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## Spatial analysis of landslide vulnerability in Enrekang District, South Sulawesi

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## Spatial analysis of landslide vulnerability in Enrekang District, South Sulawesi

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**Abstract.** Enrekang is one of the districts in South Sulawesi, which including prone areas to landslides disaster in Indonesia. Landslide events are strongly influenced by trigger factors, namely; climate, earthquakes and human activities in utilising land, while geological factors, soil factors, hydrogeological factors, land use factors and geomorphological factors (slopes and landforms) are the controlling factors for the occurrence of landslides. This study aims to link the controlling factors and triggering factors to delineate the level of landslide vulnerability in Enrekang Districts to become more detailed. The method used is the scoring with Analytical Hierarchy Process (AHP) method. The parameters were; slope, geology (lithology and structure), land cover, landform, population map, rainfall, texture of soil and earthquake event. This parameter will be evaluated by several experts through a questionnaire. The expert assessment results will be analysed further with expert choice software to get the weight values of each parameter. The weight obtained will be used to assess the vulnerability of landslides by using Argis 10.3 software by overlaying each parameter. The vulnerability of Enrekang districts is divided into five, namely very low vulnerability (1%), low (5%), moderate (21%), high (51%), and very high (22%). The Areas with a very high level of vulnerability can be found in the northern part of Maiwa Sub-District, most Enrekang Sub-Districts, the northern part of Buntu Batu Sub-District, the west to the north of Alla subdistrict, and the northern and eastern parts of Curio sub-district, and the southern part of Baraka Sub-District. Most of Enrekang Districts has a high vulnerability of landslide, so the application of vegetative and mechanical soil conservation techniques is needed in utilising land in sloping areas to prevent landslides.

### 1. Introduction

Enrekang is one of the districts in South Sulawesi, which including prone areas to landslides disaster in Indonesia [1]. The incidence of landslides every year is increasing in line with changes in extreme weather (global warming) which affects rainfall pattern distribution and has increased since 1998-2016 [2].

Climate especially rainfall, earthquakes (tremor), and human activities in utilizing land are the factors that trigger the occurrence of mass movement [3]. On the other hand, geological factors, soil factors, hydrogeological factors (slope and landform) become controlling factors for mass movement events [4–10]. These factors must be the basis in making scoring for delineation an area that vulnerable to the landslides.



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Several studies have been carried out by several experts [11], with parameters; landforms, slope, geology, soil texture, and land use, while [12] using parameters; land use, infrastructure, annual rainfall, slope, geological structure, and lithology. The difference in parameters resulted in differences level of landslides delineation in each Sub-district in Enrekang District. The research conducted using parameters; population, land cover, rainfall data slope, geology (lithology formation and geological structure), soil, landform and earthquake data. The use of triggering and controlling factors can simultaneously increase the accuracy of the data in delineating landslide vulnerability in Enrekang District. The accuracy of delineation data will help in the process of soil conservation for more sustainable land use [13].

**2. Material and methods**

The study site was located in South Sulawesi province with the location coordinate is 3°14'36"S-3°50'00"S and 119°40'53"E-120°6'33"E (Figure 1). Several parameters were collected for scoring with Analytical hierarchy Process (AHP) method. Those parameters were population (2017), land cover (2011), rainfall data (2010-2016), slope, geology (lithology formation and geological structure), soil, landform and earthquake data (2016-2019).

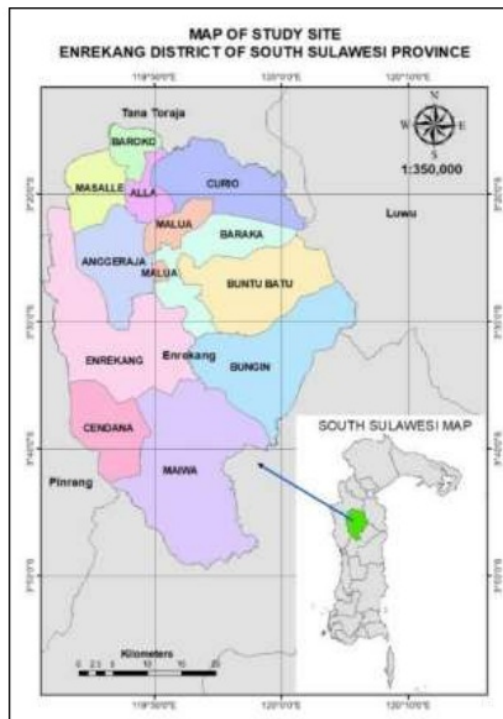


Figure 1. Location of study site

The parameters were evaluated by several experts through a questionnaire. Score assessment of expert judgment (table 1) was further analyzed by expert choice software to get weight value of each parameter. The weight obtained was compiled with earthquake data. Next, this data used to assess the hazard of landslides by using Argis 10.3 software by overlaying each parameter with used field calculator.

**Table 1.** Parameters and score of landslides vulnerability in Enrekang District

Sources	Parameters	Class	Categories of Class	Score
Population in Enrekang [14]	Population (inhabitant/km <sup>2</sup> )	<5000	not prone	1
		5000-10000	slightly prone	2
		>10000-15000	moderate	3
		>15000-20000	prone	4
		>20000	high prone	5
Landcover of Indonesia [15]	Land Cover	Primary and secondary dryland forest	not prone	1
		Bushes, savana	slightly prone	2
		Industrial forest	moderate	3
			prone	4
		Dryland agriculture, water Settlement, paddy field	high prone	5
		Bare land	very high prone	6
BMKG[16]	Rainfall (mm/yr)	<1500	not prone	1
		1500-2000	slightly prone	2
		>2000-2500	moderate	3
		>2500	prone	4
Regional Physical Planning Programme for Transmigration [17]	Slope (%)	8-15	not prone	1
		16-25	slightly prone	2
		26-40	moderate	3
	Texture of Soil	41-60	prone	4
		>60	high prone	5
		Moderate	moderate	1
Geological Map of Majene and Western Part of Palopo Quadrangles [18]	Geologi (Lithology Formation and Structural geology)	Qa and Qphs	not prone	1
		Tets, Tmps, Tomd, Tml, Tms, Tmpw	slightly prone	2
		Tetl and Tomm	moderate	3
			prone	4
		Tmpv and Tmtv	prone	4
Catalogue of Landforms for Indonesia [19]	Landform	Riverine, riverine terraces, lacustrine	not prone	1
		Ridge karstic, ridges mountain, karstic hills marble limestone, hillocky acid igneous plain	slightly prone	2
		Irregular mountain ridges, very steep over metamorphic rocks	moderate	3
		Non-vulcanic alluvial fans, hillocky sedimentary, hillocky tuffaceous, undulating tuffaceous sediment	prone	4
		Steep hills on marls, very steep tuffaceous sedimentary, sedimentary ridges, linear sedimentary ridges	high prone	5

### 3. Results and discussion

The Sub districts in Enrekang district have a population varying from <5000 inhabitants/km<sup>2</sup> in Bungin Subdistrict to >25000 inhabitants/km<sup>2</sup> in Enrekang Subdistrict (figure 2). The high population is in line with the increase in land use for dry land agriculture (figure 2). Some area in Enrekang District still not use a conservation technique for agricultural activity and trigger a landslide in the

rainy season. The Area with high agricultural activity without implementing soil conservation technique cause landslides in Nepal [20].

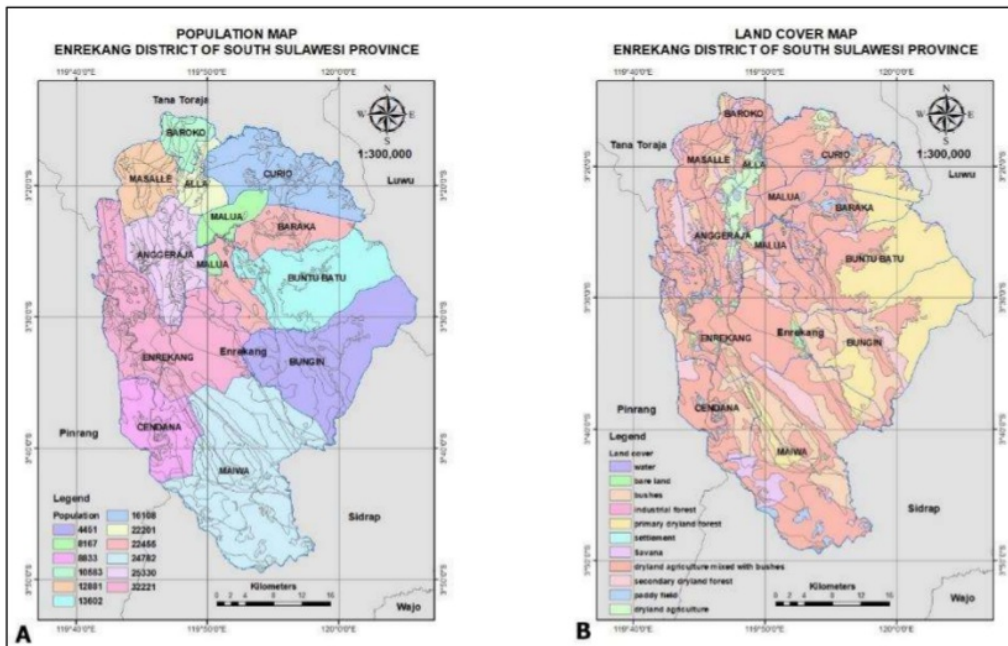


Figure 2. Population map (A) and land cover map (B) of Enrekang District

The highest rainfall was found in Buntu Batu, Maiwa, Enrekang, and Alla Subdistrict (figure 3), with an average of 2,412.25 mm/year. Most of Enrekang District has a slope >40% (figure 3), land use on slopes > 40% can trigger mass movement [2,21].

The lithology consists of quarterly deposits, sedimentary rocks and volcanic rocks (figure 4). Lithology in general have experienced cracks due to past and recent tectonic processes (figure 4). The intensity of earthquakes with occurring in Enrekang District despite having the small of magnitude the earthquake, but it has an influence in increasing the vulnerability of landslides [7]. Baraka and Buntu Batu Subdistrict have 4 earthquake magnitudes in 2016, Baraka and Cendana Subdistrict have 4.4 earthquake magnitudes in 2018, and Alla and Enrekang Subdistrict have 4 earthquake magnitudes in January 2019. The tectonic activity has to be attention for delineating an area for landslides vulnerability [22].

Dominant soils are composed of silt and clay fractions (figure 5), which can absorb large amounts of water and are easily dispersed, thereby increasing vulnerability to landslides [6,23], especially in hilly and irregular mountain landforms (figure 5). Most of landform in Enrekang District have dissected morphology with the steep slope, and all the activity in this landform was very prone to trigger a landslide. The landform has a role to increase landslide vulnerability [24].

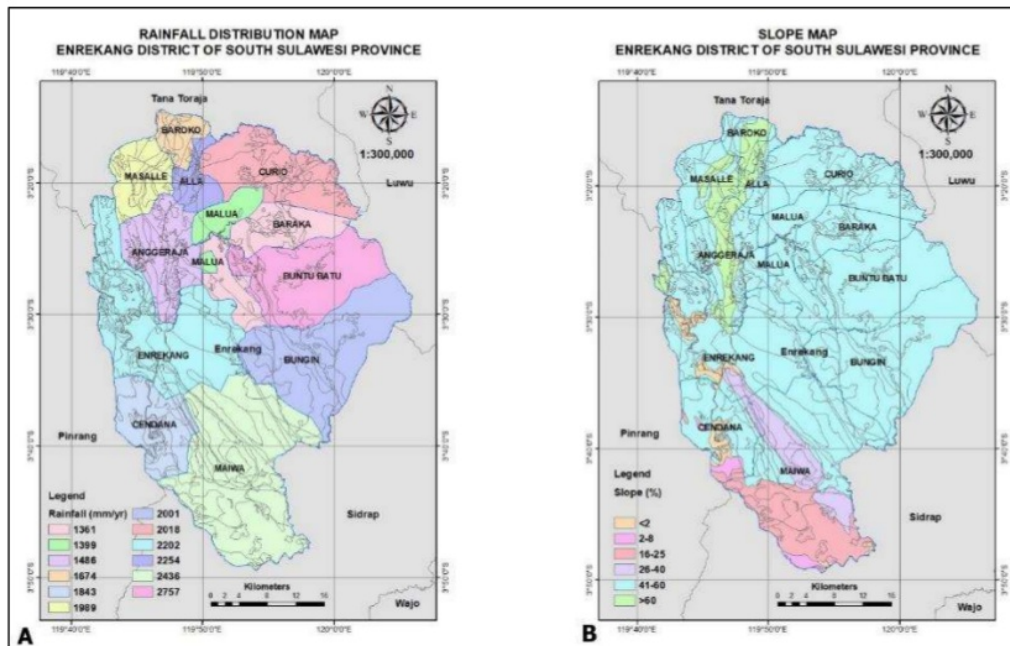


Figure 3. Rainfall distribution map (A) and Slope map (B) of Enrekang District

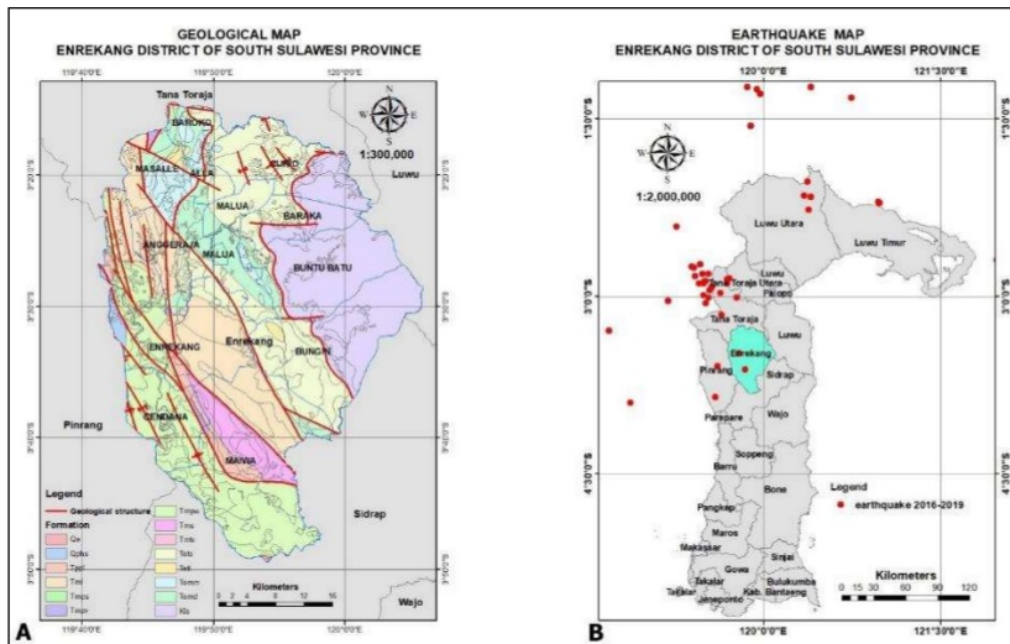


Figure 4. Geological map (A) and earthquake map (B) of Enrekang District

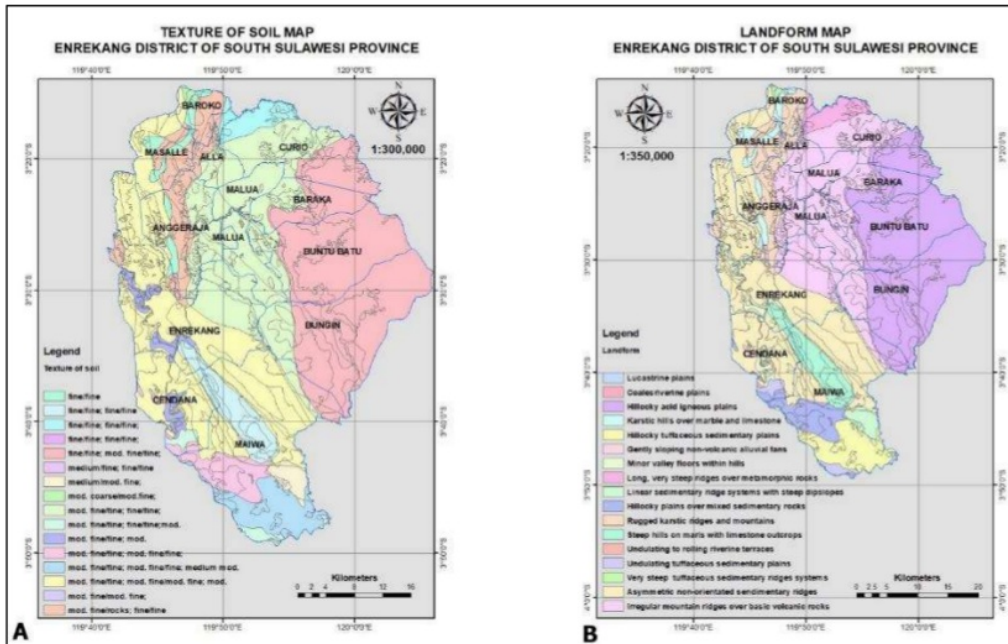


Figure 5. Texture of soil map (A) and landform map (B) of Enrekang District

The vulnerability of Enrekang districts is divided into five, namely very low vulnerability (1%), low (5%), moderate (21%), high (51%), and very high (22%) (figure 6).

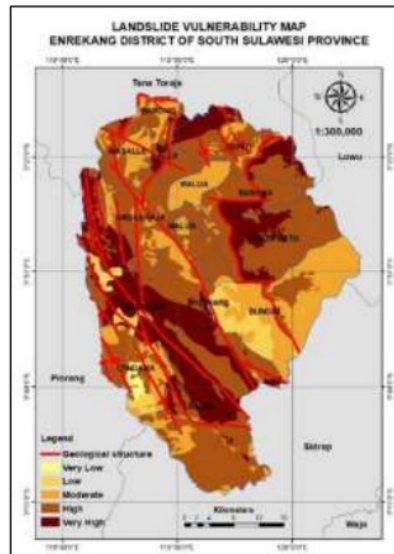


Figure 6. Landslides vulnerability map of Enrekang District

The areas with a very high level of vulnerability can be found in the northern part of Maiwa Sub-District, most Enrekang Sub-Districts, the northern part of Buntu Batu Sub-District, the west to the north of Alla subdistrict, and the northern and eastern parts of Curio sub-district, and the southern part of Baraka Sub-District. According to BNPB data [25], this area has intensively landslide event in the past four years. Most of the Enrekang Districts has a high vulnerability of landslide and the people in Enrekang District have no other alternative in developing agricultural activities in hilly and mountain landform, so it needs the application of vegetative and mechanical soil conservation techniques in utilizing land in sloping areas to prevent landslides.

#### 4. Conclusions

The vulnerability of Enrekang districts is divided into five, namely very low vulnerability (1%), low (5%), moderate (21%), high (51%), and very high (22%). Most of the Enrekang Districts has high vulnerability of landslide, so it needs the application of vegetative and mechanical soil conservation techniques in utilizing land in sloping areas to prevent landslides.

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