parameters have been processed, the two parameters are combined using the intersect overlay technique. This technique is used to obtain classification cuts from the two parameters used so that only the extension features of each parameter will be displayed (Ramadhan, 2019). Next, the results of the intersect process will be classified using the SMORPH matrix to fulfill the process requirements for landslide disaster susceptibility mapping in the SMORPH model (Permadi et al., 2019; Shaw & Johnson, 1995). The SMORPH matrix can be seen in Table 1.

The area that is the research location in this study is Cianjur Regency, which is one of the areas most frequently affected by landslide disasters. The location of Cianjur Regency is at the intersection of Bandung-Bogor-Jakarta and Bandung-Sukabumi, which means this district has a vital role as a route connecting these cities. So if Cianjur Regency is affected by a disaster such as a landslide, it can indirectly affect connectivity between regions and can result in material and non-material losses. This region has a total area of 3,614.35 km² or covers 10.85% of the total area of West Java Province.

Table 1. SMORPH Matrix

Slope Shape	**Slope**				
	A (0 – 8%)	**B (8 – 15%)**	**C (15 – 25%)**	**D (25 – 45%)**	**E (> 45%)**
Planar	Low	Low	Low	Medium	High
Concave	Low	Low	Low	Medium	High
Convex	Low	Medium	High	High	High

(Source: Shaw & Johnson, 1995; Permadi et.al., 2019)

Based on Figure 1 below, Cianjur Regency borders with Bogor Regency and Purwakarta Regency in the north; Sukabumi Regency and Bogor Regency in the west; the Indian Ocean in the south; and Purwakarta Regency, Bandung Regency, West Bandung Regency, and Garut Regency in the east.

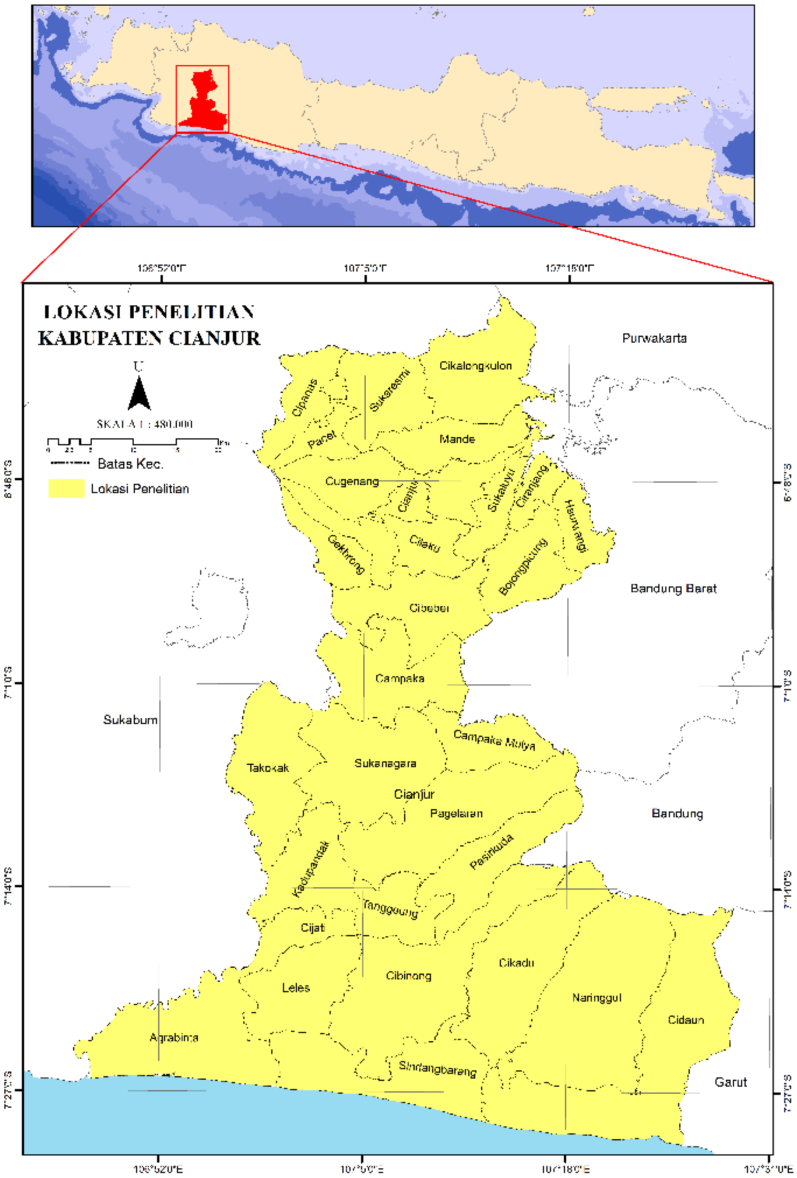

Figure 1. Study Location
(Source: Data processing, 2024)

The final step in this research process is the process of validating the results of landslide disaster susceptibility mapping using the SMORPH model with data on landslide disaster events in Cianjur Regency throughout 2022. Validation of mapping data with landslide disaster event data will be determined by carrying out the Kappa accuracy test. The accuracy test process with the Kappa coefficient will produce overall accuracy values, producer's accuracy, user's accuracy, and kappa accuracy. Overall accuracy is the number of pixels that have been confirmed to be appropriate for each classification compared to the number of samples used as an accuracy test (Firmansyah et al., 2019). The producer's accuracy is the accuracy of the map results seen from the map maker's perspective, while the user's accuracy is the accuracy of the map results seen from the map user's side (Wulansari, 2017).

Furthermore, to determine the level of accuracy of the mapping results using the Kappa accuracy test, a percentage correct standard is used in the results of calculating the overall accuracy value. As a condition for the acceptance or suitability of a mapping result, the Kappa test result must have an overall accuracy value above 0.80 (Muhammad et al., 2016).

C. RESULT AND DISCUSSION

C.1. RESULT

a) Slope

It is one of the main factors causing landslides in Indonesia. In several landslide susceptibility mapping methods, this parameter is the parameter with the highest score, which means that this parameter is the biggest causal factor in the potential for landslides in an area.

In this research, DEM data is processed using slope techniques to produce slope maps and reclassify for slope classification. Slope parameters are classified into five slope gradient classifications (Syafri et al., 2015). This slope classification has been scientifically approved as a basic classification that can be used to classify slope parameters that can be used generally throughout Indonesia.

From the results of area calculations for each parameter classification, it is found that the flat classification (0-8%) dominates the Cianjur Regency area with an area of 1,823.85 km². Meanwhile, the classification of very steep slopes (>45%) has the smallest area with an area of 9.31 km². Based on the analysis of the mapping results, it can be seen that slopes classified as steep and very steep are distributed in the northwestern and southeastern parts of Cianjur Regency.

b) Slope Shape

Slope shape is one of the main parameters in landslide susceptibility mapping using the SMORPH model. Slope shape itself refers to the physical characteristics and geometry of a slope or sloping surface which includes a description of the morphology and structure of the slope, including the character of elevation and changes in existing slopes (Latue et al., 2023).

The data used to process Slope shape parameters is DEM data with a resolution of 8.5 x 8.5 meters which is processed using ArcMap 10.8 software using curvature techniques to obtain Slope shape and reclassify to classify Slope shapes. In this research, slope shape parameters are classified according to Ramdhoni et al. (2020) which are divided into three classifications. From the results of area calculations for each parameter, it was found that the flat (planar) slope shape classification is the dominant slope shape in Cianjur Regency with an area of 1,699 km² or 47.01% of the total area of Cianjur Regency. Meanwhile, the concave slope shape classification has the smallest area with an area of 605.27 km² or 16.75% of the total area of Cianjur Regency.

Based on the mapping results of slope shape parameters, it can be seen that the slope shapes in Cianjur Regency tend to be diverse and look very complex in each region so it is not visible which type of slope shape dominates in each region.

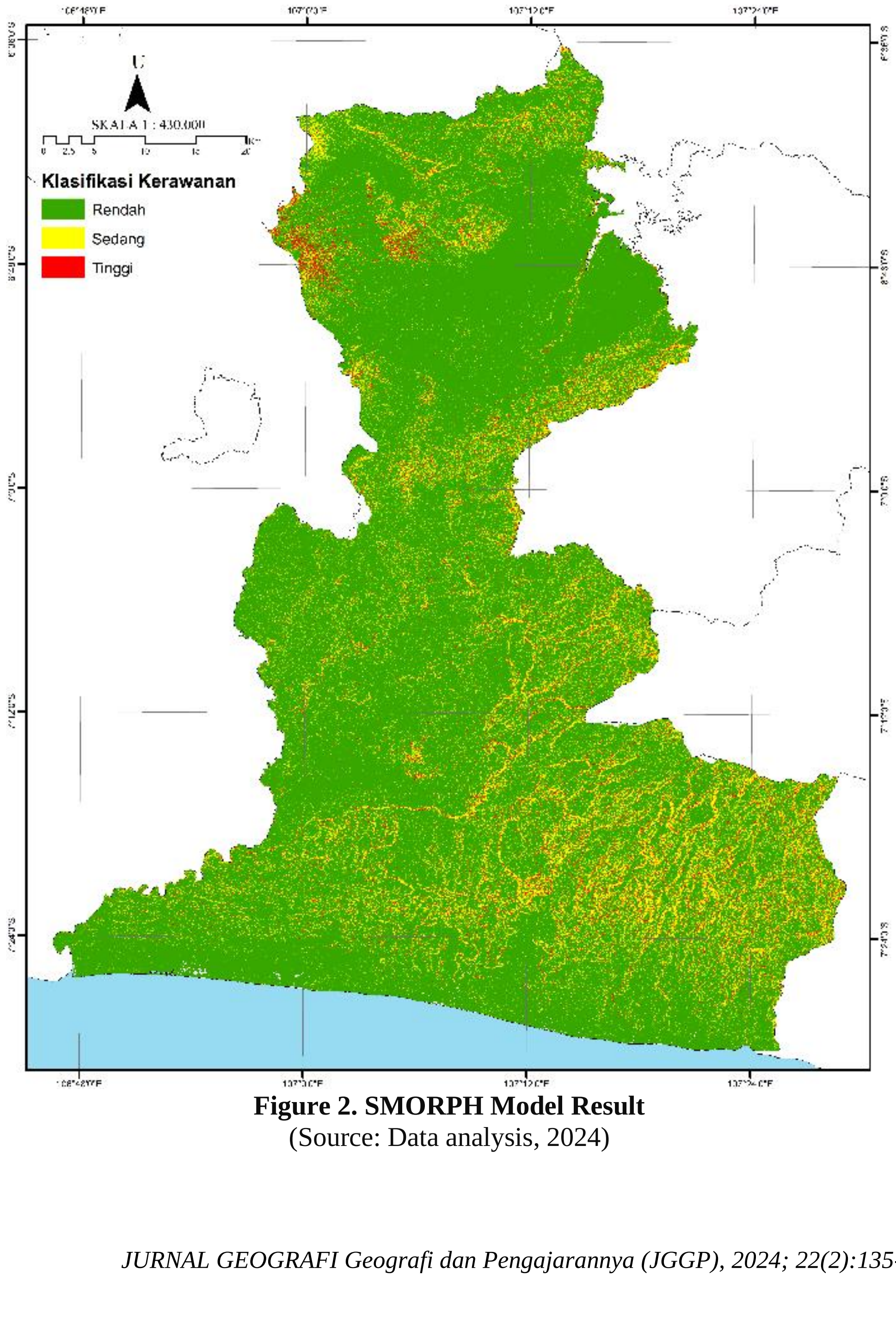

Figure 2. SMORPH Model Result
(Source: Data analysis, 2024)

c) SMORPH Model Result

The results of the intersect overlay process between slope and slope shape parameters followed by a classification process using the SMORPH matrix have produced a landslide disaster susceptibility map in Cianjur Regency using the SMORPH model. The results of the SMORPH model of landslide susceptibility mapping can be seen in Figure 2, while the numerical results can be seen in detail in Table 2.

According to Table 2, it can be seen that from the results of landslide susceptibility mapping using the SMORPH model in Cianjur Regency, the largest susceptibility class is the low susceptibility class with an area of 2,959.12 km² or 81.87% of the total area of Cianjur Regency, followed by the susceptibility class medium area with an area of 498.10 km² (13.78%) and high susceptibility class with an area of 157.13 km² (4.35%). High susceptibility classes are widely distributed in the northern and southeastern regions of Cianjur Regency.

Table 2. Results of Landslide Susceptibility Classification using the SMORPH Model

Num	Susceptibility Classification	Area (km^2)	%
1.	Low	2.959,12	81,87%
2.	Medium	498,10	13,78%
3.	High	157,13	4,35%
	Total	**3.614,35**	**100%**

(Source: Data analysis (2024)

Based on the formulas and explanations above, the next process is to carry out the analysis and calculation process of the Kappa accuracy test between mapping research results and data on landslide disaster events in Cianjur Regency. The result of calculating the overall accuracy value is 0.875, which is included in the almost perfect agreement category or has results that are almost by field conditions. Meanwhile, the Kappa coefficient (T) value is 0%. This means that landslide susceptibility mapping using the SMORPH model can be used to map landslide susceptibility, especially in the Cianjur Regency.

C.2. DISCUSSION

The results of landslide susceptibility mapping in Figure 2 are the intersection results, which are then classified again using the SMORPH matrix. This is under previous research, namely the use of the SMORPH matrix as a standard of differentiation between SMORPH modelling and other landslide susceptibility modelling (Permadi et al., 2019; Triwahyuni et al., 2017).

However, the SMORPH model itself is a landslide susceptibility mapping model that is only based on two parameters that cause landslides, while landslides are a type of complex natural disaster that can be caused by many parameters, so a more in-depth study is needed about the main parameters that cause landslides in a region.

D. CONCLUSIONS

After conducting research regarding landslide susceptibility mapping using the slope morphology (SMORPH) model, it can be concluded that based on the parameters of slope shape and slope, most of the Cianjur Regency area is an area with a low level of landslide disaster susceptibility even though it is located in an area with a regional topographic structure filled with slopes and hilly areas.

The area of the area that is at the high level of landslide disaster susceptibility based on the results of mapping using the SMORPH model is 157.13 or 4.35% of the total area of Cianjur Regency, the medium classification is 498.10 km² (13.78%), and low classification covering an area of 2,959.12 km² (81.87%);

The results of landslide susceptibility mapping in Cianjur Regency using the SMORPH model have an overall accuracy value of 0.875 or are included in the almost perfect agreement category or have results that are almost by field conditions.

RECOMMENDATIONS

From the research process carried out, several suggestions can be taken into consideration by future researchers who will use the SMORPH model to map landslide susceptibility in an area and related parties to increase the capacity to handle landslides, including:

1. The SMORPH model is a landslide susceptibility mapping model which is only based on two parameters that cause landslides, while landslides are a type of complex natural disaster that can be caused by many parameters so a more in-depth study is needed about the main parameters that cause landslides. In a region;
2. Paying attention to the stable condition of the ecosystem and preserving the preservation of vegetation areas is one of the best preventive measures to reduce the level of threat of landslides;
3. Calculation of accuracy tests in landslide susceptibility mapping using the SMORPH model also needs to consider small-scale landslide events in the study area;
4. To facilitate the research process and increase the level of accuracy of research results, it is best to use a smaller research area.

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