International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Zonation Modeling of the Potential Landslide Based on GIS Deterministic Method PVMBG Classification, Jonggol Sub-District, Bogor District, West Java

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Abstract—*The research area is administratively located in Jonggol District, Bogor Regency, West Java Province according to BNPB in the 2020 Indonesian Disaster Risk Index (IRBI) book that Bogor Regency has a score of 24 including in the high risk class which is a natural disaster of land movement or commonly called landslides, It is thus essential to understand the vulnerability class of movement, the kind of land movement, the area included in the Regional Spatial Plan (RTRW), and the present land cover. Creating a map of ground motion vulnerability zoning based on data obtained in the form of rock type map, fault distance map, soil texture map, solum soil depth map, slope map, slope facing map, and rainfall map, each of which will be given a value and weight according to the classification of ground motion vulnerability zone determination issued by the Center for Volcanology Geological Disaster Mitigation (PVMBG) in 2015 and processed into Geographic Information System (GIS) software in digital form which is then combined with one another. The results of the study there are five classes of ground motion vulnerability from the widest, namely very high, low, high, medium, and very low classes with the type of ground motion in the form of rotation or horizontal (rotational slide) and translation (translational slide) with material in the form of soil (soil) and the type of ground motion in the form of fall (fall) with material in the form of rock (rock). Based on the overlay of the ground motion vulnerability map with the RTRW map, there are 33 zones with a very high ground motion vulnerability class, the limited production forest area is the largest zone in the results of this overlay, while the overlay of the ground motion vulnerability map with land cover there are 29 zones with a very high ground motion vulnerability class with forest land cover, the largest zone in the results of this overlay.*

Keywords— *Bogor Regency, GIS, Ground Motion, Jonggol, PVMBG*

I. Introduction

Jonggol District in Bogor Regency, West Java, is one of the areas with high vulnerability to landslides. This is influenced by geological factors such as rock and soil types, as well as high rainfall, which play a role in slope instability. According to the National Disaster Management Agency (BNPB), Bogor Regency has a significant landslide disaster risk score (IRBI 2020: score 24), with Jonggol as one of the most affected areas. The study area is located at coordinates 106°58'48"–107°1'48" E and 6°30'0"–6°32'24" S, covering three villages (Jonggol, Klapanunggal, Sukamakmur) with an area of 20.09 km². The use of Geographic Information Systems (GIS) is considered effective in identifying landslide-prone zones in detail, supporting risk mitigation and further research development. This study aims to map landslide vulnerability in Jonggol to reduce its impact on the community and the environment.

II. Regional Geology

This study takes place in West Java Province, specifically in the Jonggol District of Bogor Regency. The administrative boundaries of Bogor Regency are Bekasi Regency to the north, Depok City to the west, Karawang and Purwakarta Regencies to the east, and Cianjur and Sukabumi Regencies to the south. Physiographically (Bemmelen 1949) it is included in the Bogor zone, located south of the Jakarta Coastal Zone, covering areas such as Rangkasbitung, Bogor, to Sumedang. This area is hilly, consisting of igneous rocks and tertiary sediments resulting from intrusion and extrusion activities. The Jonggol area is included in the Bogor and Cianjur Regional Geological Map Sheet. Several rock units found in this area include: Alluvial Fan (Qav) is a quaternary deposit resulting from re-deposition of volcanic rocks, composed of siltstone, sandstone, and gravel. The Klapanunggal Formation (Tmk), which is made up of reef limestone with sizable foraminifera, molluscs, and echinoderms. The age of this unit is equivalent to the Lengkong and Bojonglopang Formations (Early Miocene), and is adjacent to the Jatiluhur Formation. The thickness of this formation in the eastern part reaches 500 meters. The Jatiluhur Formation (Tmj) consists of marl and sandy clay shale in the eastern part. It is of Early Miocene age and overlaps the Klapanunggal Formation. The interaction of the Eurasian, Indo-Australian, and Pacific plates—three significant tectonic plates—has an impact on the western side of Java Island. This tectonic activity forms various geological structures such as mountains, basins, fold zones, and faults. One of the main results is the Barisan Mountains which stretch from west to east of Java, formed from volcanic activity and composed of lava, lahar, and tuff rocks. According to Bemmelen (1949), West Java experienced two main tectonic phases: Miocene–Pliocene tectonics, marked by the formation of geanticlines in the south and folds and faults in the central and northern parts of Java, along with dacite and andesite-

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hornblende intrusions. Pliocene–Pleistocene tectonics, marked by the subsidence of the northern Bandung region and pressure towards Bogor, which triggered the formation of thrust faults in the zone between Bogor and Mount Ciremai, known as the Baribis Thrust.

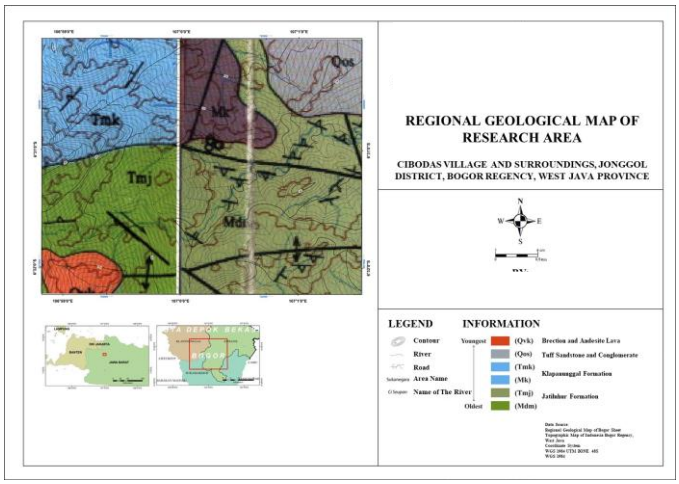

Fig. 1. Regional Geological Map of the Research Area.

III. METHOD

The method used is the weighting method based on the PVMBG 2015 classification. The parameters used include slope direction, slope gradient, rock type, distance from faults, soil type (soil texture), soil depth (solum), and rainfall.

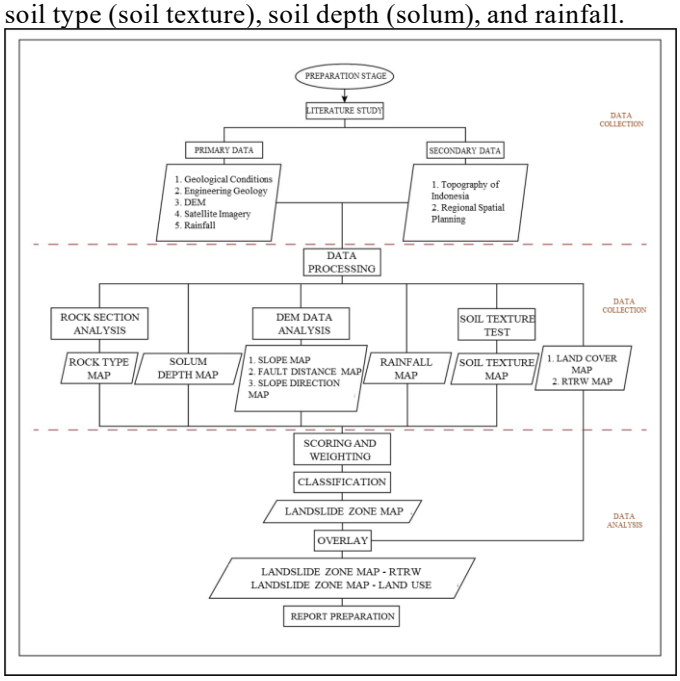

Fig. 2. Research Diagrams

The map obtained from the scoring and weighting process contains magnitude values that will be classified into their respective categories. Based on their propensity for landslides, this research categorizes landslide susceptibility zones into five groups: very low, low, moderate, high, and very high. Subsequently, an overlay process is conducted. The overlay step involves combining two or more maps—in this case, the landslide susceptibility zone map with the land cover map and the spatial planning (RTRW) map. Spatial planning and land cover classification adhere to the DVMBG (Directorate of Volcanology and Geological Hazard Mitigation) 2004 categorization.

The number of classes to be used is divided by the largest and smallest values.

These values come from the classification values used in the study

$$Ki = (Xt - Xr)/K$$

Information:
Ki = Class interval
Xt = Highest value in classification
Xr = Lowest value in classification
K = Number of classes

IV. RESULT AND DISCUSSIONS

Geological mapping at 89 locations identified various rock types, including andesite, carbonate sandstone, carbonate claystone, and reef limestone. The study area is divided into three rock units: the andesite unit, the carbonate sandstone interbedded with carbonate claystone unit, and the limestone unit.

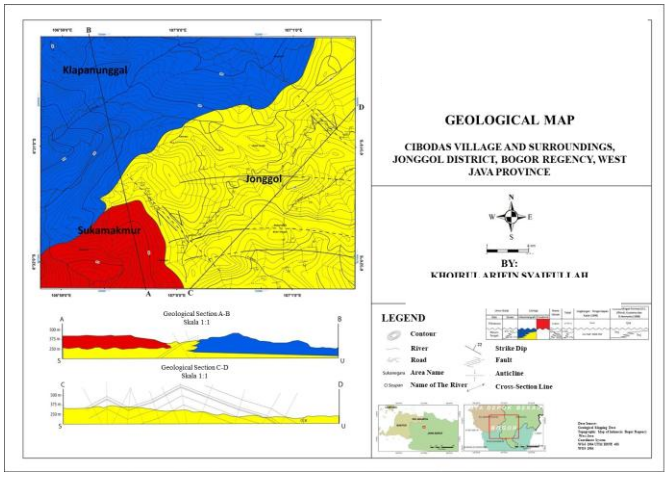

Fig. 3. Geological map of the research area.

In the research area, the interbedded unit of carbonate sandstone and carbonate shale is the most commonly found unit, covering an area of 10.27 km² (51.10%), while the andesite unit covers 2.10 km² (10.46%) of the study area

TABLE I. Distribution of rocks in the research area.

No	Types of Rocks	Modified Rock Types	Unit	Area (Km^2)	Area (%)
1	Sedimentary	Sedimentary 1	Reef Limestone	7.72	38.44
2	Sedimentary	Sedimentary 2	Interbedded Carbonate Sandstone and Carbonate Claystone	10.27	51.10
3	Volcanic	Volcanic	Andesite	2.10	10.46
		Total		20.09	100.00

Based on relative age analysis of the rock units compared to Effendy et al., 1998, the stratigraphic sequence from oldest to youngest consists of the interbedded calcareous sandstone

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and calcareous claystone unit, the reef limestone unit, and finally the andesite unit.

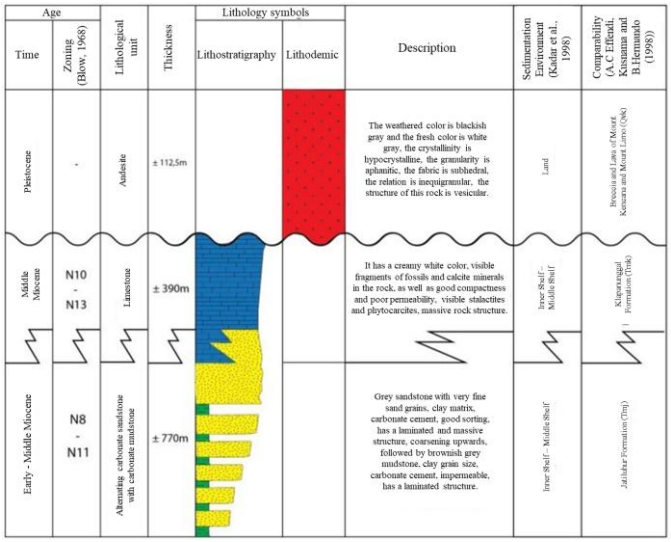

Fig. 4. Stratigraphy in the research area.

Andesite units in the mapping area are spread around ±2.10%, in the southwest with a southwest-north orientation covering the Nyalindung area. Rock outcrops are found in weathered to fresh conditions, blackish gray (weathered), and white gray (fresh). Hypocrystalline crystallinity, aphanitic granularity, subhedral fabric, and 24 inequigranular relations. The structure located in this rock is the presence of massive and vesicular appearances.

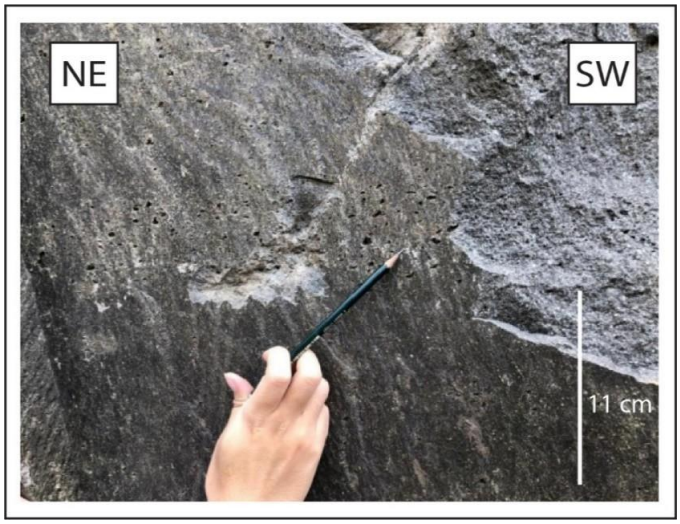

Fig. 5. Observation location of andesite unit outcrops at Lp44.

Limestone units in the mapping area are spread ±38.44% located in the western part with a west-east distribution orientation, which includes the Cibodas area. The outcrops were found to be weathered-fresh, creamy white in color, with the appearance of calcite minerals and also fossils throughout the rock, as well as very good compactness and also poor permeability.

The interbedded unit of carbonate sandstone and carbonate claystone in the mapping area covers approximately 51.10% and is predominantly located in the central part, with a west–east distribution trend, encompassing the Sukajaya region. Outcrops exhibit weathered to fresh conditions. The bottom to middle sections consist of carbonate sandstone characterized by brownish-gray coloration, very fine grain size, rounded lithic fragments, clay matrix, carbonate cement, good sorting, and moderate permeability. In contrast, carbonate claystone is observed as brownish-gray claystone with clay-sized grains, impermeable properties, and carbonate cement. Microscopic analysis reveals a massive structure and a texture dominated by fine-grained composition.

Fig. 6. Location of limestone outcrop at LP8 (close view).

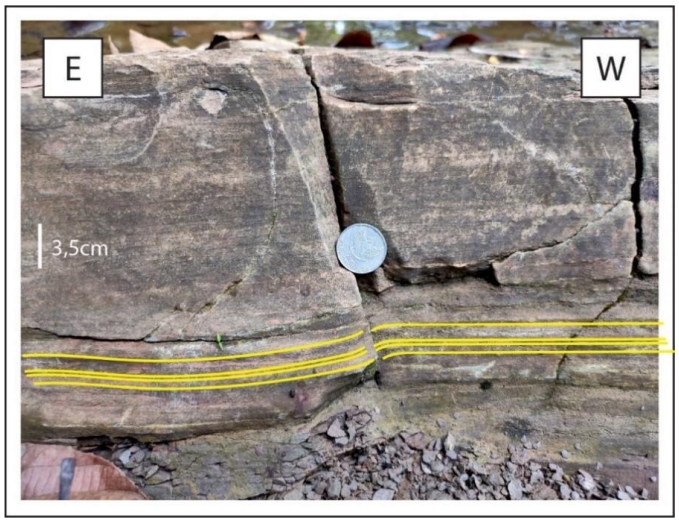

Fig. 7. Outcrop location of alternating carbonate sandstone and carbonate mudstone at LP84.

Based on contour pattern data, contour straightness, river feature alignment, and the presence of waterfalls (*curug*), as well as regional structural patterns in West Java and previous research findings, it is evident that several structures in the study area trend in a west-east direction. Parameters such as modified rock types and distance from faults or fractures—classified according to the applied classification system—can be derived or extracted from the existing geological map.

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Fig. 8. Location of outcrop of alternating carbonate sandstone and carbonate mudstone at LP81

A. Rock Type

Based on the landslide susceptibility classification (PVMBG, 2015), the rock type parameter has a weight of 0.2. The data were obtained from geological mapping that identified the distribution of rocks according to this parameter. The resulting map delineates several classes: a *moderate* class with sedimentary rock types, covering an area of 17.99 km² (89.54% of the total study area), and a *poor* class with volcanic rock types, covering an area of 2.10 km² (10.46% of the study area)..

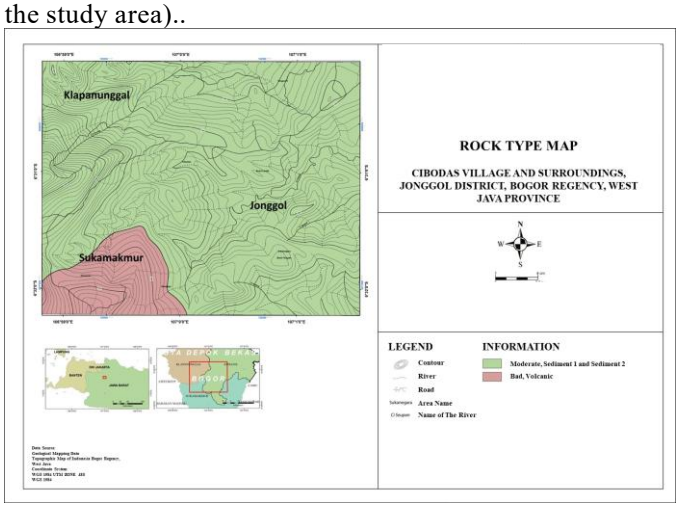

Fig. 9. Map of rock types of the research area.

TABLE II. Table of classes and weights of rock type parameters

No	Class	Rock Type	Score	Weight	Total	Area (Km²)	Area (%)
1	Good	Alluvial	1		0.2	-	-
2	Modearte	Sedimentary	2	0.2	0.4	17.99	89.54
3	Bad	Volcanic	3		0.6	2.10	10.46
			Total			20.09	100.00

TABLE III. Distribution of village administrative boundary zoning parameters of rock type

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Good			
Moderate	✓	✓	✓
Bad	✓		✓

B. Distance from fault or fracture

Based on the landslide susceptibility classification (PVMBG, 2015), the parameter of distance from faults or fractures has a weight of 0.05. This data is obtained from geological mapping data that has been processed to produce a distance-from-fault map with the following classes: very close, close, moderate, far, and very far.

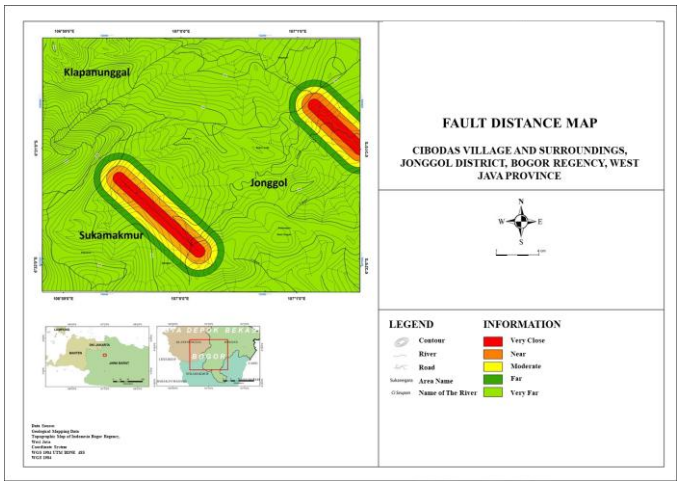

Fig. 10. Distance map of faults or fractures.

The study area was predominantly characterized by the 'very far' class, covering an area of 17.19 km² (85.57% of the total research area), while the 'very close' class was the smallest, occupying only 0.59 km² (2.92% of the study area).

TABLE IV. Class and weight of distance parameters from faults or fractures.

No	Class	Distance from Fault (m)	Score	Weight	Total	Area (Km)	Area (%)
1	Very Close	<100	1		0.05	0.59	2.92
2	Close	200-100	2		0.1	0.68	3.38
3	Moderate	300-200	3	0,05	0.15	0.77	3.84
4	Far	400-300	4		0.2	0.86	4.30
5	Very Far	>400	5		0.25	167.19	85.57
		Total				20.09	100.00

TABLE V. Distribution of village administrative boundary zoning parameters of distance from faults or fractures.

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Very Close	✓		✓
Close	✓		✓
Moderate	✓		✓
Far	✓		✓
Very Far	✓	✓	✓

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C. Slope Gradient

Based on the landslide susceptibility classification (PVMBG, 2015), the slope gradient parameter has a weight of 0.3. The data were derived from DEMNAS and processed using ArcGIS 10.8 with the Slope tool, supplemented by field survey data. This resulted in three susceptibility classes: very low, low, and moderate.

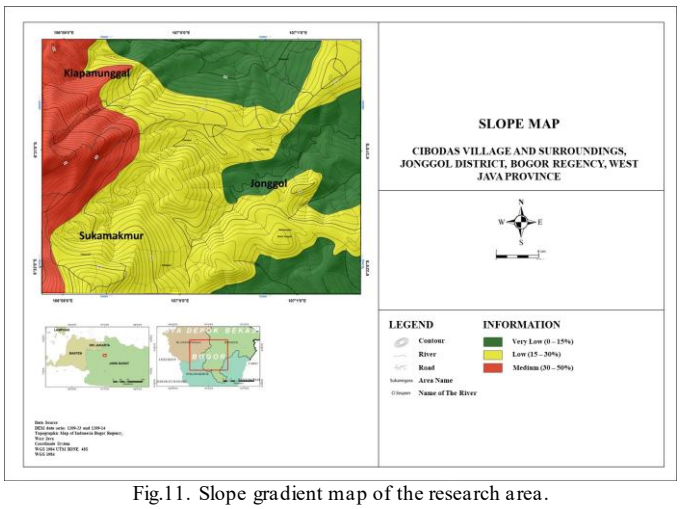

Fig.11. Slope gradient map of the research area.

The research area was predominantly covered by the Low class, with an area of 10.75 km² (53.53% of the total study area), while the Moderate class was the smallest, covering only 3.35 km² (16.69%).

TABLE VI. Table of slope gradient parameter classes and weights.

No	Class	Slope (%)	Score	Weight	Total	Area (Km)	Area (%)
1	Very Low	<15	0		0	5.98	29.78
2	Low	15-30	1		0.3	10.75	53.53
3	Medium	30-50	2	0.3	0.6	3.35	16.69
4	High	50-70	3		0.9	-	-
5	Very High	>70	4		1.2	-	-
Total						20.09	100.00

TABLE VII. Distribution of village administrative boundary zoning, slope gradient parameters.

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Very Low	✓	✓	
Low	✓	✓	✓
Medium	✓	✓	✓
High			
Very High			

D. Slope Direction

Based on the landslide susceptibility classification (PVMBG, 2015), the slope aspect parameter has a weight of 0.1. The data were derived from DEMNAS and processed using ArcGIS 10.8. The aspect feature generated 10 slope directions in the study area: flat, north, northeast, east, southeast, south, southwest, west, northwest, and northeast.

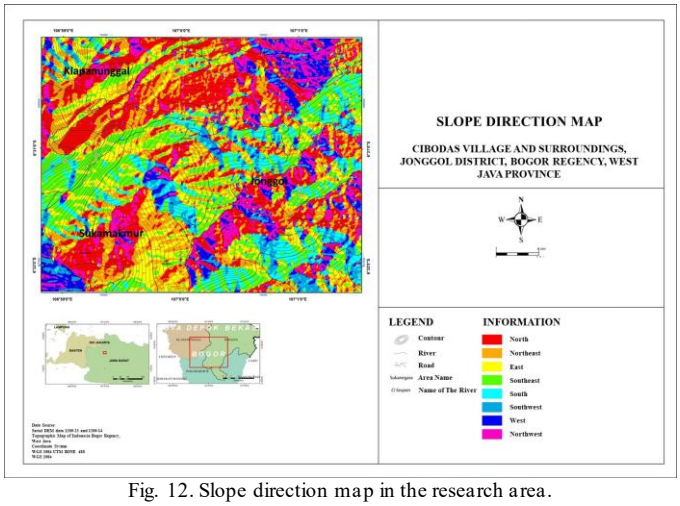

Fig. 12. Slope direction map in the research area.

The research area is dominated by the north class, covering 4.08 km² (20.32%), while the northeast class has the smallest area of 1.22 km² (6.07%) of the total research location.

TABLE VIII. Class table and weighting of slope direction parameters.

No	Class	Azimuth	Score	Weight	Total	Area (Km)	Area (%)
1	Flat	-	0		0	-	-
2	North	337.5 – 22.5	1		0.1	4.08	20.32
3	Northwest	22.5 – 67.5	2		0.2	3.48	17.32
4	West	67.5 – 112.5	3		0.3	2.76	13.75
5	Northeast	112.5 – 157.5	4	0.1	0.4	3.27	16.28
6	Southwest	157.5 – 202.5	5		0.5	1.76	8.76
7	Northeast	202.5 – 247.5	6		0.6	1.22	6.07
8	Southeast	247.5 – 292.5	7		0.7	1.36	6.75
9	South	292.5 – 337.5	8		0.8	2.16	10.75
Total						20.09	100.00

TABLE IX. Distribution of village administrative boundary zoning according to slope direction parameters.

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Flat			
North - Northwest	✓	✓	✓

E. Soil Texture

Based on the landslide susceptibility classification (PVMBG, 2015), the soil texture parameter has a weight of 0.05. A total of 27 samples were processed in the laboratory to determine the soil texture of each sample. As a result, two soil texture classes were identified: the *moderate* class, consisting of sandy-clayey soil textures, and the *poor* class, consisting of clayey soil textures.

The Moderate class dominates the parameters with an area of 16.98 km² (84.52% of the research location), while the Poor class has the smallest area of 3.11 km² (15.48% of the research location).

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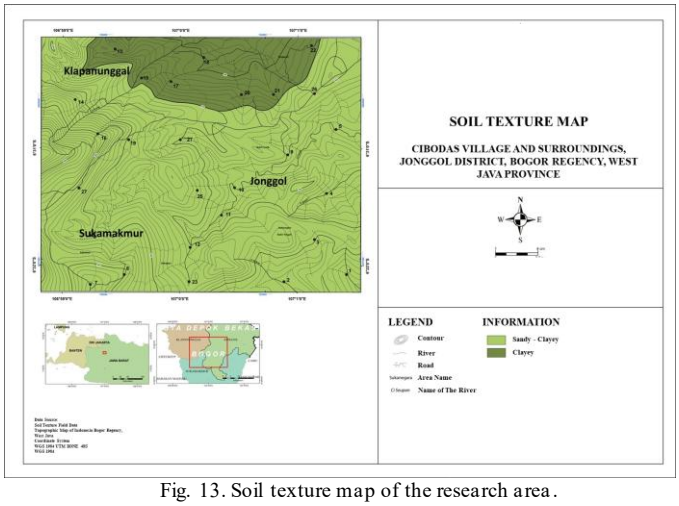

Fig. 13. Soil texture map of the research area.

TABLE XI. Class and weight of soil texture parameters.

No	Class	Rock Type	Score	Weight	Total	Area (Km)	Area (%)
1	Good	Sandy	1		0.1	-	-
2	Moderate	Sandy – Clayey	2	0.1	0.2	16.98	84.52
3	Bad	Clayey	3		0.3	3.11	15.48
			Total			20.09	100.00

TABLE XII. Distribution of village administrative boundary zoning soil texture parameters.

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Good			
Moderate	✓	✓	✓
Bad	✓	✓	

F. *Soil Depth (Solum)*

Soil depth data collection was carried out by overlapping the slope gradient map and the land cover map, resulting in 17 zones with two samples taken for each zone.

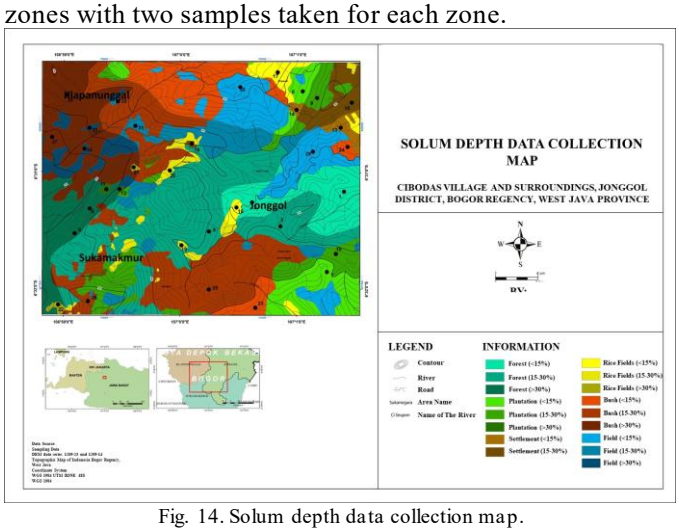

Fig. 14. Solum depth data collection map.

Based on the landslide susceptibility classification (PVMBG, 2015), the soil depth (solum) parameter has a weight of 0.1. According to the obtained data, four classes of soil depth were identified: shallow, moderate, deep, and very deep. The deep class dominates with an area of 6.66 km² (33.13% of the study area), while the very deep class has the smallest coverage, spanning 1.55 km² (7.74% of the study area).

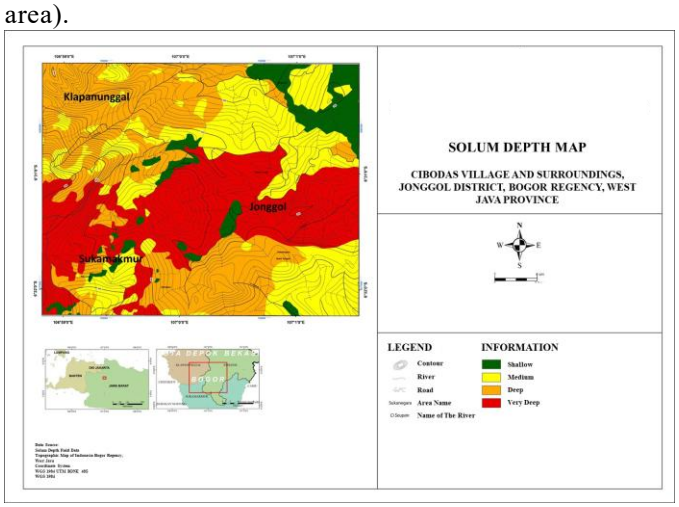

Fig. 15. Solum depth map of the research area.

TABLE XII. class and weighting of solum depth parameters.

No	Class	Solum Depth	Score	Weight	Total	Area (Km^2)	Area (%)
1	Shallow	<30	1		0.5	1.55	7.74
2	Moderate	30-60	2		1	5.69	28.33
3	Deep	60-90	3	0.5	1.5	6.66	33.13
4	Very Deep	>90	4		2	6.19	30.80
			Total			20.09	100.00

TABLE XVI. Distribution of village administrative boundary zoning parameters of solum depth.

Class	**Village**		
	Jonggol	Klapanunggal	Sukamakmur
Shallow	✓		✓
Moderate	✓	✓	✓
Deep	✓	✓	✓
Very Deep	✓	✓	✓

G. *Rainfall*

The rainfall parameter with a weight of 0.2 (PVMBG, 2015) was analyzed based on 10-year annual average data obtained from the BPS. Based on the acquired data, it resulted in one rainfall class, namely the high rainfall class with an annual rainfall of >3000 mm.

In this rainfall parameter, there is only 1 class, namely the high class with an area of 20.9 km² covering the entire research location.

H. *Land Cover*

This research maps land cover using the latest SAS Planet satellite imagery data through the digitization method. Based on the classification PVMBG (2015), the study area is divided into four classes: forest or dense vegetation and water bodies, gardens and mixed shrubland, plantations and irrigated rice fields, industrial and residential areas, as well as the dominant conditions in the field.

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TABLE XV. 10-year rainfall data table

Month	Year										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
January	275	275	1.334	1123	313	425	266	266	576	190	284
February	218	218	672	976	524	448	394	394	381	308	185
March	120	120	467	1000	554	244	389	389	212	214	213.5
April	137	137	701	428	459	416	358	358	326	233	257
May	33	33	474	336	274	314	225	225	73	323	146.5
June	91	91	552	134	486	264	196	196	79	299	181
July	60	60	325	74	336	274	90	90	20	148	123
August	35	35	111	122	388	241	125	125	68	328	183
September	85	85	93	118	458	267	144	144	43	470	162
October	185	185	65	102	597	454	246	246	279	228	278
November	243	243	694	473	437	566	588	588	11	151	267.5
December	489	489	867	457	174	325	277	277	342	291	285
Annual rainfall (mm/year)	1971	1971	6355	5343	5000	4238	3298	3298	2410	3183	2566
Average rainfall over 10 years	3602.95										

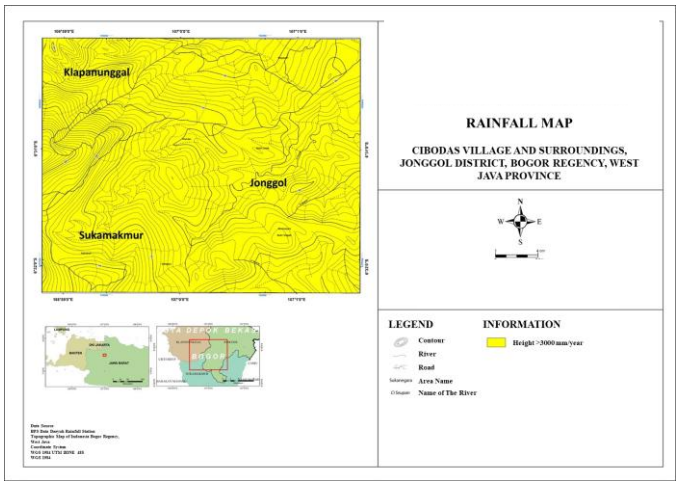

Fig. 16. Rainfall map of the research area.

TABLE XVI. Class table and weighting of rainfall parameters.

No	Class	Annual Rainfall (mm/year)	Score	Weight	Total	Area (Km^2)	Area (%)
	Low	<2000	1		-	-	-
	Medium	2000-3000	2	0.2	-	-	-
1	High	>3000	3		0.6	20.09	100.00
	Total					20.09	100.00

TABLE XVII. Distribution of village administrative boundary zoning rainfall parameters.

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Low	✓	✓	✓
Medium	✓	✓	✓
High	✓	✓	✓

Forests and dense vegetation dominate the study area, covering 19.40 km² or 50.96% of the total research area, while industrial and residential areas constitute the smallest class, with an area of 1.40 km² or 6.84% of the study area.

I. Spatial Plans

The Regional Spatial Planning Map (RTRW) was digitized from the spatial planning data of Bogor Regency Regional Regulation (Perda) No. 11 of 2016. Based on the classification by PVMBG (2015), the study area is divided into seven classes: protected forest, limited production forest, permanent production forest, dryland agriculture, wetland agriculture, residential areas, and tourism zones, in accordance with the Bogor Regency RTRW for 2016–2036.

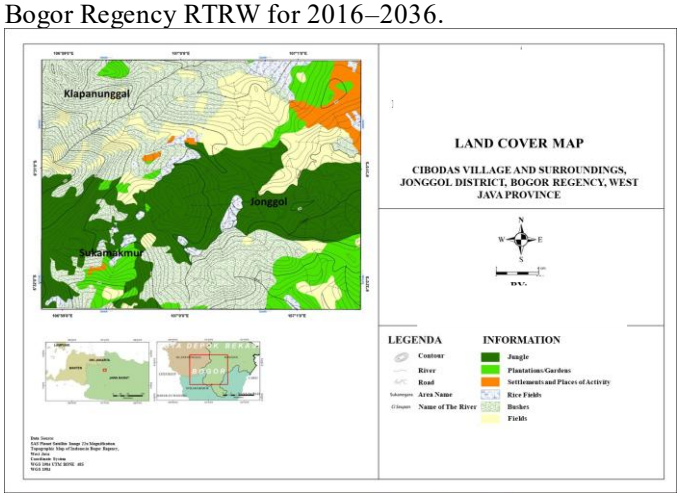

Fig. 17. Land cover map of the research area.

TABLE XVIII. Land cover in the research area.

No	Class	Land Cover	Area (Km)	Area (%)
1	1	Forest or dense and water bodies	6.19	30.80
2	2	Gardens and mixed shrubs	9.99	49.71
3	3	Plantations and irrigated rice fields	3.18	15.81
4	4	Industrial and residential areas	0.74	3.68
	5	Vacant land	-	-
	Total		20.09	100.00

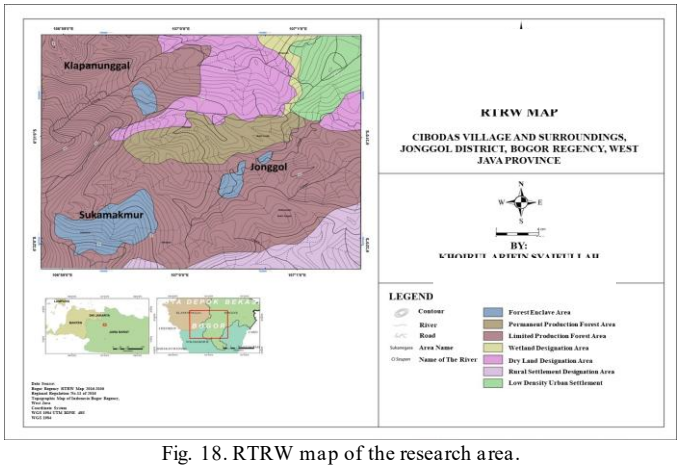

Fig. 18. RTRW map of the research area.

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The limited production forest area class dominates the study area, covering 11.46 km² (57.04%), while the wetland class is the smallest, with an area of 0.30 km² (1.51%) of the research location

TABLE XIX. Spatial planning pattern 2016-2036 in the research area.

No	Region	Area (Km^2)	Area (%)
1	Forest Area Enclave	1.38	6.88
2	Permanent Production Forest	1.62	8.05
3	Limited Production Forest	11.46	57.04
4	Wetland	0.30	1.51
5	Dryland	2.66	13.24
6	Rural Settlement	1.43	7.10
7	Urban Settelement Density	1.24	6.18
	Total	20.09	100.00

TABLE XX. Distribution of administrative boundaries of RTRW villages 2016-2031.

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Forest Area Encalve	✓		✓
Permanent Production Forest	✓		
Limited Production Forest	✓	✓	✓
Wetland	✓		
Dryland	✓	✓	
Rural Settlement	✓		
Urban Settelement Density	✓		

Landslide Vulnerability

Using the union feature, the map is divided into five classes of landslide susceptibility. The class intervals are determined by subtracting the lowest value from the highest value and dividing the result by five.

Class interval = (3.25 − 1.45) / 5

Class interval = 0.36

The lowest value of the landslide susceptibility class is 1.45, while the highest value is 3.25, with a class interval of 0.36. This results in five susceptibility classes: very low (1.45–1.81), low (1.82–2.17), moderate (2.18–2.53), high (2.54–2.89), and very high (2.90–3.25). Based on this classification, the study area comprises five susceptibility levels: very low, low, moderate, high, and very high.

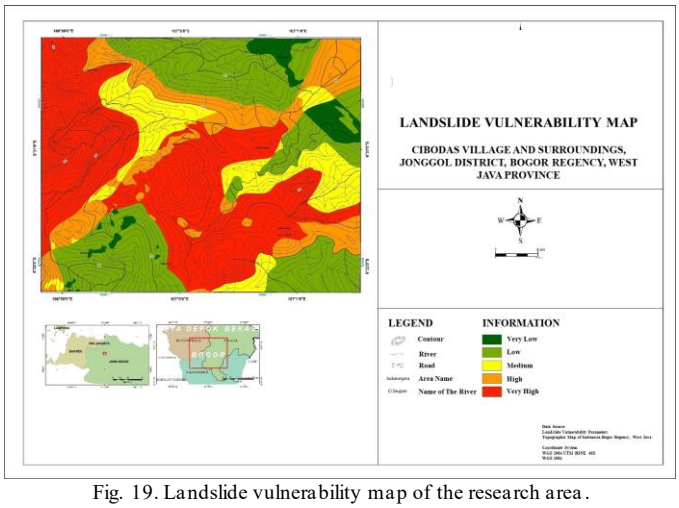

Fig. 19. Landslide vulnerability map of the research area.

The high-density class dominates the study area, covering 7.02 km² or 34.97% of the research location, primarily in the western and central regions. In contrast, the very low-density class is the smallest category, spanning 0.84 km² or 4.20% of the study area, located in the northern to northeastern parts of the research site.

TABLE XXI. Landslide vulnerability class table.

No	Class	Class Interval	Area (Km^2)	Area (%)
1	Very Low	1.45 – 1.81	0.84	4.20
2	Low	1.82 – 2.17	5.91	29.43
3	Moderate	2.18 – 2.53	2.22	11.07
4	High	2.54 – 2.89	4.08	20.34
5	Very High	2.90 – 3.26	7.02	34.97
	Total		20.09	100.00

TABLE XXII. Distribution of administrative boundaries of villages vulnerable to landslides

Class	Village		
	Jonggol	Klapanunggal	Sukamakmur
Very Low	✓		✓
Low	✓	✓	✓
Moderate	✓	✓	✓
High	✓	✓	✓
Very High	✓	✓	✓

There are 14 landslide points with predominantly very high and low soil susceptibility. The soil material in sandstone and limestone lithology, as well as rock in limestone lithology, are the main factors contributing to landslides. According to the landslide classification (Varnes, 1978), the landslides occurring in the study area are of the rotational slide, translational slide, and fall types.

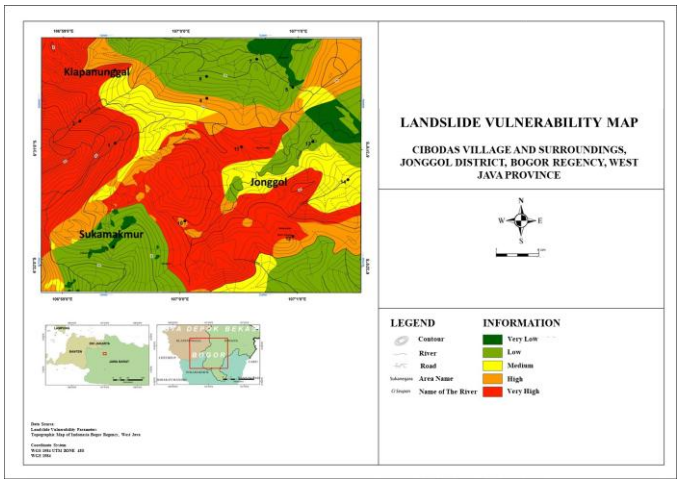

Fig. 20. Landslide vulnerability map with landslide points.

The landslide susceptibility map was overlaid with the spatial planning map (RTRW), resulting in 33 zones. For the *very low* class, the zones include forest areas, limited production forests, wetland agriculture, dryland agriculture, rural settlements, and low-density residential areas. The *low* class comprises forest areas, permanent production forests, limited production forests, wetland agriculture, dryland agriculture, rural settlements, and low-density residential areas. The *moderate* class includes forest areas, permanent

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production forests, limited production forests, wetland agriculture, dryland agriculture, rural settlements, and low-density residential areas. The *high* class consists of forest areas, permanent production forests, limited production forests, wetland agriculture, dryland agriculture, rural settlements, and low-density residential areas. Lastly, the *very high* class covers forest areas, permanent production forests, limited production forests, wetland agriculture, dryland agriculture, rural settlements, and low-density residential areas.

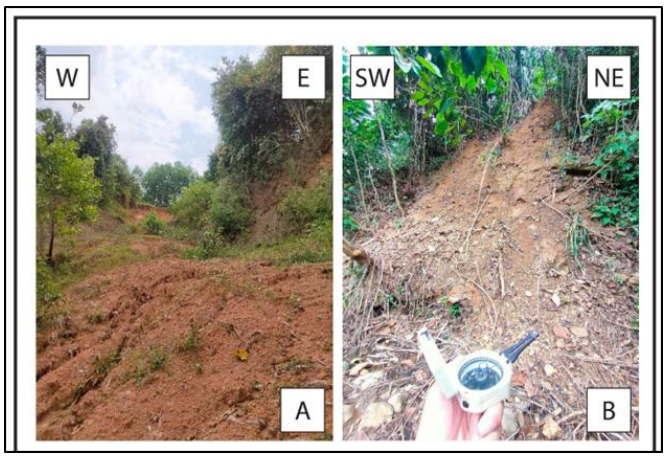

Fig. 21. Photo of landslide events in the research area rotation (rotational slide) (A), translation (translational slide) (B).

Fig. 22. Photos of landslide events in the fall research area (C and D).

The area with a very high landslide susceptibility zone is predominantly covered by limited production forest, spanning 5.12 km² (25.50%), while the smallest zone is wetland, covering only 0.03 km² (0.01%) of the total research area.

The landslide susceptibility map was overlaid with the land cover map, resulting in 29 zones. The very low class includes forest, residential, plantation, rice field, shrubland, and agricultural field areas. The low class comprises forest, residential, plantation, rice field, shrubland, and agricultural field areas. The moderate class consists of forest, residential, plantation, rice field, shrubland, and agricultural field areas. The high class encompasses forest, residential, plantation, rice field, shrubland, and agricultural field areas. Lastly, the very high class includes forest, plantation, rice field, shrubland, and agricultural field areas.

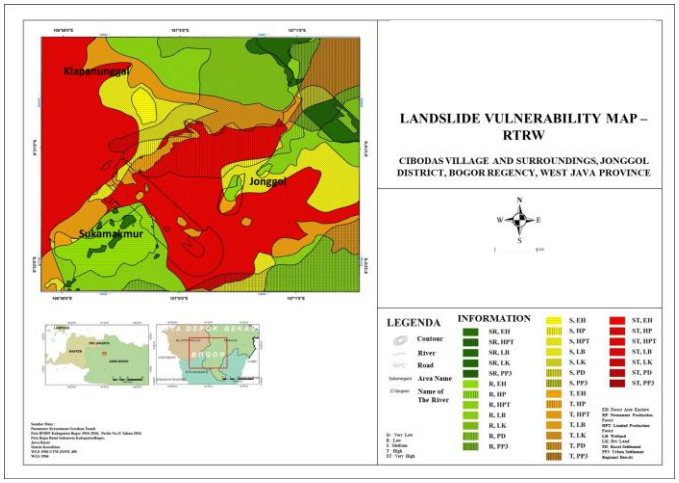

Fig. 23. Landslide vulnerability map-RTRW.

The zone of very high landslide susceptibility is predominantly covered by dense forest, with an area of 3.60 km² (17.94% of the research location), while the smallest zone is rice fields, covering only 0.01 km² (0.06%).

The overlay results of landslide susceptibility and land cover maps indicate that forest areas with very high susceptibility classes are prone to landslides, supported by numerous field occurrences. Conversely, land cover with very low to low susceptibility is relatively safer due to the minimal occurrence of landslides based on field data.

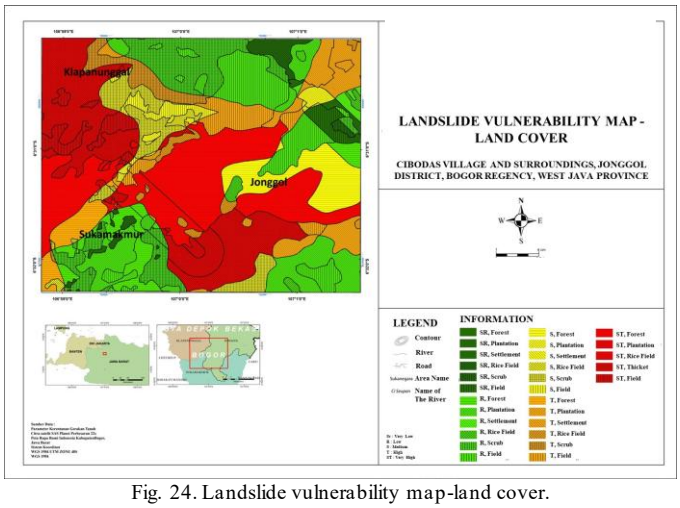

Fig. 24. Landslide vulnerability map-land cover.

V. Conclusion

There are five classes of landslide susceptibility, ordered from the largest to the smallest area: very high, low, high, moderate, and very low. In the study area, there are 14 landslide points with types of ground movement including rotational slides, translational slides (with soil material), and falls (with rock material). Jonggol Village has the highest occurrence of rotational and translational slides, while Klapanunggal Village has the highest number of rockfall events.

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Overlaying landslide susceptibility with the spatial planning (RTRW) resulted in 33 zones, with the largest being the very high susceptibility zone in limited production forest areas and the smallest being the very high susceptibility zone in wetland areas. Additionally, overlaying landslide susceptibility with land cover produced 29 zones, where the very high susceptibility zone in dense forest areas was the largest, while the very high susceptibility zone in rice fields was the smallest in the study area.

ACKNOWLEDGMENT

We extend our sincere gratitude to the Dean of the Faculty of Earth and Energy for the invaluable support provided during this research, as well as to all individuals who contributed to the successful completion of this research.

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