

# Detection landslide vulnerable zones of West Lampung Regency using the geographic information system approach

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**Abstract.** West Lampung Regency is one of the regencies in Lampung Province that is vulnerable to landslides. Quoted from the official website of the National Disaster Management Agency (BNPB), it is stated that 50% of sub-districts in the West Lampung Regency are areas prone to landslides. This study detects landslide-prone zones in West Lampung Regency with a GIS spatial analysis approach. The results showed some sub-districts in West Lampung Regency that are at high to very high risk of landslide hazards with a percentage of 40.66% of the district's area.

## 1. Introduction

Indonesia is located on the equator, so it receives a lot of heat from the sun and high rainfall. As a result, Indonesia has become one of the areas prone to hydro-meteorological natural disasters such as floods, droughts, large ocean waves, and so on [1]. Data from the National Disaster Management Agency [2] recorded that throughout 2021 there had been various disasters in Indonesia, ranging from earthquakes, fires, droughts, floods, landslides, cyclones tidal waves.

Based on the data on the page, a landslide disaster is a disaster that ranks third in terms of the number of occurrences. It was recorded that throughout 2021 from January to mid-April, 222 landslides occurred across Indonesia. Landslide is a downslope movement by the mass of soil and rock that makes up the slope. This soil movement is one of the geological processes that occur due to the interaction of several conditions, including geomorphology, geological structure, hydrogeology, and land use [3].

The main factors that cause landslides include steep slopes, less dense and thick soil, high rainfall, types of land use, vibration, the presence of heap material on cliffs, old landslides, deforestation, and waste disposal areas [1]. In general, landslides occur in tropical, hilly areas, which often occur during the rainy season due to disturbance of soil stability. This disturbance of soil stability triggers the movement of soil and rock masses or a mixture of the two to descend the slope.

Like floods, landslides are natural disasters that can be predicted because they are associated with high rainfall. Because the water content factor is quite dominant, landslides often occur in the rainy season in areas with steep topography. The elements are closely related, such as soil type, rock type, rainfall, land slope, and land use. In addition, human factors, namely human activities on land that burden slopes, also contribute to the occurrence of landslides and in utilizing lands such as mining, explosions, land changes, and uncontrolled deforestation [4].

West Lampung Regency is one of the regencies in Lampung Province, with the capital city Liwa. The land area is dominated by hilly geographical conditions, mountainous regions, which are the ridges

of the Bukit Barisan with a land slope of more than 45%. Quarter volcanic overlooks the rock formations from several geological formations with rendzina and lithosol soil types. In general, West Lampung Regency is located at more than 500 meters above sea level, with high precipitation conditions. It is traversed by the Semangko Fault, with a zone width of 20 kilometers. This is what causes the West Lampung Regency area to have the highest vulnerability to the danger of landslides.

According to the geological agency, the threat of landslides in the West Lampung Regency is relatively high, even the highest in Lampung Province. More than 50% of the sub-districts in West Lampung Regency are areas with moderate to high landslide-prone areas.

One way that can be applied to predict landslide disasters is to use an application program approach that can take an inventory of affected locations using a Geographic Information System (GIS). Modeling by utilizing GIS through spatial analysis methods makes it possible to formulate pre-disaster management policies such as early warning, which can be an alternative for the West Lampung Regency Government, in providing thematic geospatial data information on which areas have high or very high vulnerability to environmental hazards. Landslide hazard in the form of a thematic map of landslide hazard zones. The objectives of this research activity are (1) determining the Landslide Prone Class Zone in the West Lampung Regency and (2) Making a Thematic Map of the Landslide Prone Zone in the West Lampung Regency.

## **2. Method**

This research uses geospatial analysis research by utilizing graphic visual data in several thematic maps, which are the parameters that cause landslide hazards. The results of the geospatial analysis of the location are grouped into categories of vulnerability with the design of activities, as presented in Figure 1.

The materials used in this research activity consisted of the Administrative Map of West Lampung Regency, Map of Daily Rainfall for West Lampung Regency, Land Cover Map of West Lampung Regency, Slope Map of West Lampung Regency, Geological Map of West Lampung Regency, and Soil Type Map of West Lampung Regency. At the same time, the tools used in this research activity are computers, printers, and Arc Gis 10.3 software.

The research stages include (i) collecting information and data, (ii) scoring and parameter weighting, (iii) digital map overlaying, (iv) determining the total score, (v) determining class intervals, (vi) analyzing the level of vulnerability landslides, and (vii) presentation of a landslide hazard map in West Lampung Regency.

### *2.1 Stages of Research Implementation*

*2.1.1. Data information and collections.* This research's information and data are secondary data, a parameter for determining landslide hazard analysis using a Geographic Information System (GIS) approach. The data was collected as mentioned in the section above.

*2.1.2. Parameter scoring and weighting.* Analysis of landslide hazard data was carried out after the thematic maps, namely soil type maps, rock type maps, land use maps, rainfall maps, and slope maps, were available and ready in the form of digital maps. Each type of map is classified based on the score. After that, the maps of the five parameters were overlapped to find the total score multiplied by the weight, then added up and classified the level of vulnerability based on the analysis of the total score.

Scoring is used to determine or assess the level of landslide susceptibility in the study area. The scoring refers to the parameters issued by the 2004 Puslittanak, where these parameters are used to classify and weight each map. The weight is based on the effect of the map on the occurrence of

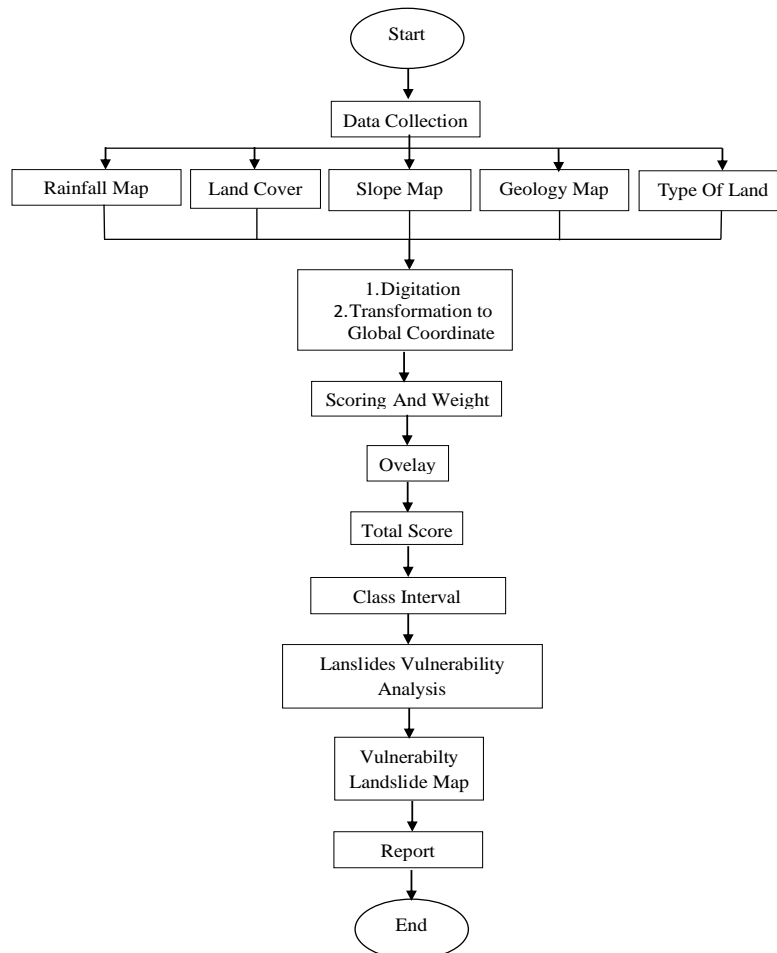
landslides. The estimation model for analyzing landslide susceptibility refers to the research of the Research Center for Research and Development in 2004 with the formula:

$$\text{Total Score} = 0,3\text{FCH} + 0,2\text{FBD} + 0,2\text{FKL} + 0,2\text{FPL} + 0,1\text{FJT}$$

Where:

- FCH = Rainfall Factor
- FBD = Type of Geology
- FKL = Slope Factor
- FPL = Land Use Factor
- FJT = Type f Land Factor

The weights and scores based on the results of the 2004 Puslittanak research in terms of analyzing landslide susceptibility are as presented in Table 1 to Table 5.



**Figure 1.** Flow Chart of Research Implementation.

**Table 1.** Classification of Rainfall Intensity (mm year<sup>-1</sup>).

Parameter	Weight	Score
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Very Wet (>3000)		5
Wet (2501-3000)		4
Slightly Wet (2001-2500)	30%	3
Dry (1501-2000)		2
Very Dry (<1500)		1

Source : [5]

**Table 2.** Classification of Sloope.

Parameter (%)	Weight	Score
>45 (Very Steep)		5
30-45 (Steep)		4
15-30 (a bit Steep)	20%	3
8-15 (Sloping)		2
<8 (Flat)		1

Source : [5]

**Table 3.** Classification of Geology.

Parameter	Weight	Score
Volkanik-2 (Qvsb, Qvst, Qvb, Qvt) dan Sediment-2 (Tmb, Tmbl, Tmtb)		4
Sediment-1 (Tmn, Tmj)	20%	3
Volkanik-1 (Qvsl, Qvu, Qvcp, Qvl, Qvpo, Qvk, Qvba)		2
Aluvial (Qav, Qa, a)		1

Source : [5]

**Table 4.** Classification of Land Used.

Parameter	Weight	Score
Moor, Ricefield		5
Bush		4
Forest dan Plantation	20%	3
City		2
Pond, Reservoir, waters		1

Source [5]

**Table 5.** Classification of Type Of Land.

Parameter	Weight	Score
Regosol		5
Andosol, podsolik, Grumusol		4
Brown Latosol, Kambisol	10%	3
Latosol, Yellow Brown Latosol Association		2
Aluvial		1

Source : [5]

## 2.2 Vulnerability Analysis

The value of an area's vulnerability to landslides is determined from the total score of each parameter. Very vulnerable regions will have a high total score, and vice versa, areas that are not prone to will have

a low total score.

**Table 6.** Vulnerability Class.

No.	Vulnerability Class	Total Score
1	Very Vulnerable (K1)	> 4,3
2.	Vulnerable (K2)	3,5 – 4,3
3.	Slightly Vulnerable (K3)	2,6 – 3,4
4.	Safe (K4)	1,7 – 2,5
5.	Very Safe (K5)	< 1,7

Source :[1]

### 3. Results and Discussion

#### 3.1 Administration Map of West Lampung Regency

West Lampung Regency is one of the regencies in Lampung Province, formed based on Law no. 6 of 1991 dated July 16, 1991, and promulgated on August 16, 1991, with the capital city Liwa. West Lampung is a highland with an average height of + 645 meters above sea level, located at a position of 4°47'16" - 5°56'42" south latitude and between 103°35'08" - 104°33'51" east longitude. The administrative boundaries of West Lampung Regency are:

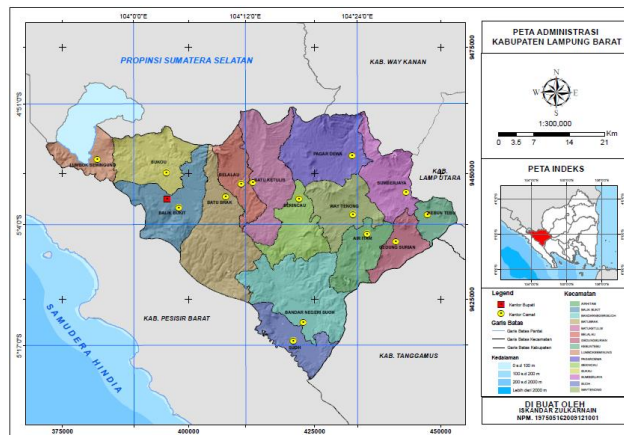
- In the north, it is bordered by South OKU Regency (South Sumatra Province);
- The east is bordered by North Lampung Regency, Way Kanan Regency.
- To the south, it is bordered by Pesisir Barat Regency and Tanggamus Regency,
- In the west, it is bordered by the Pesisir Barat Regency

The total area of West Lampung is in the form of a land area of 2,064.4 km<sup>2</sup>. The administrative area of West Lampung Regency consists of 15 sub-districts based on Law no. 6 of 1991 dated July 16, 1991, as presented in Table 7. The administrative map of West Lampung Regency with the existing fifteen sub-districts is shown in Figure 2.

**Table 7.** Total Area of Sub District West Lampung Regency.

No.	Sub District	Area (Km <sup>2</sup> )	No.	Sub District	Area (Km <sup>2</sup> )
1.	Balik Bukit	159.41	9.	Gedung Surian	76.96
2.	Sukau	146.07	10.	Kebun Tebu	61.55
3.	Belalau	93.91	11.	Air Item	108.12
4.	Sekincau	115.09	12.	Pagar Dewa	197.71
5.	Suoh	150.22	13.	Batu Ketulis	182.01
6.	Batu Brak	199.29	14.	Bandar Negeri Suoh	267.23
7.	Sumber Jaya	130.44	15.	Limbok Seminung	98.88
8.	Way Tenong	129.70			
Total Area Of West Lampung Regency 2.116,59					

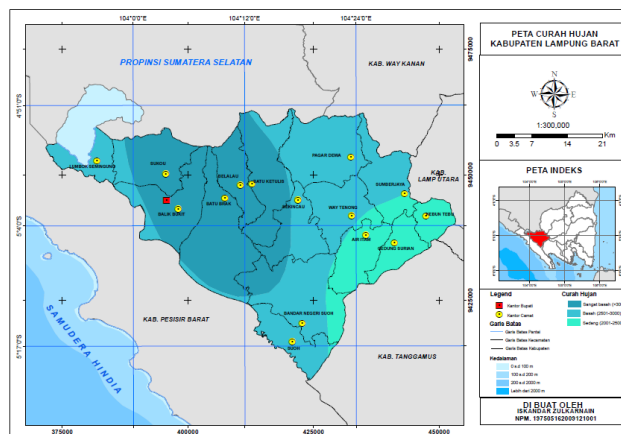
Source : [6]



**Figure 2.** Administration Map of West Lampung Regency.

### 3.2 Rainfall Map of West Lampung Regency

Rainfall in West Lampung Regency, based on climate data found at the Balik Bukit and Belalau Climatology Stations, is known to range from 2,000-3,500 mm per year. The humidity regime is classified as wet (UDIC), with 50 – 80% humidity. The temperature regime ranges from hot (is hypothemic) in the coastal plains (in the west) to cold (isosesic) in hilly areas, with the percentage of sunlight ranging from 37.9 – 50.0%. Rainfall Map of West Lampung Regency as presented in Figure 3.



**Figure 3.** Rainfall Map of West Lampung Regency.

Rainfall in the range of 2000 mm – 2500 mm (moderate humidity) occurs around Kebun Tebu District, Gedung Surian, Air Itam, a small part of Sumber Jaya District, and Bandar Negeri Suoh. Average rainfall of 2500 mm – 3000 mm (wet humidity) occurred in Suoh, Bandar Negeri Suoh, Sekincau, Way Tenong, Sumber Jaya, Pagar Dewa, Lumbok Semingung, and a small part of the sub-districts of Batu Ketulis, Balik Bukit, and Sukou. Meanwhile, high rainfall > 3500 mm (very wet humidity) occurred in the Districts of Belalau, Batu Brak, Batu Ketulis, Balik Bukit, Sukou, and a small part of the districts Sekincau Subdistrict and Bandar Negeri Suoh.

### 3.3 Slope Map of West Lampung Regency

The shape of the land slope in the administrative area of West Lampung Regency is divided into 5 (five) land slope classes as presented in Table 8.

**Table 8.** Slope Of Land In West Lampung Regency.

No.	Land Type	Sloope (%)	Area (Km <sup>2</sup> )	Percentage
1	Flat	0 – 8	604,84	29.30%
2.	Sloping	8 – 15	487,68	23.62%
3.	A Bit Steep	15 – 30	643,19	31.16%
4.	Steep	30 – 45	240,87	11.67%
5.	Very Steep	> 15	87,83	4.25%
Total			2064,4	100%

Source : Data Analysis, 2021

Based on Table 8, it can be said that the shape of the slopes of the Lampung Regency area varies significantly with flat to sloping land by 52.92% while the slope conditions with the steep, steep to very steep at 47.08%. For each sub-district, the percentage of land slope type is presented in Table 9

**Table 9.** Percentage Sloope in Each Sub-District West Lampung Regency.

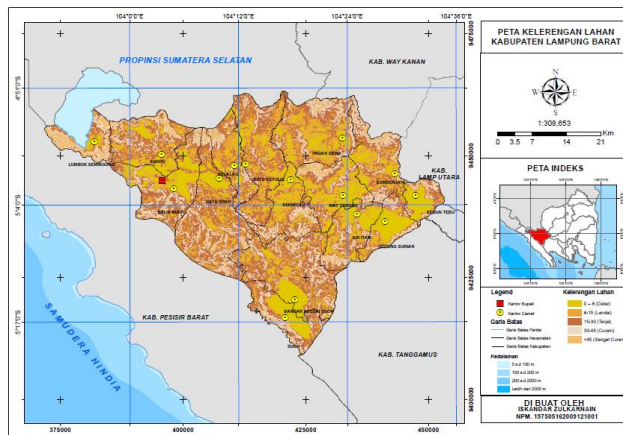
No.	Subdistrict	% of Type of Land				
		Flat	Sloping	A Bit Steep	Steep	Very Steep
1	Balik Bukit	34.74%	19.26%	30.17%	12.13%	3.71%
2.	Sukau	25.74%	23.46%	34.95%	11.64%	4.22%
3.	Belalau	26.50%	30.23%	30.24%	9.46%	3.57%
4.	Sekincau	30.13%	25.47%	28.76%	12.13%	3.50%
5.	Suoh	34.85%	13.73%	30.82%	15.27%	5.34%
6.	Batu Brak	17.96%	23.79%	41.98%	13.30%	2.97%
7.	Sumber Jaya	25.48%	23.04%	29.66%	15.67%	6.14%
8.	Way Tenong	41.30%	23.16%	21.12%	9.39%	5.04%
9.	Gedung Surian	50.73%	15.83%	19.11%	10.55%	3.78%
10.	Kebun Tebu	50.17%	11.45%	23.48%	11.06%	3.84%
11.	Air Itam	39.20%	23.90%	23.05%	10.14%	3.71%
12.	Pagar Dewa	28.83%	29.98%	26.28%	11.04%	3.86%
13.	Batu Ketulis	27.46%	33.02%	33.30%	5.73%	0.49%
14.	Bandar Negeri Suoh	24.33%	23.67%	39.88%	10.52%	1.59%
15	Lumbok Seminung	10.25%	12.02%	24.15%	24.84%	28.74%

Source: Data Analysis, 2021

The dominance of the slope class ranging from a bit steep, steep dan very vertical with a percentage of more than 50% is in the Sukau, Suoh, Sumber Jaya, Lumbok Seminung, Suoh, and Batu Brak Sub-districts. 50% of the sub-district area is dominated by a bit steep to very steep.

The dominance of slope classes ranging from flat to sloping with 50% - 60% is in the Districts of Balik Bukit, Belalau, Sekincau, and Pagar Dewa. The dominance of slope classes ranging from flat to sloping with more than 60% is in Way Tenong, Gunung Surian, Kebun Tebu, Air Itam, and Batu Ketulis Districts.

Overall, the graphic data in the Thematic Slope Map of West Lampung Regency is presented in Figure 4.



**Figure 4.** Slope Map Of West Lampung Regency

### 3.4 Geology Map of West Lampung Regency

Based on the search for soil type data in the West Lampung Regency, the results are presented in Table 10.

**Table 10.** Soil Type of West Lampung Regency.

No.	Soil Type	Area (ha)	Percentage
1	Latosol	43.53	2.11%
2.	Yellow Brown Latosol Association	907.24	43.95%
3.	Aluvial Hidromorf	773.05	37.45%
4.	Podsolc	340.58	16.50%
Total			100%

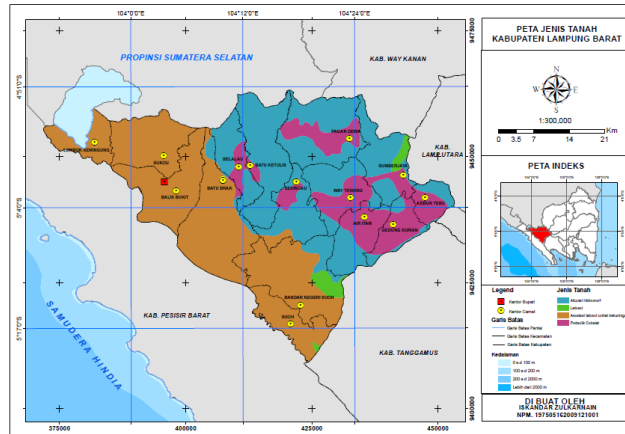
Source : Data Analysis, 2021

Based on Table 10, it can be seen that the type of soil in West Lampung Regency is dominated by Latosol soil by 46.6%, which is spread over several sub-districts. At the same time, the minor type of soil is Podsolc which reaches an area of 16.50%. The details of the soil types in the West Lampung Regency are as follows:

- Soil types in West Lampung Regency are dominated by four soil types, namely Alluvial Hydromorph, Latosol, Yellow Brown Latosol Association.
- Alluvial Hydromorph soil type is found in some areas of Kebun Tebu Sub-district, part of Sumber Jaya District, part of Pagar Dewa District, part of Batu Ketulis District, part of Way Tenong Sub-district of Way Tenong, part of Gunung Surian District, part of Air Itam District, part of Sekincau sub-district area, part of Bandar Negeri Suoh sub-district, and Belalau.
- Latosol soil type is found in a small part of Sumber Jaya District and Bandar Negeri Suoh
- Soil type Asosiasi Yellow Brown Latosol Association is found in the District of Suoh, Bandar Negeri Suoh, Batu Brak, Batu Ketulis, Sukou and Lumbok Seminung
- Podsolc soil type is found in part of Kebun Tebu Sub-district, part of Gunung Surian District, part of Air Itam District, part of Way Tenong District and part of Sekincau Sub-district, part of Belalau District, part of Belalau District, part of Batu Ketulis, and part of the Pagar Dewa District Area

Overall graphic data in the form of the Thematic Map of Soil Types for West Lampung Regency is presented in Figure 5





**Figure 5.** Soil Type of West Lampung Regency.

### 3.5 Land Use Map of West Lampung Regency

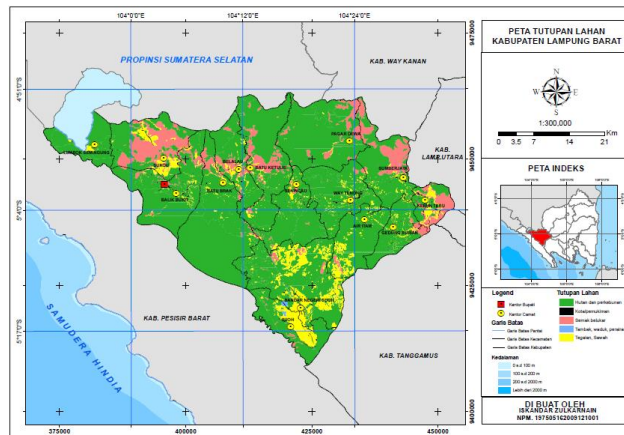
Based on the search for land use data in the West Lampung Regency, the results are presented in Table 11.

**Table 11.** Land Use Map of West Regency.

No.	Land Use	Area (ha)	Percentage
1	Plantation/Gardens	1187.749	57.53%
2	Lake	2.322211	0.11%
3	Pond	0.017408	0.00%
4	Swamp	0.073436	0.00%
5	River	3.838707	0.19%
6	Shrub	242.144	11.73%
7	Bare Land	0.997445	0.05%
8	Ricefield	113.4756	5.50%
9	Building	28.44557	1.38%
10	Forest	427.0068	20.68%
11	Moor/Field	58.32932	2.83%
Total			100%

*Source: Data Analysis, 2021*

Overall, the graphic data in the Thematic Map of Soil Types for the West Lampung Regency is presented in Figure 6.



**Figure 6.** Land Use Map Of West Lampung Regency.

### 3.6 Data Analysis

Based on the parameters identified and collected, with the overlay method using the Arc Gis 10.3 application, a spatial analysis of the overlay with the intersect toolbox will be carried out, which will overlap all the thematic map parameters.

Based on the calculation of the total score of each parameter that determines the potential for landslide hazard and using an interval range of 0.68, it is obtained a classification of the area with five classes of flood vulnerability, namely Very Safe, Safe, Slightly Vulnerable, Vulnerable and Very Vulnerable.

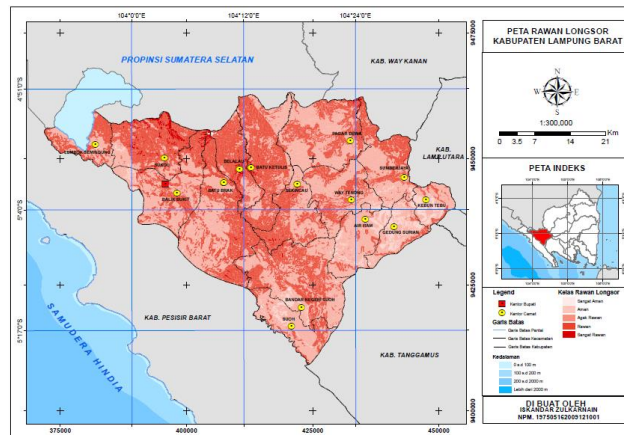
The results of the classification of landslide-prone classes using the Sturges formula can be seen in Table 12.

**Table 12.** Vulnerability Class Base on Sturges Formula.

No.	Class of Vulnerability	Total Score
1.	Very Vulnerable (K1)	4,02 – 4,70
2.	Vulnerable (K2)	3,34 – 4,02
3.	Slightly Vulnerable (K3)	2,66 – 3,34
4.	Safe (K4)	1,98 – 2,66
5.	Very Safe (K5)	1,30 – 1,98

*Source : Data Analysis, 2021*

An Overlay Analysis with Intersect is performed in the ArcGis 10.3 arc toolbox. The overlay involves spatial elements in the form of a map of each parameter and the accompanying attributes. The results of overlaying landslide-prone parameter maps can be seen in Figure 7.



**Figure 7.** Landslide-Prone Class Map of West Lampung Regency.

Based on the results of the overlay of the landslide-prone parameter map, the calculation of the area of each class was carried out with the help of ArcGIS 10.3 software. The results of the analysis of the location of each class classification map prone to landslides in the West Lampung Regency are presented in Table 13.

**Table 13.** Prone Class Map of West Lampung Regency.

No.	Prene Class	Score	Area	Percentage
1	Very Vulnerable (K1)	4,02 – 4,70	27.55	1.30%
2.	Vulnerable (K2)	3,34 – 4,02	833.16	39.36%
3.	Slightly Vulnerable (K3)	2,66 – 3,34	1136.67	53.70%
4.	Safe (K4)	1,98 – 2,66	119.02	5.62%
5.	Very Safe (K5)	1,30 – 1,98	0.19	0.01%
Total				100%

Source: Data Analysis, 2021

#### 4. Conclusion

Based on the results of the analysis and discussion, it can be concluded several things, namely: (1) The level of vulnerability to landslides in the West Lampung Regency is divided into five classes: Very Safe, Safe, Slightly Vulnerable, Vulnerable dan Very Vulnerable.; (2) The landslide-prone level that dominates West Lampung Regency is the landslide-prone level in the category Slightly Vulnerable with an area of 1.136,67 km<sup>2</sup> (53.70%); (3) Areas prone to landslides with a category Very Vulnerable are located in the Districts of Balik Bukit, Sukau, Belalau, Sekincau, Batu Brak, Sumber Jaya, Pagar Dewa, Batu Ketulis, and Bandar Negeri Suoh. With a relatively Curam land slope and very high rainfall and soil types that are susceptible to landslide hazards.; and (4) Most of the areas are categorized as Safe to Very Safe are in Kebun Tebu District, Gedung Surian District, Suoh District, and Air Itam District.

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