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Modeling vulnerability density of landslide using IFSAR DEM in Manuju and Bungaya District Gowa Regency, South Sulawesi

Modeling vulnerability density of landslide using IFSAR DEM in Manuju and Bungaya District Gowa Regency, South Sulawesi

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Abstract. Recently in Indonesia landslide is one of major natural disaster that claims lives and property. Therefore it is necessary to have a Landslide Vulnerability Zone Map to improve the accuracy of natural disaster risk analysis and mitigation needs by using IFSAR DEM. Generally, Gowa area contains with moderate to strong undulating topography is very often created landslide issue. Parameters are used to analyze the landslide zoning are lithology, slope, slope aspects, distance from faults, distance from river, distance from road, land cover, slope length, rainfall, soil type, and curvature. Each parameter map and landslide map were integrated to compute the value of density and landslide occurrence percent obtained in different units from each of the maps. Determination by using all parameters above showing accuracy value of 89,4% where 85% area on past landslides occurred on very high hazard zone and 12.92% occurred on high hazard zone, meanwhile selected parameter accuracy value is 98,5% where 85% area on past landslide event occurred on very high hazard zone while 12.92% occurred on high hazard zone. Parameter selection can improve the accuracy of landslide zoning on the research area.

1. Introduction

Indonesia contains with more geological phenomena where it lies on subduction belt with macro and micro plates surrounding. Interaction of this geological concept on this matter is more often result the natural disaster in Indonesia. Landslide is the natural phenomena resulted from interaction of this geological situation. This natural disaster has claimed lives and property. Therefore, it is necessary to have a landslide vulnerability zone map, to analyze natural disaster risk, analyze the mitigation needs and references in regional planning and development. Landslide zonation needs supported and controlling from field data that helping the accuracy of data. More often the landslide occurred not following with existing theory thus confused the mitigation or planning to remove the result this disaster. Gowa Regency in South Sulawesi Province which has a relatively undulating topography that is moderate to strong or steep waves. Landslide is slightly often happened in this area which is almost claimed lives and property. Various studies on the vulnerability zoning of landslide have been carried out, but the accuracy of the mapping results has not provided maximum results. This is due to the different methods and parameters were used. The level of accuracy of the results of analysis of zoning vulnerability of landslide should be tested so that the results of the analysis can be believed to be accurate and accountable research.

2. Data

2.1. *Landslide event*

Information about past landslide events that happened on the area was collected from Sentinel-2A satellite imagery acquired in 2019 and verification of field surveys. Number of landslide locations identified was 158 point where 71 points (103.44 has) were chosen to create the zoning of landslide and 87 points was used to validate the zoning of landslide (figure 1). Landslides were classified according

to the classification of Varnes (1978) [1]. 95% of the landslides occurred in debris flow (figure 3.). 5% of the landslides occurred in rotation landslide (figure 4.).

2.2. *Lithology*

Research area consists of are Lompobattang Volcano Rock Formation, Cindako Baturape Volcano Rock Formation, Camba Formation and Alluvial. The eldest stratigraphy is Camba Formation Middle Miocene to Pliocene consists of marine sedimentary rocks interspersed with clastic volcanoes, which sideways turn into dominant volcano rocks. Baturape Cindako Volcano Formation consists of lava, tuff and breccia with age Pliocene. Lompobattang Volcano Formation consists of volcanic material such as lava agglomerates, lava breccia, lava deposits and tuffs age Quarter [2].

Field mapping in the research discovered that the landslide occurred in Baturape - Cindako Volcano rock lithology with value of 81.57%, the Camba Formation around 16.79% while Lompobattang Volcano Formation around 1.64% and no landslide occurred on alluvium deposits (figure 2.).

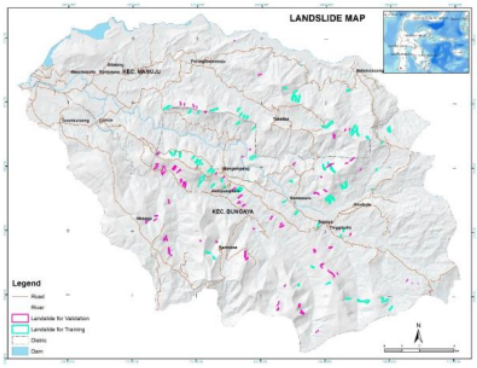

Figure 1. Landslide Event Map

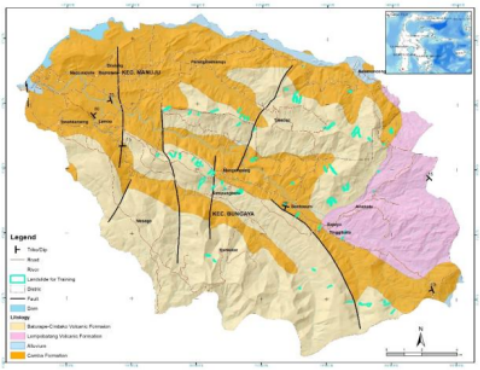

Figure 2. Geological map

2.3. Road Distance

Highway variables can contribute to an increase in the incidence of landslides, because generally the design of highway engineering in developing countries is often poor [3]. Road also contribute tendency of landslide occurred where the has road distance class> 200 m landslide event value 80.03%, (100-200) m distance 10.88%, (50-100) m 4.70% and (0-50) m distance is 4.38% (figure 5.).

2.4. Soil

Physical properties of soil commonly support the level of ground stability became consideration parameter in determination of vulnerability of landslide zoning.

Typic Dystrudepts - Typic Hapludults - Aquic Dystrudepts with a value of 42.47%, then on Typic Dystrudepts - Typic Hapludults - Typic Eutrudepts with a percentage value of 38.98%. Then on Typic Eutrudepts - Typic Hapludalfs - Aquic Eutrudepts with a percentage value of 18.40%. In Typic Hapludands, Andic Eutrudepts, Andic Dystrudepts percentage of landslides with a percentage value of 0.15% for Typic Fluvaquents - Typic Endoaquepts - Fluvaquentic Endoaquepts, Typic Endoaquepts, Typic Hapludults - Typic Dystruds, Typic Hapludults - Typic Hapludults, Udic Haplustepts – Typic Haplustalfs-Typic Eutrudeptsno Landslide can be seen in Figure 6.

Figure 3. Example debris flow

Figure 4. Example rotation landslide

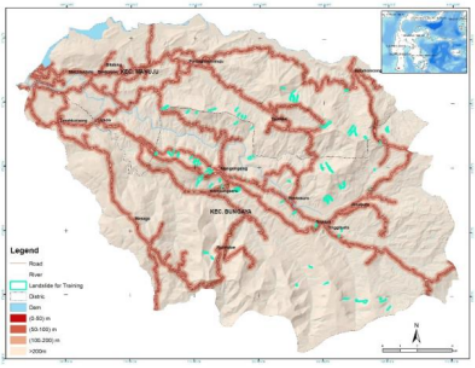

Figure 5. Distance from road map

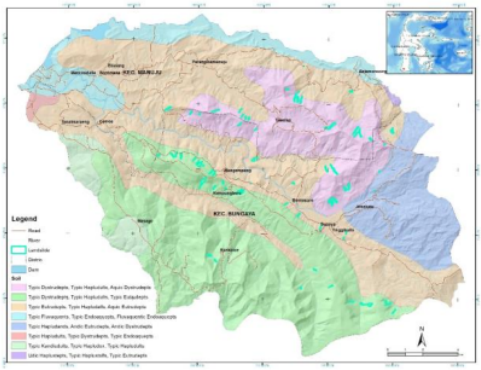

Figure 6. Soil map

2.5. Land Use

Land use is considered as a major factor in landslides. Area coverage of plant became factor supports for landslide condition in the research area. Vegetable land is rarely vulnerable to weather, erosion, and slope instability [4, 5].

Land use information was taken from SPOT 7 satellite images acquired in 2016. The area of landslides that occur in the moorings is around 44.54%, on plantations 29.79%, in the forest around 16.97%, in the bushes around 5.87%, in the field around 2.26%, in settlements around 0.58%. In water bodies, sand does not have landslides (Figure 7.).

2.6. Rainfall

One of the causes of high landslides in an area is high rainfall [6, 7]. Gowa area include in tropical area with high rainfall. Rainfall analysis from the last 7 years were compared with potentially actual landslide on the same period showing rainfall with (2500-3000) mm/year potentially landslide occurred 51.86% , (2000-2500) mm/year potentially landslide occurred 48.14% (Figure 8.).

2.7. Distance from River

Area distance from river most likely controlling potentially to landslide occurred where it possibly edge of wall river fall due to erosion from river current or from sloping around area.
River distance of 50 m has potentially landslide event 34.21%, distance of > 200 m potentially landslide events 24.66%, 200 m distance landslide event is 23.10%, distance of 100 m potentially landslide event 18.03% (Figure 9).

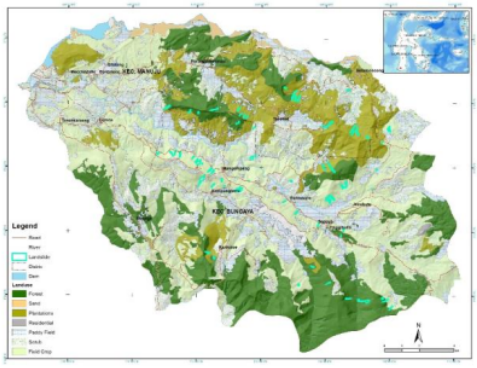

Figure 7. Land use map

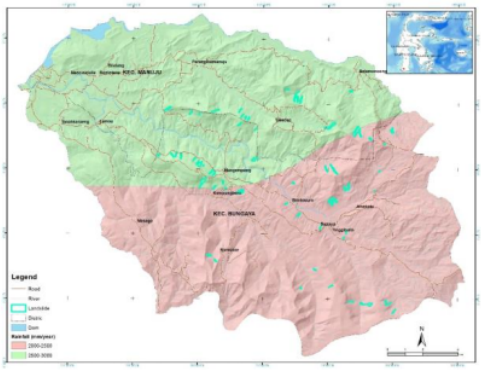

Figure 8. Rainfall map

2.8. Slope

The greater the slope angle, the higher the tendency for landslides to occur [8]. Slope information was derived from IFSAR DEM data grouped in 5 classes, namely (0 – 5)%, (5-15)%, (15-30)%, (30-40)% and > 40%. Slope > 40% has 66.50% potentially landslide event, slope (30-40)% has 19.55%, (15-30)% slope has 19.95% and slope (5-15)% and slope (0-5)% no potentially landslide event (Figure 10).

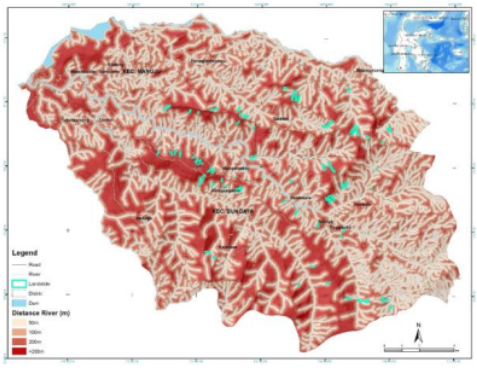

Figure 9. Distance from river map

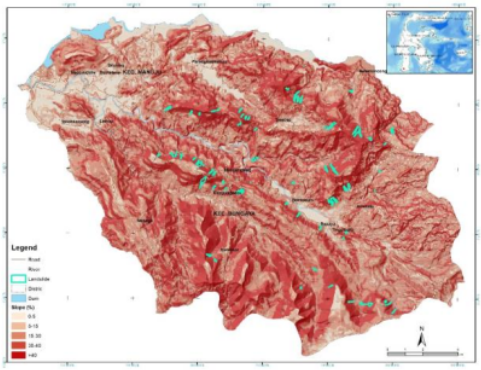

Figure 10. Slope map

2.9. Slope Aspect

Slope aspects can affect soil moisture while affecting the vegetation on it. The slope humidity is very influential on the strength of the soil so that it can cause landslides [9]. In this parameter the slope aspect is divided based on the direction of East, Flat, North, North East, North West, South, Southeast, Southwest, and West. The largest percentage of landslides occurring at North East's slope 21.35%, Southwest value of 15.85%, North 15.59%, North direction 15.50%, South direction reaches 8.88%. Slope aspect with East direction is 7.70%, West direction reaches 4.60%, Flat was not found to be a landslide (figure 11.).

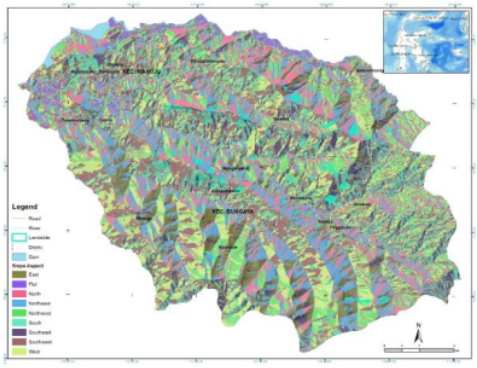

Figure 11. Slope aspect map

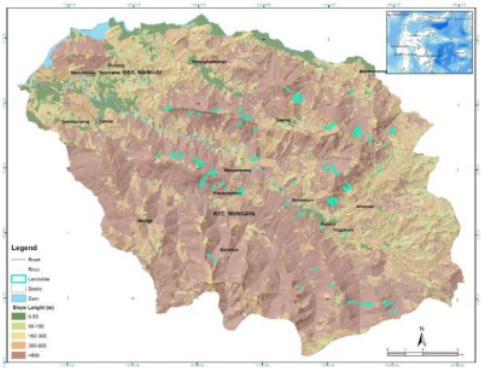

Figure 12. Slope length map

2.10. Slope Length

Slope gradients are generally considered a causal factor for landslides [10]. The parameters of the length of the slope in this study are divided based on 5, namely 0-50 m, 50-150 m, 150-300 m, 300-600 m and > 600 m. The biggest landslide area in this parameter is at> 600 m 77.33%, (300 – 600) m is 19.21%, then the slope length (150 – 300) m with a percentage value of 3.32%. (50 – 150) m is 0.12% and the smallest at the slope length (0 – 50) m with a percentage value of 0.021% (Figure 12.).

2.11. Curvature

Passing time of surface water also affected the stability of soil or ground. Concave slope can contain more water and maintain it longer than convex slope. As a result, the concave slope profile of the area has a higher probability of landslides than the convex area [11]. Landslide event on concave area has 66.89 % and the convex area is 33.10% (Figure 13).

2.12. Distance from Fault

Generally, fault formed as joint thus generated cracking on the lithology. Fault zone become unstable area and potentially landslide occur especially around high slope area [12]. Area potentially to landslide occur on class> 1000 m with value 57.59%. Class 500-1000 m with percentage 25.11%, than class (200-500) m with potentially value 12.65%. Range (0-100) m percentage potential value 2.59% while the lowest potentially percentage at class (100-200) m with value 2.05% (Figure 14).

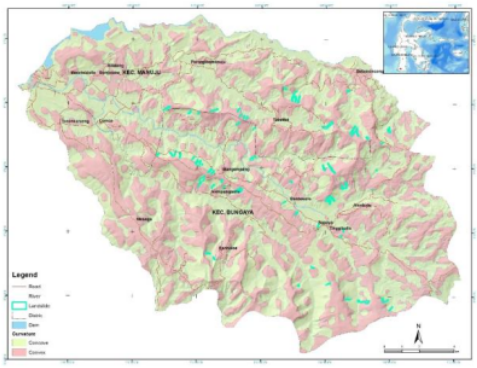

Figure 13. Curvature map

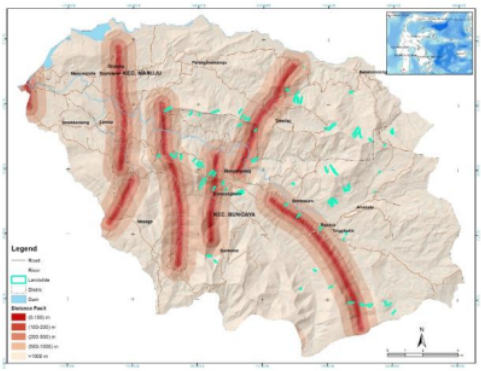

Figure 14. Distance from fault map

Numbering each of parameter was overlaid with the distribution of landslide events on the research area resulted the numbering of each of parameter showing on table 1.

Table 1. Level numbering of parameter

Parameter	Area unit (ha)	Land - slide (ha)	Density	Weight	Parameter	Area unit (ha)	Land-slide (ha)	Density	Weight
Litology					Rainfall (mm/year)				
Baturape-Cindako Formation	14008.20	84.38	0.006456	1.9547	2000-2500	16497.74	49.80	0.003020	0.91422
Volcanic Lompobatang Formation	3631.15	1.70	0.000468	0.1417	2500-3000	14837.80	53.65	0.003618	1.09540
Alluvial	572.80	0.00	0.000000	0.0000					
Camba Formation	13123.39	17.37	0.001324	0.4008	Curvature				
					Concave	17886.03	69.20	0.003872	1.17224
Soil					Convex	13449.30	34.25	0.002547	0.77107
Dystrudepts,Hapludults,Aquic Dystrudepts	4097.14	43.93	0.010722	3.2462					
Dystrudepts,Hapludults,Eutrudepts	9275.62	40.33	0.004350	1.3170	Distance from fault				
Eutrudepts,Hapludalfs,Aquic Eutrudepts	11655.15	19.03	0.001633	0.4944	(0-100) m	836.26	2.69	0.003282	0.99355
Fluvaquents,Endoaquepts,Fluvaquentic Endoaquepts	2287.15	0.00	0.000000	0.0000	(100-200) m	875.87	2.12	0.002420	0.73267
Hapludands,Andic Eutrudepts,Andic Dystrudepts	2977.42	0.16	0.000053	0.0159	(200-500) m	2847.29	13.09	0.004596	1.39152
Hapludults,Dystrudepts,Endoaquepts	145.54	0.00	0.000000	0.0000	(500-1000) m	5079.66	25.98	0.005114	1.54829
Kandiudults,Hapludox,Hapludults	852.47	0.00	0.000000	0.0000	>1000 m	21696.44	59.57	0.002746	0.83129
Udic Haplustepts,Haplustalfs,Eutrudepts	45.04	0.00	0.000000	0.0000					
					Distance from road				
Landuse					(0-50) m	2259.74	4.54	0.002009	0.60822
Water Body	171.83	0.00	0.000000	0.0000	(50-100) m	2079.80	4.86	0.002340	0.70841

Forest	7249.51	17.56	0.002422	0.7332	(100-200) m	3665.69	11.26	0.003072	0.93002
Sand	361.79		0.000000	0.0000	>200m	23330.30	82.78	0.003551	1.07496
Plantations	4407.96	30.82	0.006991	2.1166					
Urban	346.77	0.60	0.001723	0.5218	Slope Aspect				
Paddy Field	4121.86	2.34	0.000568	0.1720	East	2954.56	7.97	0.002698	0.81697
Scrub	3162.78	6.06	0.001915	0.5799	Flat	703.55	0.00	0.000000	0.00000
Field Crop	11053.98	46.07	0.004168	1.2619	North	3901.46	16.03	0.004110	1.24434
					Northeast	4503.59	22.09	0.004906	1.48530
Slope Length (m)					Northwest	4484.25	15.78	0.003521	1.06596
0-50	2039.53	0.02	0.000011	0.0033	South	3132.00	9.18	0.002934	0.88824
50-150	1870.41	0.13	0.000067	0.0202	Southeast	2255.59	11.26	0.004995	1.51228
150-300	3994.68	3.43	0.000860	0.2603	Southwest	4630.06	16.37	0.003537	1.07080
300-600	7799.57	19.87	0.002548	0.7713	West	4770.47	4.76	0.000998	0.30226
>600	15631.35	79.99	0.005117	1.5494					
					Distance from river				
Slope (%)					50m	9805.93	35.39	0.003614	1.09411
0-5	2773.72	0.00	0.000000	0.0000	100m	7924.06	18.65	0.002354	0.71271
5-15	2906.95	0.00	0.000000	0.0000	200m	8508.49	23.89	0.002808	0.85027
15-30	10284.15	14.43	0.001404	0.4250	>200m	5097.06	25.51	0.005007	1.51583
30-40	5939.85	20.23	0.003407	1.0316					
>40	9430.79	68.78	0.007294	2.2085					

3. Methodology

Vulnerability of landslide analysis was conducted by overlaying between landslide maps with map correlated with according parameter. Overlay with parameter map give the value of each parameter. All parameters mentioned above would reveal the accuracy of vulnerability of landslide density using landslide density method and weight value method [13, 14].

$$In\ W = \frac{Denclass}{Denmap} = In\ \frac{\frac{AL(clas)}{Aclas}}{\frac{\sum AL}{\sum AM}} \qquad (1)$$

Where : W = Weight
Denclass = Density of Class
Denmap = Density of Map
AL(class) = Landslide area class
Aclas = Area class parameter
$\sum AL$ = Cumulative landslide area
$\sum AM$ = Cumulative map area

Accuracy of vulnerability density of landslide was confirmed by using IFSAR DEM as data source in gathering all parameter needed. Resolution till 5 meters hopefully supporting the accuracy of landslide zoning with rms 0.28 m and 0.55 m with confidence 95%. Highly accuracy fulfilled the IFSAR DEM to use as data analysis for topography on large area with relatively flat [10].

4. Result and Discussion

4.1. Zonation

Zoning vulnerability of landslide is categorized into 5 classes, namely very high hazard, high hazard, moderate hazard, low hazard and very low hazard zone. Zoning with 11 parameters showing 14.01% of the area falls in very high hazard zone, 21.45% in high hazard zone, 23.14% in medium hazard zone, 21.94% in low hazard zone, 19.47% in very low hazard zone, (figure 15, table 2).

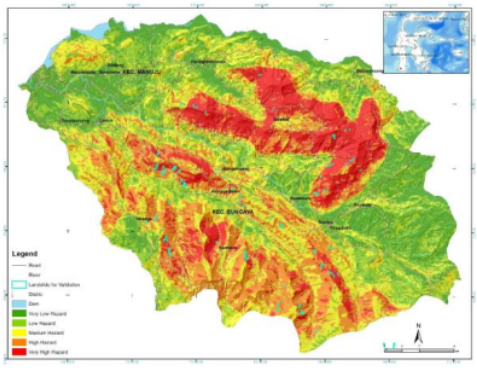

Figure 15. Zoning Used Parameter

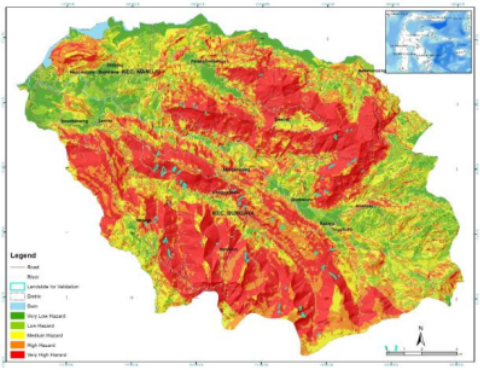

Figure 16. Zoning Selected Parameter

Other simulation was conducted by selected parameter that picking by manual where it supposed subjective based on previous theory [15]. Selection parameter used followed the Logistic Regression Model and Discriminant Analysis Method [16] and depend on relation between landslide density model with factor cause landslide. Correlations with all parameter hopefully gain the consistency and accuracy of landslide event potentially.

Slope, distance from river, road, fault are not showed the consistency of landslide event occurred thus those parameter are not used into landslide analysis (Figure 17.).

Zoning with parameter selected showing 34.88% of the area falls in very high hazard zone, 24.01% in high hazard zone, 18.39% in medium hazard zone, 13.56% in low hazard zone, 9,16% in very low hazard zone, (figure 16, table 2).

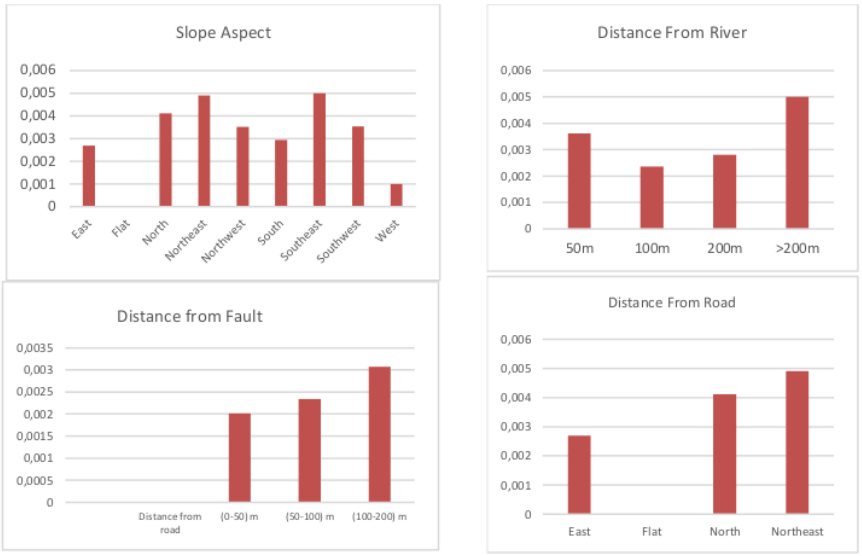

Figure 17. Graphic Unused Density Parameter

4.2. Validated zone

Overlay between distribution map of landslide and result of zonation found the accuracy value is 89.39%. Analysis used the selected parameter (figure 18.) such as curvature, slope length, rainfall, slope, land use, soil type and lithology resulted the accuracy potentially landslide occurred 98.5% where on past landslide event area distribution showed 85.58% landslide occurred on very high hazard and 12.92% landslide occurred on high hazard zone, medium hazard 1.50% while low and very low hazard zone is no landslide occurred. (Table 2.)

Table 2. Validated landslide vulnerable landslide zoning

Zoning	All Parameter				Parameter Selected			
	Area Zoning (ha)	% Zoning	Area Landslide (ha)	% Accuracy	Area Zoning (ha)	% Zoning	Area Landslide (ha)	% Accuracy
Very High	4389.39	14.01	26.25	47.36	10929.24	34.88	47.44	85.58
High	6721.04	21.45	23.30	42.03	7523.02	24.01	7.16	12.92
Medium	7250.59	23.14	5.17	9.33	5762.58	18.39	0.83	1.50
Low	6874.04	21.94	0.71	1.28	4250.37	13.56	0.00	0.00
Very Low	6100.49	19.47	0.00	0.00	2870.32	9.16	0.00	0.00
Total	31335.54	100	55.43	100.00	31335.54	100.00	55.43	100.00

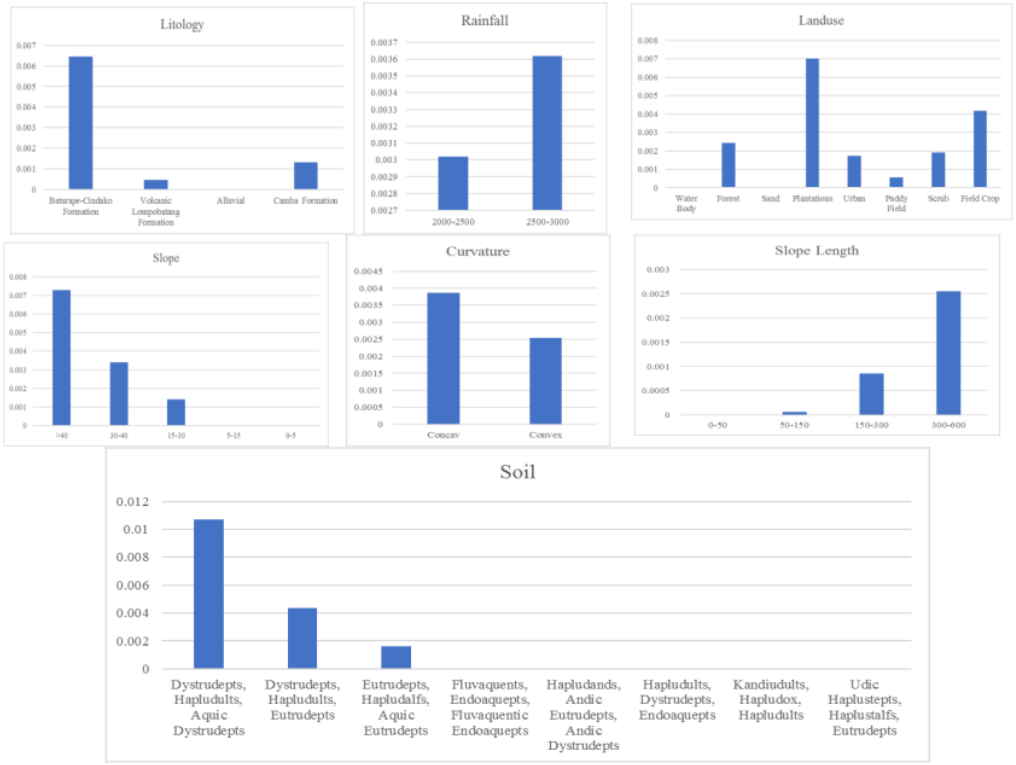

Figure 18. Used Parameter Graphic

5. Conclusion

This research objectives to generate accurate of zoning vulnerability of landslide. IFSAR DEM was used as source data for curvature, slope, slope aspect, slope length while 11 parameters to classified into in 2 groups (all parameter and selected parameter) with are lithology, distance from fault, distance from river, distance from road, land use, rainfall, soil type, curvature, slope aspect, slope length. Analysis method used is numbering of level parameter based on landslide density event that already occurred on research area. GIS spatial overlay with all parameters has resulted the level of numbering for all parameter where it completed with 5 zone categories. The accuracy of landslide potentially event that yielded are 89.39% on 47.36% of landslide area occurred on very high hazard zone while 42.03% landslide event happened on high hazard zone.

Analysis with selected parameters resulted accuracy of potentially landslide is 98.5% where 85% area on past landslide occurred on very high hazard zone while 12.92% occurred on high hazard zone.
The utilization of IFSAR DEM data was to generate the vulnerability of landslide zoning give the potentially of prediction landslide event with high accuracy. Number of parameter used in analysis for landslide prediction does not guarantee the accuracy of that analysis but parameter selection and data quality such as using IFSAR DEM data accuracy is high.

6. Acknowledgement

We would like acknowledge the contribution Department of Geology Engineering Hasanuddin University for encouragement and guiding along writing this research. Also for community around research area that helped in gathering field data related with topic.

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