Spatial analysis of landslide vulnerability in Enrekang District, South Sulawesi

Spatial analysis of landslide vulnerability in Enrekang District, South Sulawesi

A Ahmad[1], C Lopulisa[1], A M Imran[2], S Baja[1] and M S Solle[1]

[1]Department of Soil Science, Faculty of Agricultural, Universitas Hasanuddin, Makassar, Indonesia
[2]Department of Geological Engineering, Faculty of Engineering, Universitas Hasanuddin, Makassar, Indonesia

E-mail: asmita.ahmad@agri.unhas.ac.id; asmitaahmad@yahoo.com

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.

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).

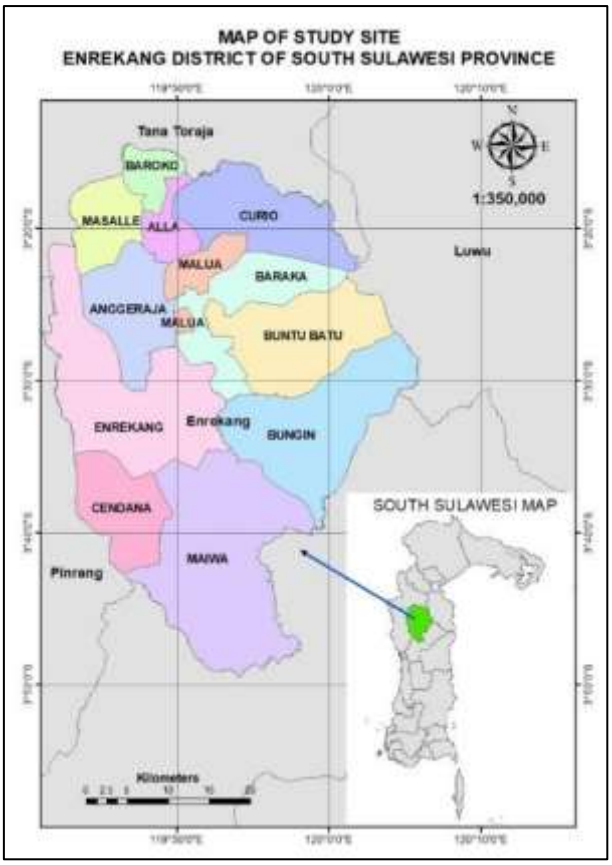

Figure 1. Location of study site

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^2)	<5000	not prone	1
		5000-10000	slightly prone	2
		>10000-15000	moderate prone	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 prone	3
		Dryland agriculture, water	prone	4
		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 prone	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 prone	3
		41-60	prone	4
		>60	high prone	5
	Texture of Soil	Moderate	moderate prone	1
		Medium	prone	2
		Fine	high prone	3
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 prone	3
		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 prone	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^2 in Bungin Subdistrict to >25000 inhabitants/km^2 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].

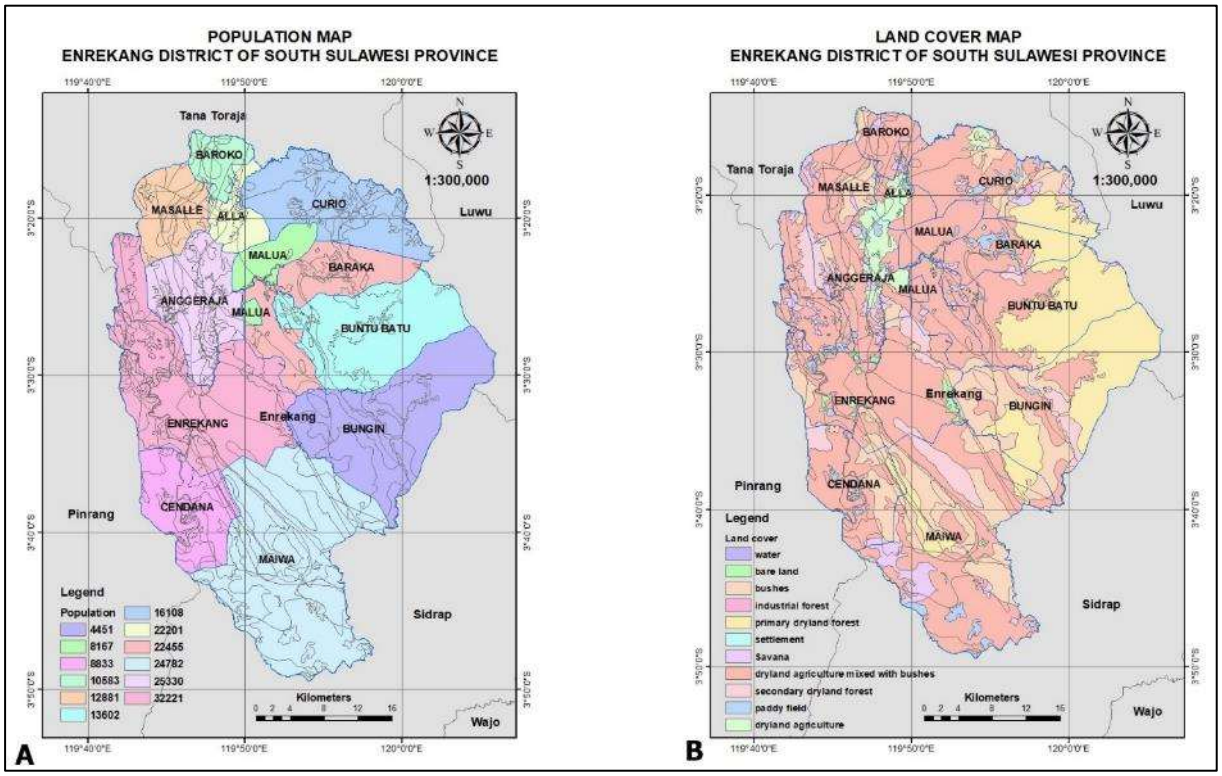

Figure 2. Population map (A) and land cover map (B) of Enrekang District

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 hillocky 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].

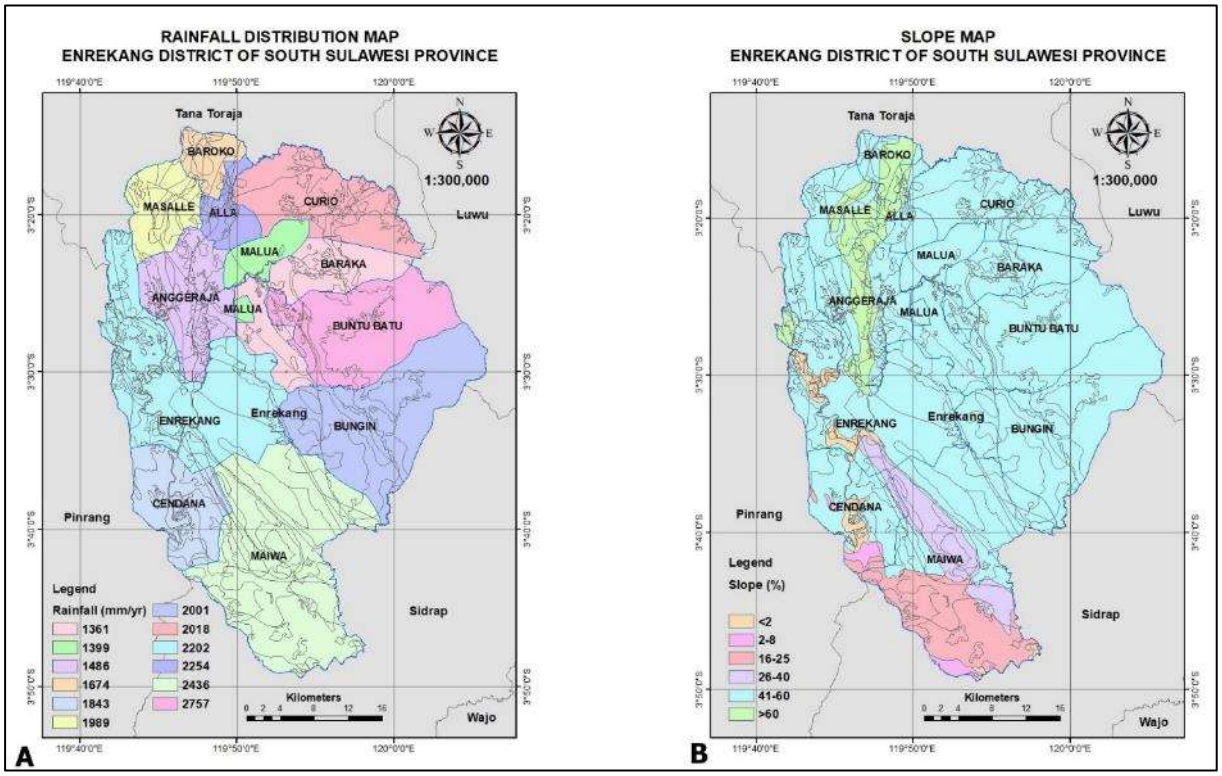

Figure 3. Rainfall distribution map (A) and Slope map (B) of Enrekang District

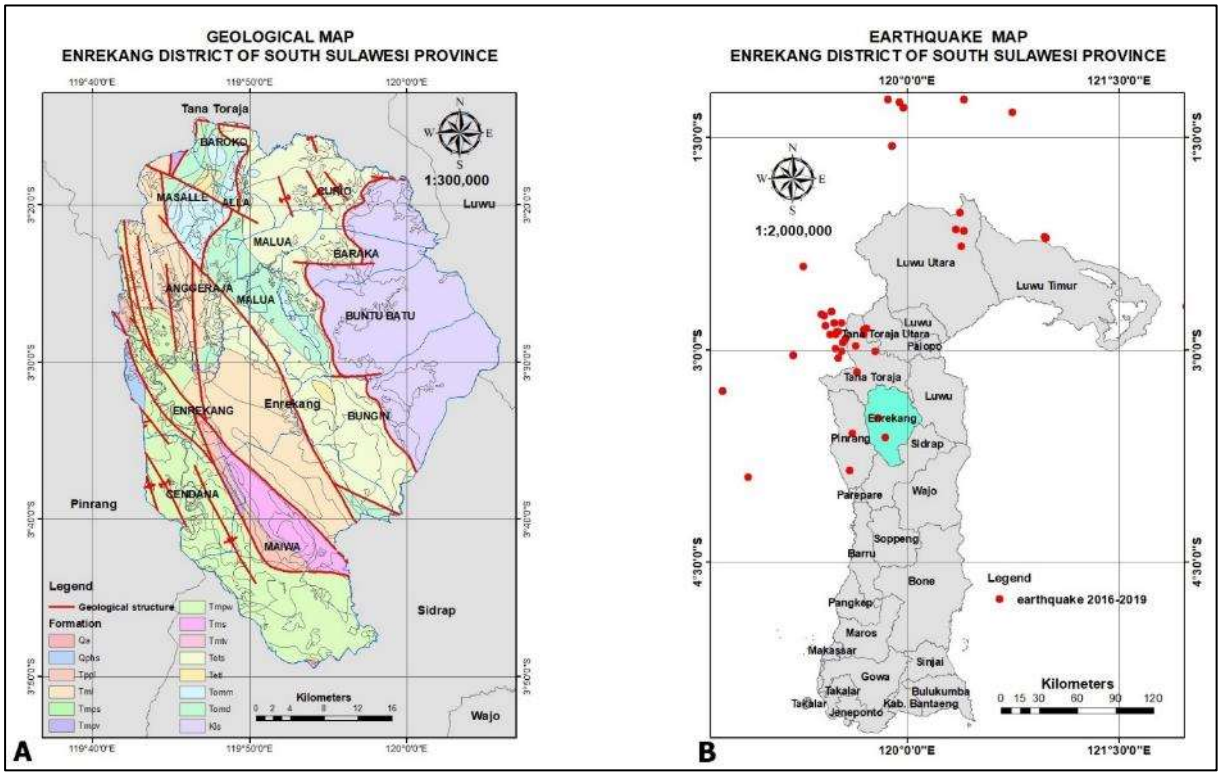

Figure 4. Geological map (A) and earthquake map (B) of Enrekang District

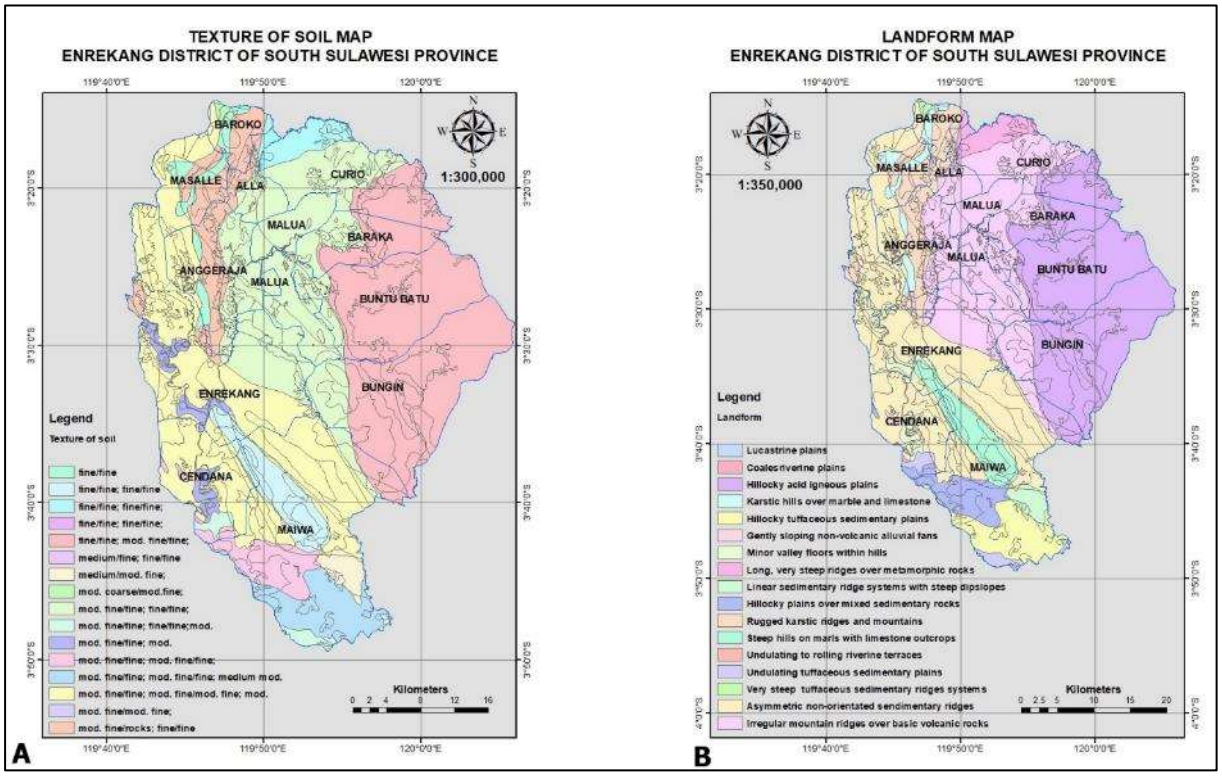

Figure 5. Texture of soil map (A) and landform map (B) of Enrekang District

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).

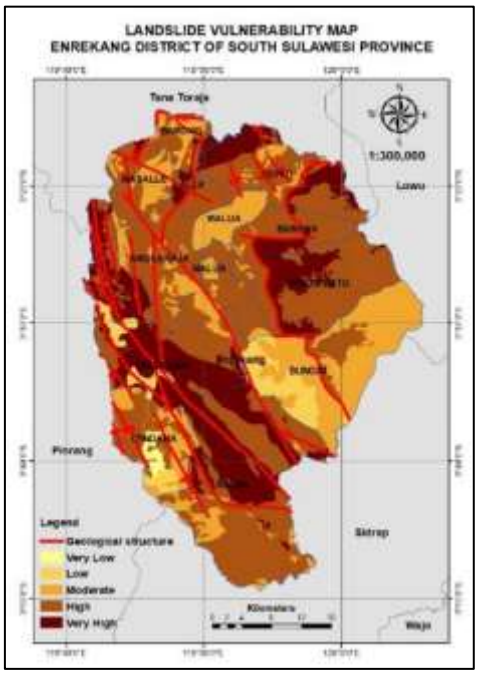

Figure 6. Landslides vulnerability map of Enrekang District

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 hillocky 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 devided 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.

References

[1] ESDM 2009 *Peta Zona Kerentanan Gerakan Tanah Provinsi Sulawesi Selatan (Map of Soil Susceptibility of South Sulawesi Province)*
[2] Ahmad A, Lopulisa C, Imran A M and Baja S 2018 Soil physicochemical properties to evaluate soil degradation under different land use types in a high rainfall tropical region : A case study from South Sulawesi , Indonesia *Earth and Environmental Science* (IOP Publishing) pp 1–7
[3] Ali M S S, Arsyad M, Kamaluddin A, Busthanul N and Dirpan A 2019 Community based disaster management: Indonesian experience *IOP Conference Series: Earth and Environmental Science* vol 235 (IOP Publishing) p 12012
[4] Karnawati D 2007 the Mechanism of Rock Mass Movements As the Impact of Earthquake ; *Din. Tek. Sipil* **7** 179–90
[5] Imran A M, Azikin B and Sultan 2012 Peranan Aspek Geologi Sebagai Penyebab Terjadinya Longsoran Pada Ruas Jalan Poros Malino – Sinjai (the Role of Geological Aspects As the Cause of Landslides At Road Malino - Sinjai) *Bul. Geol. Tata Lingkung. (Bulletin Environ. Geol.* **22** 185–96
[6] Regmi A D, Yoshida K, Dhital M R and Pradhan B 2014 Weathering and mineralogical variation in gneissic rocks and their effect in Sangrumba Landslide, East Nepal *Environ. Earth Sci.* **71** 2711–27
[7] Lacroix P, Berthier E and Maquerhua E T 2015 Earthquake-driven acceleration of slow-moving landslides in the Colca valley, Peru, detected from Pl??iades images *Remote Sens. Environ.* **165** 148–58
[8] Barkey R, Nursaputra M, Mappiase M F, Achmad M, Solle M and Dassir M 2019 Climate change impacts related flood hazard to communities around Bantimurung Bulusaraung National Park, Indonesia *IOP Conf. Ser. Earth Environ. Sci.* **235** 1–12
[9] Solle M S and Ahmad A 2016 Landslides Intensity on River Morphology of Jeneberang Watershed after Collapse of Caldera Wall at Mt. Bawakaraeng *Res. J. Appl. Sci.* **11** 874–8
[10] Purbandini, Pratama R and Susmiandri 2019 Application of GIS for the mapping of landslide-vulnerable areas by through android-based Analytical Hierarchy Process (AHP) method in Bantul Regency *IOP Conf. Ser. Earth Environ. Sci.* **245** 12008
[11] Sideng U, Maru R, Nyompa S, Arfan A, Malik A and Abidin M R 2018 Mapping and Zonation Level of Landslides Hazard and Risk Assessment: A Case Study of Enrekang Regency, South Sulawesi, Indonesia *EnvironmentAsia* **11** 149–63
[12] Rasyid A R, Sastrawati I, Syam S and Jaya F S 2012 Mitigasi daerah rentan gerakan tanah di kabupaten enrekang *Pros. Has. Penelit. Fak. Tek.* **6** 978–9
[13] Tarigan S D 2012 Methods for Delineating Degraded Land at Citarum Watershed, West Java, Indonesia *J. Trop. Soils* **17** 267–74

[14] BPS 2017 *Population in Enrekang Regency* (Enrekang, Sulawesi Selatan, Indonesia)
[15] KLKH 2017 Peta Penutupan Lahan Indonesia Tahun 2009 dan 2011 2017
[16] BMKG 2017 Data curah hujan tahun 2008-2016 untuk Kabupaten Gowa, Enrekang, Toraja Utara dan Luwu Timur (Rainfall Data in 2008-2016 for Gowa, Enrekang, North Toraja, and East Luwu District)
[17] RePPProT 1988 *Regional Physical Planning Programme fo Transmigration. Tinjauan Hasil-Hasil Tahap I Sulawesi* (Jakarta, Indonesia: Direktorat Bina Program dan Direktorat Jenderal Penyiapan Pemukiman Departemen Transmigrasi)
[18] Djuri and Sudjatmiko 1974 Geologic Map of The Majene and Western Part of The Palopo Quadrangles, South Sulawesi
[19] Desaunettes J 1977 *Catalogue of Landforms for Indonesia* (Bogor: Prepared for the Land Capability Appraisal Project at the Soil Research Institute)
[20] Chalise D and Kumar L 2019 Land Degradation by Soil Erosion in Nepal : A Review *Soil Syst.* **3** 1–18
[21] Reichenbach P, Busca C, Mondini A C and Rossi M 2014 The Influence of Land Use Change on Landslide Susceptibility Zonation : The Briga Catchment Test Site (Messina , Italy) *Environ. Manage.* **54** 1372–84
[22] Bhandari R 2010 Importance of earthquake induced landslides in landslide hazard mapping *SAARC Work. Landslide Risk Manag. South Asia* 81–90
[23] Solle M S and Ahmad A 2016 Identification of Soil, Rock and Tecto-Volcanism on Landslides in Tondano Watershed *J. Geol. Resour. Eng.* **4** 271–82
[24] Kishore N, Anil T and Misra K 2019 Landslide vulnerability assessment in Gangotri valley glacier Himalaya through GIS and remote sensing techniques *Appl. Water Sci.* **9** 1–10
[25] BNPB 2019 Data Informasi Bencana Indonesia (DIBI) *https://bnpb.cloud/dibi/laporan5*