EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 11(2) (2018) 149-163
DOI 10.14456/ea.2018.30
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Mapping and Zonation Level of Landslides Hazard and Risk Assessment: A Case Study of Enrekang Regency, South Sulawesi, Indonesia.

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Received: November 29, 2017; Accepted: :March 27, 2018

Abstract

Enrekang Regency is one of the districts in South Sulawesi that often happens landslide. Therefore it is necessary to mapping and zonation areas prone to landslides. This study aims to map and determine the risk level of landslides hazard in Enrekang Regency. Zonation level of landslides hazard risk is carried out by overlay technique of: landform map, gradien slope map, geology map, soil texture map, land use map and landslides hazard map, respectively. The landscape, gradien of slope, type of rock, soil texture and land use make in five class respectively, with the value 1 until 5. The landslides risk level is performed by overlay using ArcGis 10.3.The result of analysis shows there are 3 classes of landslides risk level in Enrekang Regency that is low, medium and high, respectively. There are sequences of areas most vulnerable to landslides, there are Bungin, Buntu Batu, Anggeraja, Enrekang, Masalle, Baraka, Baroko, Alla, and Maiwa.

Keywords: Mapping; Zonation; Landslide hazard; Risk assessment

1. Introduction

Landslide, as one of the natural hazard in the world (Dai *et al.*, 2002; Jian and Xiang-guo, 2009). As well as in Indonesia, landslide is one of the most common types of natural hazards, have caused large number casualties and huge economic losses. National Hazard Mitigation Agency (BNPB) noted there are about 721 incidents of landslides hazard occurred in all parts of Indonesia between 2014 until 2016 years. Events of landslides or movements of soil masses, rocks or combinations, occur on the slopes (Avanzi *et al.*, 2004). The phenomenon of landslide occurs because the process of seeking new balance due to the interference. Landslides often occur during heavy rainstorms, especially in the mountains regions (Lee and Yi Ho, 2009). In South Sulawesi, some areas prone to landslides during the rainy season are Enrekang, Tana Toraja, Palopo, North Luwu, East Luwu, Soppeng, Wajo, Sinjai, Jeneponto, Bantaeng, and Gowa. Enrekang regency is ranked 2nd among 24 districts/municipalities that enter areas prone to landslides (Environmental Impact Management Agency). Landslide are not only caused by physical factors such as slopes and shapes but also influenced by human intervention (Marcato *et al.,* 2012). The development of a region will increase the need for land as a residence and economic activity, availability of land is not increased. Thus some residents occupy an uninhabitable location such as in hilly terrain and mountain slopes that are prone to landslides. Steep slopes of human activity will trigger higher levels of vulnerability, when land is being over-exploited without regard to land carrying capacity. The type of landslides based on the speed of movement can be divided into 5 (five) types: flow; avalanches; collapse; compound; subsidence (land subsidence). Meanwhile, the main factors causing landslides are natural factors and management factors. Natural factors are derived from natural conditions, such as: rainfall, geological conditions, the existence of fracture/fault/ escape, and the depth of the soil (regolith). Management factors consist of: land use, road infrastructure, and settlement density

Hazard risk is the possibility of a hazard occurring causing a special loss rate. Risk needs to be assessed so that it can determine the amount of the loss that has been estimated and it can be anticipated in a region (UNDRO, 1992). Many experts have developed a formulation in assessing hazard risks. And in general hazard risk is a combination of hazard and vulnerability. However, in addition to these factors, individual and group exposure and capacity are also critical in risk assessment (Wisner *et al.,* 2004). The objective of assessing risk is substantially different between landslide hazard and assessment of other hazards. The assessment of landslides risk aims to determine the estimated loss of life, injuries, property destruction and loss of economic activities caused by landslides events.

The urge of the population to the land in Enrekang Regency is increasing as the population grows. Land use in areas with steep slopes is increasing. Land cultivation that ignores conservation methods will trigger landslides. Even lately the phenomenon of forest encroachment began to appear that will result in the loss of large long-rooted trees that can strengthen the soil mass bonds (Ayalew *et al.,* 2005; Maru *et al.,* 2016). The encroachment triggered the occurrence of landslides, especially in the sloping areas Ayalew *et al.,* 2005; Maru *et al.* 2016). The availability of a complete landslides hazard risk map is essential to prevent the occurrence of casualties and the economic impact on the community (*J*iana, Xiang-guo, 2009). Therefore Enrekang Regency is needed landslides zonation map. In addition, it can also serve as input for the preparation of the spatial plan of Enrekang Regency.

2. Material and Methods

a. *Location of the study area*

Enrekang Regency is located in south Sulawesi, Indonesia. The Enrekang Regency lies between at the $119^0$40'53"- $120^0$06'33" east- longitude and $3^0$14'36"- $3^0$50'00" south-latitude. Enrekang Regency is 1,786.01 km^2 in size. Boundary of Enrekang Regency is north of Tanah Toraja Regency, South of Sidenreng Rappang Regency, West of Tana Toraja Regency and Pinrang Regency and east of Luwu Regency. Enrekang regency has a varied topography of hills, mountains and valleys with a height of 47 to 3,293 meters above sea level and has no coastal area. The hills and the mountains are 84.96%, while the flat area is only 15.04%. The rainy season occurs in November-July, while the dry season occurs in August-October (Figure 1).

This research was conducted by using quantitative descriptive approach, by compiling tabular data, which is paired with GIS analysis in spatial analysis and scoring based assessment. In this research there are 5 variables for the determination of landslides prone areas that refer to the Studies Center for Natural Hazard (Pusat Studi Bencana Alam: PSBA) UGM (2001). The variables are as follows: landform, slope, rock type, soil texture and land use. The variable used to determine the risk assessment for a landslides hazard is population density, the number of people per unit area that will be threatened in case of landslides hazard. In this study using units of hectares (ha).

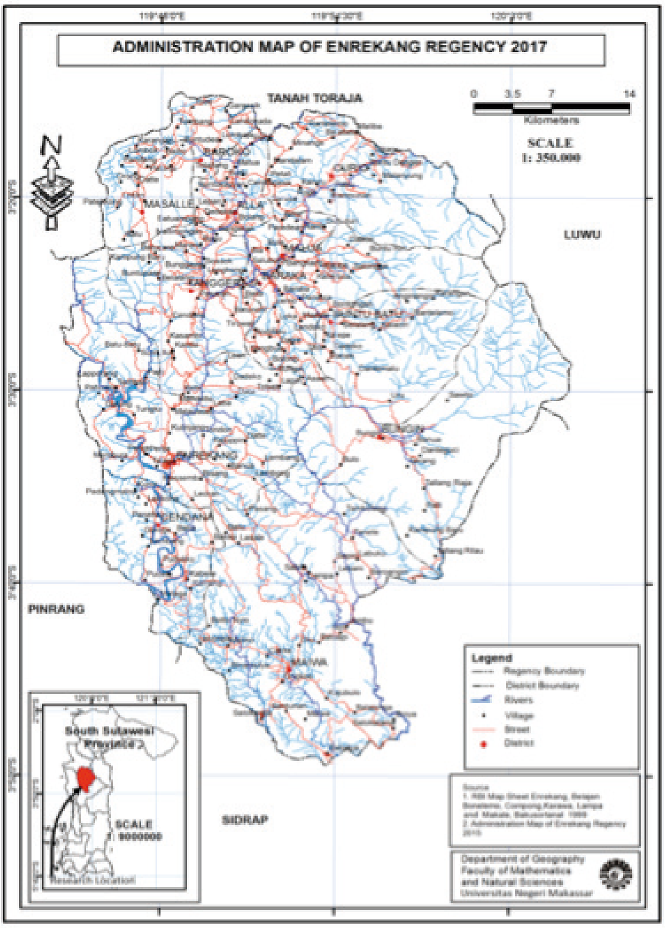

Figure 1. Location of the study area

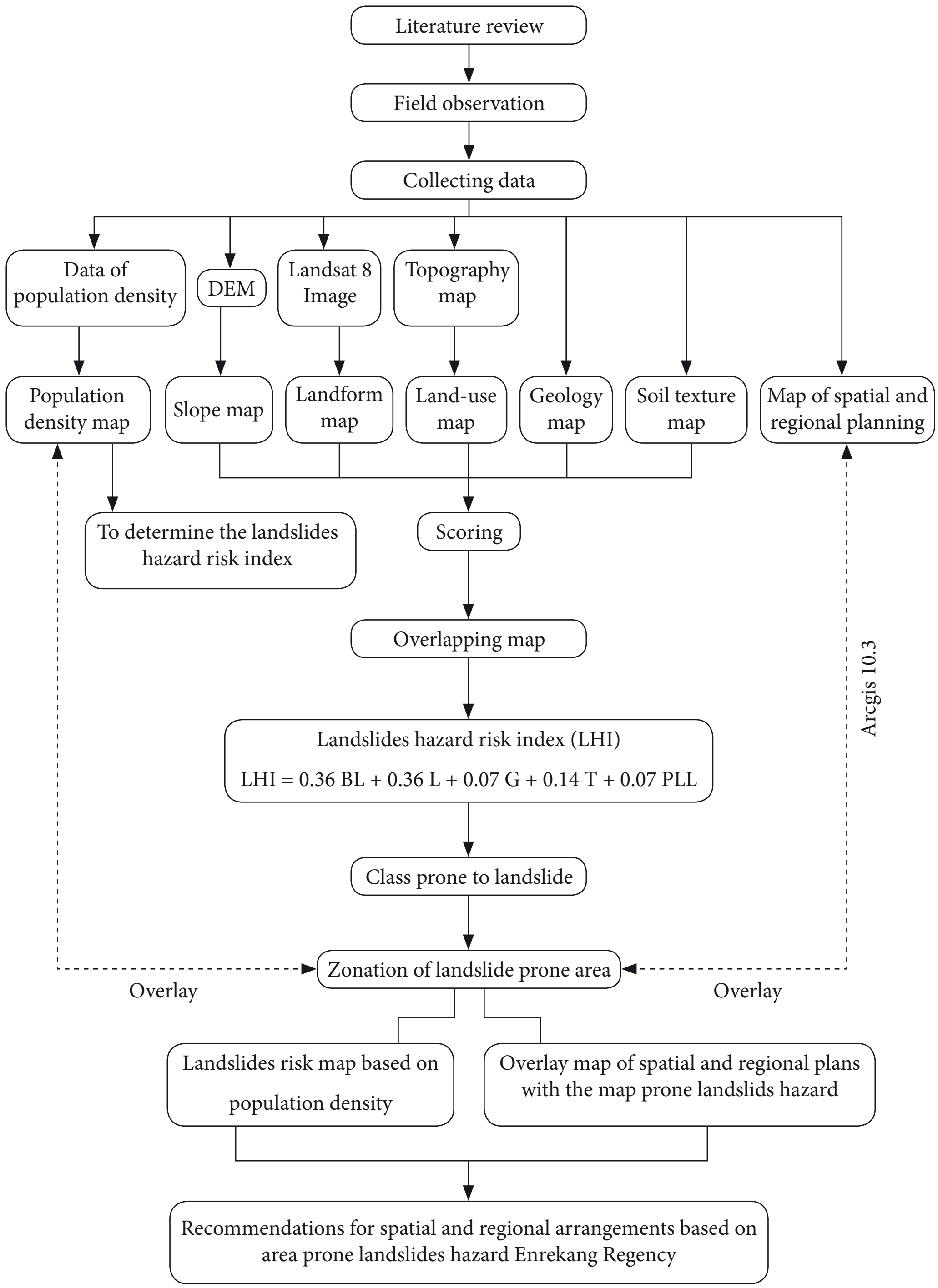

Figure 2. Landslide disaster risk management and land use planning strategy

b. Parameter in hazard assessment.

Influencing factors of landslide hazard in a region are landform, slope, geology, soil and land use (Hadmoko *et al.*, 2010; Marcato *et al.*, 2012). In addition, landslide can be triggered by various external factors such as rainfall intensity, earthquake, changes in groundwater level and river bank erosion (Dai *et al.*, 2002; Harp *et al.*, 2009). Human activities such as the construction of roads cutting slopes and clearing of land can also trigger landslide (Jaiswal *et al.*, 2010). The probability of accurrence is one of the key components of the risk equation. To assess this probability in landslides risk analysis, using two different approaches have been traditionally and probability is obtained by means of the statistical analysis of the past landslides event (Corominas and Moya, 2008). Enrekang Regency did not have data of landslides events that have occurred both time and spread. Therefore, to map the spread of landslides hazard using semi-quantitative method, that is based on factors that can cause landslides, geology (based on type of rock), soil (texture), slope (gradient slope), and land use (land management) (*Harp et al., 2009*). This research is using scoring technique on each parameter. Scoring for each assessment variable is based on the level of influence variables in giving impact of landslides hazard. The higher the value of score, the higher the vulnerability. Determination of total value of score is done by overlay of landform map, slope, geology, soil texture and land use (Sartohadi *et al.*, 2010). The criteria for determining landslides prone areas are shown in Table 1.

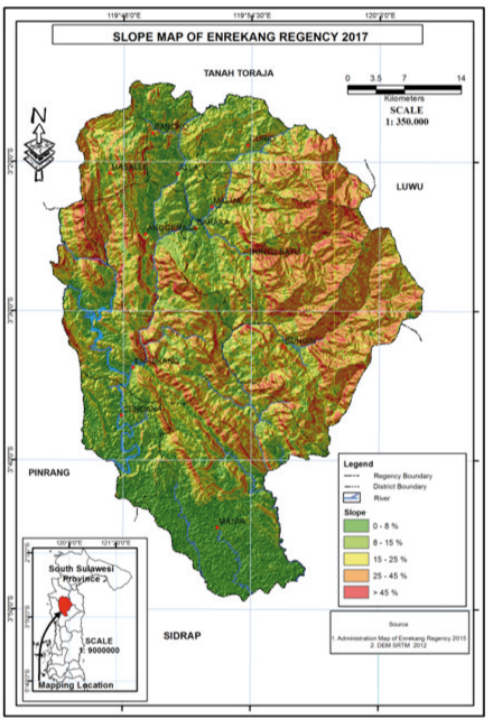

Figure 3. Slope map of Enrekang Regency

Soil samples are taken on each every of land unit. The land unit are made by overlay between gradient slope map, land use map and geological map. These two maps (land use and geological map) were obtained from the Government Enrekang District. The analysis of soil texture using pipette and sieve method. This type of rock is obtained from the geological map of Enrekang Regency. This geological map was re-digitized, and then analyzed the rock types. The land form is obtained from the archives sources landform map Government Enrekang District and ground checks sources. Land use maps were obtained from SPOT 5 satellite images, the result of cooperation between the Enrekang District Government and The National Aviation and Space Agencies Pare-pare, South Sulawesi, Indonesia. While the slope map is obtained from topographic maps in digital form. Then by using the methods DEM (Digital elevation model) to obtaining the parameters map can be represented as a raster (grid of squares) or as a vector-based triangular irregular network (TIN) (Fernandez *et al.*, 2003).

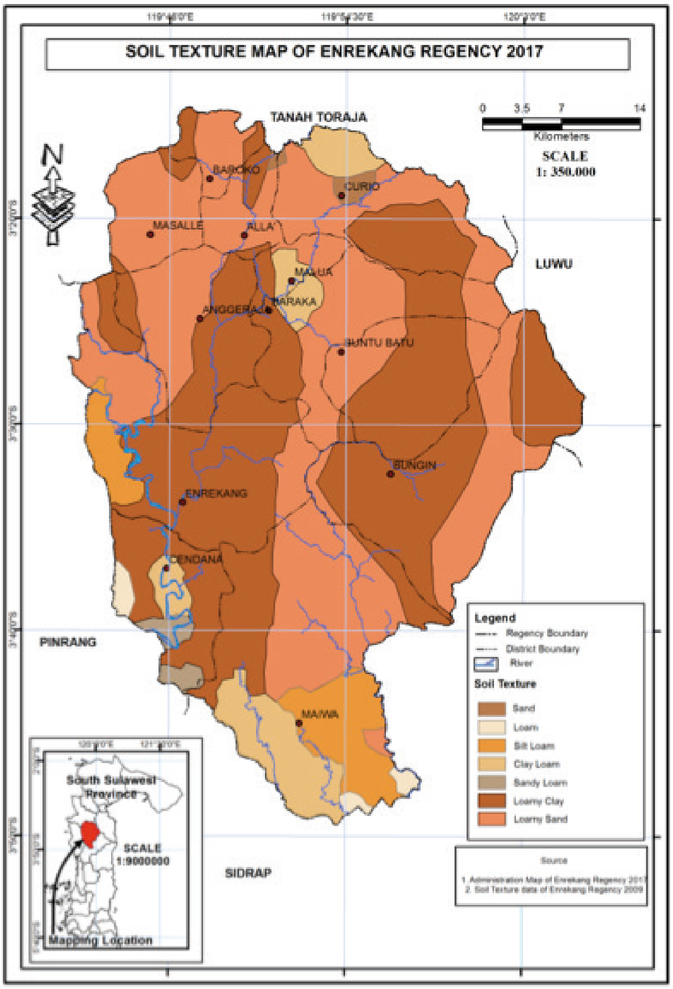

Figure 4. Soil texture map of Enrekang Regency

Table 1. Criteria for determining score and weight value to each parameter in hazard assessment

No	Parameters	Variabels	Score	Weight factors
1	Landforms	Alluvial plains, flood plains, natural levee	1	0.36
		Colluvial-alluvial footslope	2	
		Eroded hills, fault escape, footslope of structural hills, footslope of denudational hills	3	
		fault block mountains, struktural hills	4	
		Mountains eroded, denudational hills	5	
2	Gradient of slope	0-8 %	1	0.36
		8-15 %	2	
		15-25 %	3	
		25- 45 %	4	
		> 45 %	5	
3	Geology	Alluvium (Al), Alluvium volcanic (Av)	1	0.07
		Clastic Limestone (Cl)	2	
		Marl (M)	3	
		Plutonic intrusion (Pt)	4	
		Non-clastic limestone (NCL), Andestic Breccias(Bc), Sandstone (Sd)	5	
4	Soil texture	loam	1	0.14
		Clayed loam	2	
		Silt loam	3	
		Sandy loam	4	
		Loamy clay, loamy sandy, clay, sand	5	
5	Landuse	forest	1	0.07
		Mixed forest	2	
		plantation	3	
		Rice fields, settlement	4	
		Open soil, Savana, dryland farming, mining	5	

Determination of landslides prone index equation:

IRL = (0.36 Score Bl + 0.36 Score L + 0.07 Score G + 0.14 Score T + 0.07 Score Pl)

Where :

IRL = Index of landslides prone

Bl = landform

L = gradient of slope

G = geology

T = soil textur

Pl = land use

To determine the value of the class interval prone to landslides, where the highest value is 5, the lowest value is 1 and the number of landslides classification class is 3 so that the class interval can be determined by the following equation

Class Interval =

(maximum value - minimum value)/(number of class)

Based on the above equation, then the interval class of each class prone to landslides hazard is:

Class Interval = (5-1) / 3 = 1.3

Thus, the class prone to landslides hazard can be set at interval 1.3 as presented in table 2 below.

Tabel 2. Lanslide hazard index

No	Class	Interval value	Hazard level
1	I	1-2.33	low
2	II	2.34-3.67	medium
3	III	3.68-5	high

Source: Hadmoko *et al.* (2010)

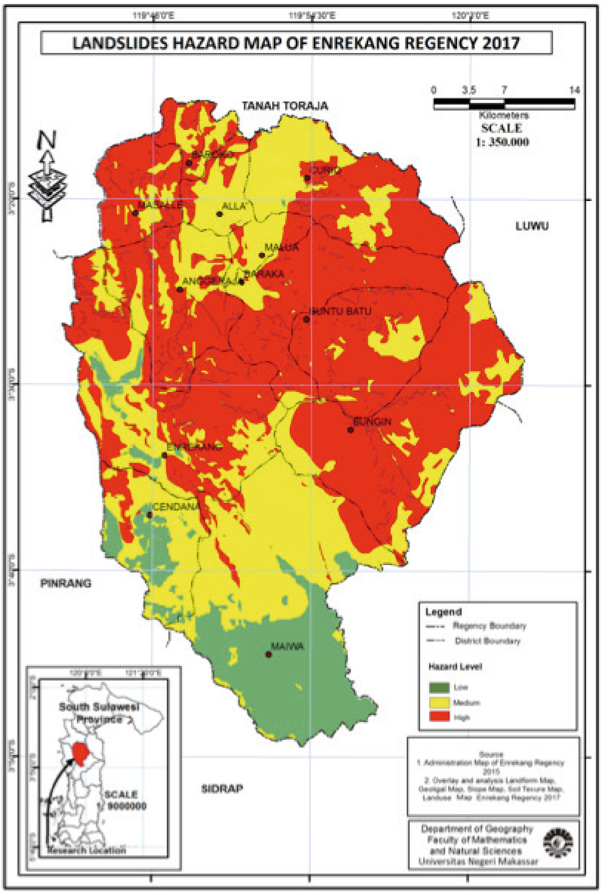

Figure 5. Landslide hazard map of Enrekang Regency

Table 3. Criteria used to determine the risk index

No	Density of population (people/ ha)	Risk index
1	0 (no people)	low
2	1-10	medium
3	>10	high

Source: Hadmoko *et al.* (2010)

The Landslides Hazard Index score will be matched with the value in the landslides prone classification table to determine the level of vulnerability. Landslides risk assessment can use the parameters of infrastructure and population density but in this study only used population density parameters with the following conditions

c. *Risk assessment*

Disaster risk determinations in Enrekang District were made semi-quatitatively using risk index (Hadmoko *et al.,* 2010). Determination of risk assessment focuses on the number of affected populations in case of landslides. Population data were obtained from Registry and Population of Enrekang Regency. To determine the landslide hazard index map using the methodoverlay between landslide hazard map and population density (people/ha).

The risk index is divided into three classes, namely low, medium and high. The criteria for to determine class risk based on the number of people affected per hectare in case of landslide.

Risk level assessment is carry out by overlaying between risk map and landslides vulnerability map so that it can be analyzed with low, medium and high risk areas in areas with low, medium or high vulnerability.

3. Result and Discussion

a. *Zoning Areas Prone*

Overlay the landform map, slope map, geology map, soil texture map and of land use map, will obtained of landslides hazard map Enrekang Regency. Zonation of landslides prone areas in Enrekang Regency is divided in to three, there are low level of vulnerability, medium vulnerability and high level of vulnerability. The area with the highest vulnerability was the widest area with 98,748.26 ha (54.50%), followed by medium of vulnerability 61,375.51 ha (33.85%) and low level of vulnerability with the widest area is 21,090.91 ha (11.64%). Zonation division of landslides prone areas seen in the following Table 4.

Table 4. The area of landslides vulnerability Enrekang Regency

No	Risk index	Area	
		(ha)	Percen (%)
1	Low	21,090.91	11.64
2	medium	61,337.51	33.85
3	hight	98,748.26	54.50

Source: The result of research (2017)

Factors that causing low level of vulnerability are soil texture (loam), and than gradient slope only between 0-15 %. The loam soil texture have characteristics swelling and shrinking is low, so as not to trigger the movement of the soil to the bottom of the slope (Harp *et al.,* 2009). As well as for gradient slopes between 0 % - 15 %, so as not to trigger and than only slightly the effect on the occurrence of landslides. In medium vulnerability level, landform variables are still dominated by plains and hills landform, while the landuse is dominated by the garden, settlements, shrubs, and rice fields. On the other hand the region with the medium vulnerability level, is a dominated by slope of class III and IV, the clay and sandy clay textures of soil, and landform is the mountain region. The clay soil texture can to the trigger even landslides because have a characteristic swelling and shrinking (Baldivieso *et al.,* 2003). The higher clay content most of the significant quaitities that renders it susceptibility to slope failure (Harp *et al.,* 2009). On the high levels of vulnerability are the slope class IV (25-45 %) and V (≥ 45 %), dominated by clay and sandy clay texture and than landform mountain region. In the region is characterized by rugged topography, high of gradient slope and relatively frequent heavy precipitation event is the trigger of landslide (Marcato *et al.,* 2012).

As slope increased, the percentage of land affected by landslide, indicating that agricultural activity and the associated removal of deep-rooted permanent vegetation increased the landslide hazard on steep sites (Baldivieso *et al.,* 2003). While the land use are settlements, mixed garden, rice fields, and scrub. In the region with have slope IV and V class can to trigger landslides, because the differently of anggle between normal force and gravity force only a slight (Hadmoko *et al.,* 2010). The landslide influenced by the gradient slope and landuse/cover (Baldivieso *et al.,* 2004).

4. Landslides Risk Level

a. Low Risk Level

The low-risk areas of landslide threats are the areas not occupied by the population, so that if there is a landslide disaster no residents who become victims or the possibility of casualties is very small. The final risk map point out the critical regions in relation to the respective processes hazard and the elements at risk *(*Bell and Glade, 2004). The total area for the low risk level is 180,904 ha which is spread over three levels of landslides vulnerability.

Table 5. Population density Enrekang Regency, based on districts

Districts	Area (ha)	Number of population	Population density (people/ha)
Maiwa	39,287	24,261	0.62
Bungim	23,684	4,426	0.19
Enrekang	29,119	31,737	1.09
Cendana	9,101	8,805	0.97
Baraka	15,915	22,081	1.39
Buntu Batu	12,665	13,351	1.05
Anggeraja	12,534	24,867	1.98
Malua	4,036	8,000	1.98
Alla'	2,466	21,729	8.81
Curio	17,851	15,715	0.88
Masalle	6,835	12,715	1.86
Baroko	4,108	10,506	2.56

Sources: Data BPS Enrekang Regency 2017

b. Medium Risk Level

Areas with a medium risk level is the areas whose population density is between 1-10 people/ha. In this study the medium risk level has a total area of 1,225.38 ha. Almost all settlements are at a medium risk level. The existence of settlements with medium risk levels in areas prone to landslides are shown in Table 5. From the table it is known that the level of risk is 472.96 ha area is located at the high landslides vulnerability of the Sub-districts in Bungin, Buntu Batu, Masalle and Anggeraja which need to be wary of.

c. High Risk Level

Areas with high risk level that is the area whose density is more than 10 people/ha. In this research, the high risk level is only found in Alla sub-district, namely in Sudu, Belajen, Tobanga, and Kalosi villages. Although it is located in areas with moderate levels of vulnerability, but must remain alert to the occurrence of landslides because the population dense. The following table covers the extent of landslides risk in Enrekang Regency.

Table 6. The area of landslides hazard risk level of Enrekang Regency

No	Risk level hazard	Area (ha)
1	low	180,904
2	medium	1,225.38
3	hight	99.68

Source: The result of research (2017)

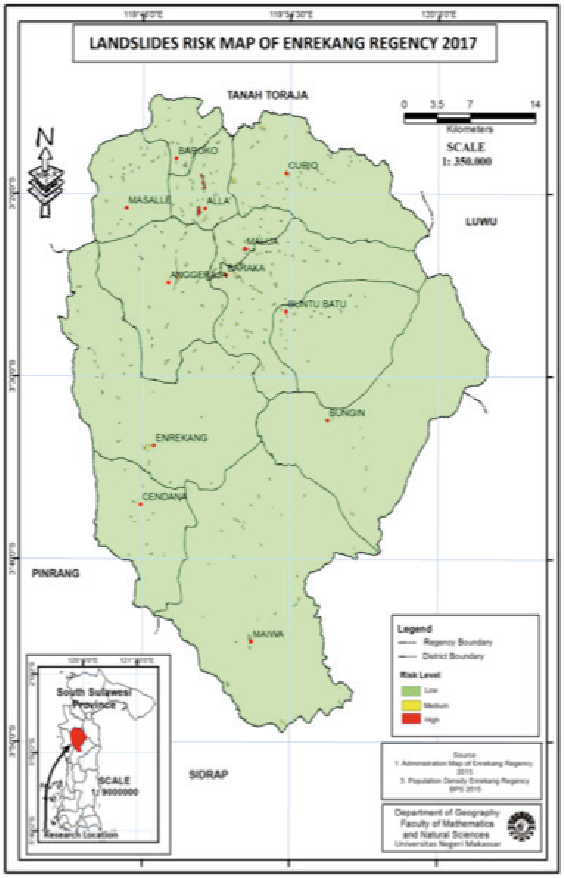

Figure 6. Landslide risk map Enrekang Regency

5. Spatial and regional plans based on landslide prone area and risk landslide hazard in Enrekang Regensi.

Spatial and regional planning based on the landslide hazard map and risk map landslide hazard is aimed to preventing the occurrence of casualities of death and injury of the people if any event of landslide. The development regional based on landslides hazard is a form of spatial planning by giving priority to consideration on the basic physical condition of the area. The direction of regional development based on landslides prone areas is emphasized so that each region can direct the development of its region with the concept of development based on hazard mitigation especially in the geographical area which is vulnerable to landslides. Regional development directives shall be based on the degree of vulnerability to landslides. Based on the results of the landslides vulnerability analysis of Enrekang Regency, the high level of vulnerability is the most widespread, the extent reaches 98,748.26 ha or 54.50% of the total. Areas with high levels of vulnerability in the development process need to be controlled, especially the utilization of space.

The result of the overlay of the spatial and regional planning map with the map of landslides vulnerability level of Enrekang

Regency shows that the area with the highest vulnerability is the protected forest, plantation and agro-forestry. The areas with high levels of vulnerability to land use as protected forests and agro-forestry are appropriate. While the plantation area is less appropriate for areas with high levels of trigger, plantation activities especially on the steep slopes can disturb the stability of the slope so it can trigger the occurrence of landslide. In areas of vulnerability in this study, the designation plan is dominated by limited production forests, plantations and agro-forestry. Plantation activities, production forests in areas of low vulnerability can be carried out under the following conditions: 1) Planting vegetation with appropriate types and patterns of planting, 2) Need to apply the right terrain and drainage system on the slope, 3) Avoiding slope cutting and excavation. In areas with low vulnerability in this study, land use planning is dominated by dry-land farming. In general, in areas with low vulnerability, land use that is not allowed in high and medium prone areas is permitted with due regard to the characteristics and capabilities of the land.

6. Conclusion

Based on zonation results of landslides prone areas of Enrekang Regency, the level of vulnerability is divided into three, there are: low, medium, and high. The high level of vulnerability is the most widespread of 98,748.26 ha (54.50%) and most of them are in District Bungin, Baraka, Enrekang, and Anggeraja with the dominant cause factor is slope. The risk level of landslides hazard in Enrekang Regency for population density parameters is still safe, and high risk level is only found in Alla Sub-district, whereas other sub-districts are classified as medium and low risk. Based on the Enrekang District spatial and regional planning map, land use as a protected forest and plantation area is the most widespread. From the analysis result for high landslides vulnerability of protected forest area, agro-forestry and plantation is the most widespread, protected forest area need to be maintained for area with high landslides vulnerability while for plantation activities need to be evaluated so as not to trigger the landslide.

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