Preliminary Study of Landslide Hazard in Kutai Kartanegara Regency, East Kalimantan using Digital Elevation Model

To cite this article: S M Polawan and N A Raharjanti 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1071** 012007

Preliminary Study of Landslide Hazard in Kutai Kartanegara Regency, East Kalimantan using Digital Elevation Model

S M Polawan[1*] and N A Raharjanti[1].

[1]Undergraduate Program of Geological Engineering, Faculty of Science and Engineering, Universitas Muhammadiyah Kalimantan Timur, Samarinda, Indonesia.
*Corresponding author's e-mail : ssm340@umkt.ac.id

Abstract. The Kalimantan Island is part of the Sundaland crust, namely the Eurasian Continental Plate. The plate is moving to the southeast colliding with the Indo-Australian plate which is moving north. Whereas for Kutai Kartanegara Regency in the Kalimantan Island position is far from the collision zone, so it is relatively stable tectonically. This is important to research that is, due to tectonic processes that occurred earlier, resulting in the formation of geological structures, especially faults. The purpose of the study was to determine the morphotectonic and landslide hazards in the Kutai Kartanegara Regency, where this research was carried out quantitatively with data collection techniques, then analyse landslide hazards based on data; DEM (Digital Elevation Model) including the slope, slope direction, and slope length for vulnerability analysis, geological data from Regional Geological Maps, which include rock formations, distances from faults data and administrative boundary spatial data in the form of vector GIS for the preparation of landslide hazard maps. The result showing Kutai Kartanegara predominantly categorized as moderate to high hazard zone. The low hazard zone covering 9.88% area, moderate hazard zone covering 35.81% area, and 54.31% area is high hazard zone of landslide. The analysis showing that the hazard of the research area consist predominantly sedimentary rocks and controlled by structural geology identified as thrust fault, strike slip fault, and fold which include in Anticlinorium Samarinda. Those lithology and geological structure features along with the slope are identified as controlling factor to the landslide hazard in the research area.

1. Introduction

Indonesia is a country with multiple disaster threats, but Indonesia is also a place for disaster research or (disaster laboratory) so that Indonesia has a very large disaster potential, because it's traversed by a row ring of fire. The background in this study is a need for an analysis related to spatial geomorphological aspects as an early stage in disaster mitigation, identifying the potential and vulnerability disasters caused at the research focus location, namely Kutai Kartanegara regency.

Kutai Kartanegara regency based on geographic and administrative is included in East Kalimantan Province. Kutai Kartanegara Regency is located at 115°26'28" East Longitude – 117°36'43" East Longitude and 1°28'21" North Latitude–1°08'06" South Latitude. Kutai Kartanegara is surrounded by Malinau Regency in the north, Kutai Timur Regency and Makassar Strait in the east, North Penajam Pasir and Balikpapan City in the south, and North Kutai Regency in the West. The land area of the Kutai Kartanegara Regency is around 27.263.10km^2 or 2.726.310 Ha around 12% from the total area of East Kalimantan Province, meanwhile the water area is 4.097 km [1].

Kutai Kartanegara Regency was divided into 18 districts and 237 villages. The districts in Kutai Kartanegara Regency are Kecamatan; Samboja, Muara Jawa, Sanga-Sanga, Anggana, Muara Badak, Marang Kayu, Tenggarong Seberang, Loa Janan, Loa Kulu, Tenggarong, Sebulu, Muara Kaman, Kota Bangun, Muara Muntai, Muara Wis, Kenohan, Kembang Janggut, dan Tabang. Kutai Kartanegara Regency has many rivers that spread in all district and become the main transportation facilities along with land transportation. The biggest river is Mahakam River about 920 km long.

The disaster potential that can happen ini Kutai Kartanegara Regency can be divided into geological disaster including landslide, and hydrometeorology disaster including, flood, drought, forest fires, and extreme weather [2]. From the description above, the problem formulation that becomes the limitation of the research is disaster geomorphology one of the approaches in disaster studies. Disaster geomorphology examines aspects of landforms, processes, and results of physical processes that have the potential and can cause disasters. Sustainable development requires spatial data and information about the potential for landslides and information dissemination to the public about disasters.

2. Regional Geology

Kalimantan is a part of Sundaland and a part of Eurasia [3]. Eurasian plate moves to the southeast and collide with Indo-Australian plate which moves to the north. The direction of Sulawesi movement reversed causing the direction from north – south become northwest – southeast and now have the direction west – east. The subduction zone located in western Sumatra, southern Java extends to Bali and Nusa Tenggara. The Position of Kalimantan is far from these subduction zone, therefore Kalimantan relatively stable in tectonic, but due to the tectonic activity which happened beforehand faults were formed in the Island [4].

Physiographic condition of Kutai Kartanegara Regency varies and can be categorized into ten (10) physiographic units namely: (1) Beach Sand Sediment, (2) Tidal Swamp, (3) Alluvial Plain, (4) Meander Belt, (5) Swamp, (6) Alluvial Valley, (7) Terrain, (8) Plain, (9) Hill, and (10) Mountain. Based on [5, 6] physiographic classification Kalimantan divided into five zones, namely Kutai Basin Zone, Kuching Highland Zone, Schwanner Block, Pasir Basin Zone, and Pathenosphere Block (Figure 1).

The physiographic characteristic of East Kalimantan is part of Tertiary Kutai Basin located in southern of Kuching Highland. The Basin was divided from Barito Basin by tectonic called paternoster cross high. The stratigraphic characteristic of Kutai Basin consists of sediments that deposited from early Tertiary and filling the basin to the east [7]. The earlier sediment deposited in the west side of the basin about 1000 – 2000 m in depth, than moved toward east continuously and increase in depth (Figure 2).

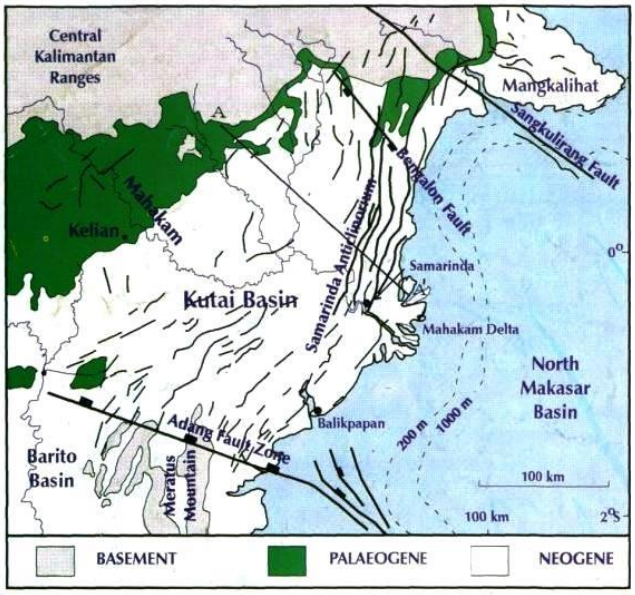

Figure 1. Regional geology of the Kutai Basin in [7].

3. Methodology

The aim of the research is to identify morphology-tectonic and the hazard of landslide in Kutai Kartanegara Regency. The data was collected from study literature and analysed with quantitative method to identify the zone of the landslide hazard. Through quantitative predictions using statistical combination factors (Probabilistic) or means predicting events that have occurred in the past in an area that has not experienced an event but has similar conditions to an area that has experienced it before, a probabilistic method is used as the approach formula. The location of the research was Kutai Kartanegara Regency and research was done in November 2020 to February 2021. The process of the research that done presented in Figure 2 explains the sequence of the hazard index analysis process from two data, namely the landslide potential zone (slope >15% or 8.51° and the runout potential zone (angle threshold min. 8.51°) for result area delineation and class hazard and then hazard index. The final result of the landslide hazard in the research area then presented as landslide hazard map to identify the area distribution of the hazard.

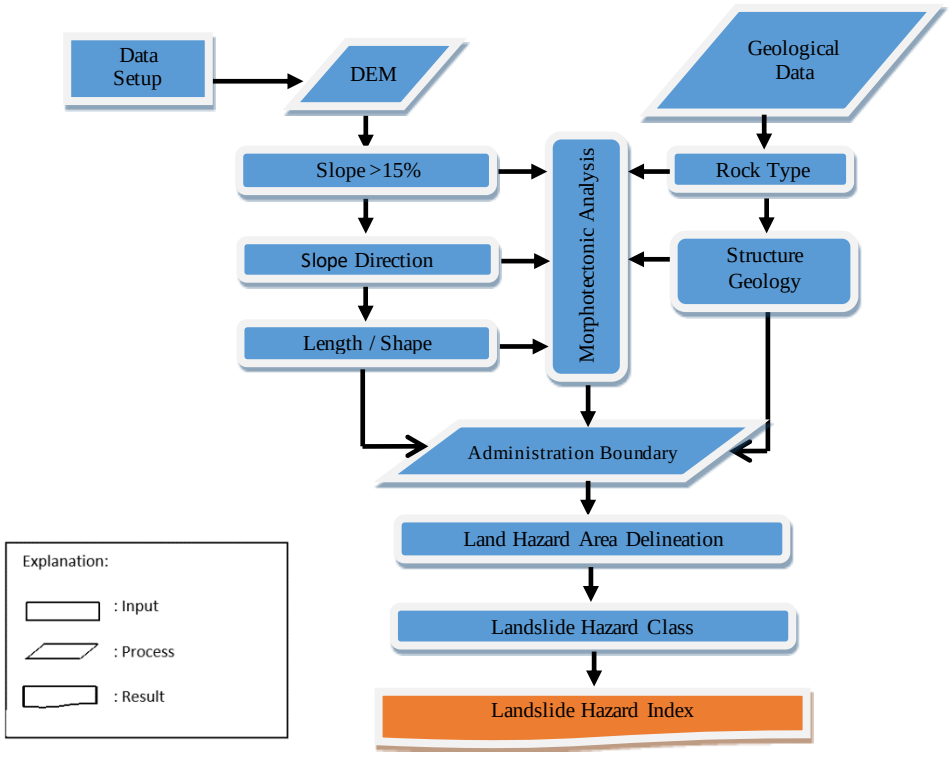

Figure 2. The process design to produce landslide hazard map based on DEM and Geological Data.

3.1. Quantitative data collection

The data collected in this research categorized as primary and secondary data. The secondary data used in the research to analyse the landslide hazard are (1) DEM to identify the slope, the direction of the slope, and the dimension of the slope to analyze the vulnerability to the landslide. The data was collected from the official website DEMNAS [8]. (2) Geology Data taken from Regional Geology Map [9] including rock formation and the structure geology, and (3) spatial data of the administrative border to delineate the area of the research. The primary data are strike dip and lithology from regional data and confirmed by field observation of landslide affected area.

3.2. Hazard analysis

Hazard analysis method is done by identifying the areas that have potential in slope failure, calculating the probability of the event, and interpretation of the landslide that happen. All of these process was analyze using software ArcGIS Dekstop-ArcMap.

The analyses of the data that done are:

- Morphotectonic analyisis including historical geology,
- Calculation of the parameters, including determining the score and weight of the data that already collected. The classification, score determination, and weighting using parameter for producing landslide hazard map with deterministic method based on Technical Module to Arrange the Analysis of the Landslide Disaster Risk (*BNPB*) [10].
- Delineating the border of morphology unit and administrative border to identify the potential area of landslide.
- Calculate the landslide index. The formula that used based on *BNPB* [10]:

$$\text{Landslide hazard zone} = (\text{weight} \times \text{score})\ \text{landslide potential zone} + (\text{weight} \times \text{score})\ \text{runout potential zone} \quad (1)$$

The values of the indexes from formula (1) then divided in to three: (1) the lowest hazard have the value of the index ≤0.333, (2) the moderate index have value $0.333 < H \leq 0.666$ and (3) the high index of hazard have value $H > 0.666$ [10].

4. Results

The geomorphological analysis divided the Kutai Kartanegara regency into four category of the slope from the flattest to steep respectively: <15% (gentle slope), 15 – 30% (moderate steep slope), 30 – 50% (steep slope), and 50 – 70% (extremely steep slope). The geomorphological map (Figure 3) showing the research area predominantly categorized in moderately steep slope area that occurs in the northwest and southeast part. Relatively more plain area which categorized as gentle slope area concentrated in the middle of the Kutai Kartanegara Regency.

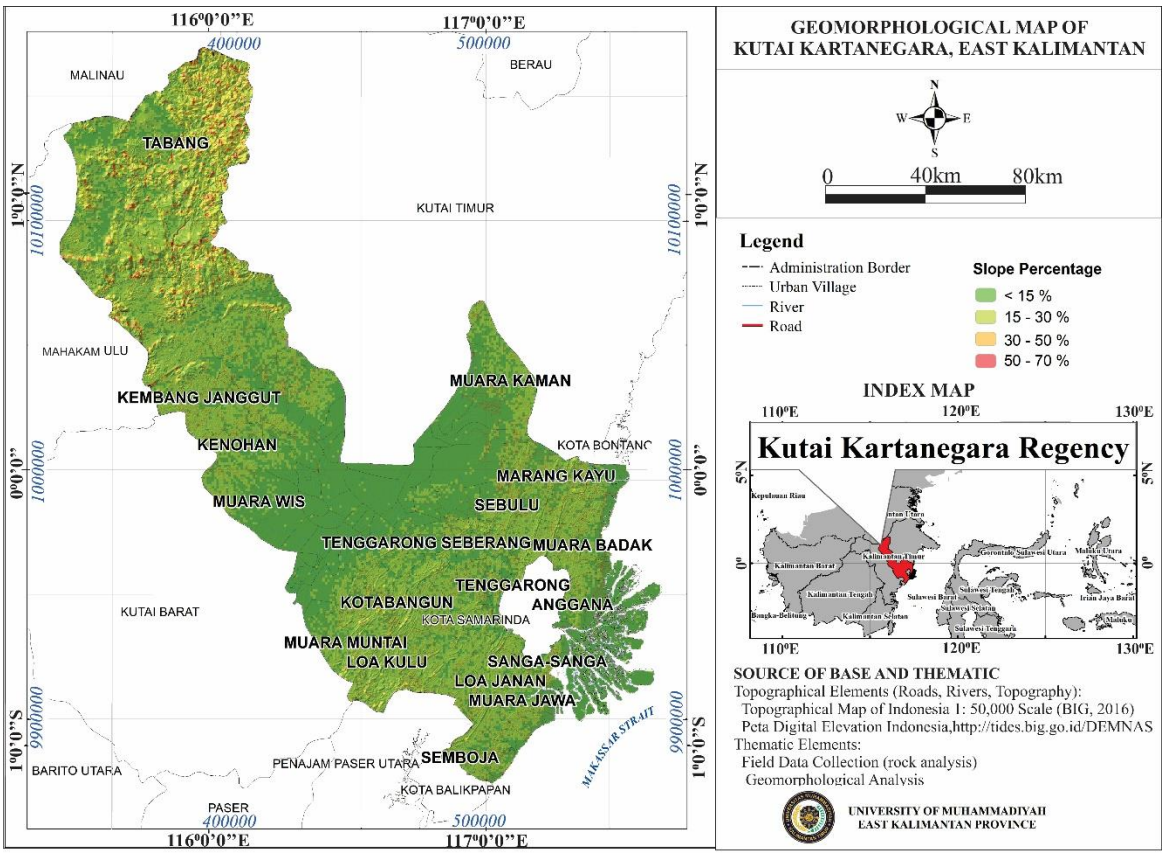

Figure 3. The geomorphological map in Kutai Kartanegara Regency

The landslide hazard analysis conducted combining the geomorphological (DEM) and geological features. Based on the analysis that was conducted the landslide in the Kutai Kartanegara Regency divided into 3 categories namely low, moderate, and high (Table 1). The area that categories as low hazard class identified only Anggana districts which the area of this low hazard zone is ±76.469Ha. The moderate hazard zones occupied in most of the districts including Kembang Janggut, Kenohan, Kotabangun, Loa Janan, Marang Kayu, Muara Badak, Muara Jawa, Muara Kaman, Muara Muntai, Muara Wis, Sanga-Sanga, Semboja, and Kota Tenggarong with total area ± 901.841Ha. There are only four districts categorized as high landslide hazard class, which are Loa Kulu, Sebulu, Tabang, and Tenggarong Seberang with the total area is ± 932.696Ha. Even though there are only four districts categorized as high landslide hazard, these class also occupied the other hazard class area. The result of the calculation showing the high landslide hazard class in the Kartanegara Regency have the largest distribution with the total area is ±1,367.936Ha.

Table 1. The result of landslide hazard base on districts in Kutai Kartanegara.

No	District	Area of Each Hazard Class (Ha)			Hazard Class
		Low	Moderate	High	
1	Anggana	76,469	23,373	6,121	Low
2	Kembang Janggut	6,367	79,582	102,111	Moderate
3	Kenohan	4,450	82,231	35,195	Moderate
4	Kotabangun	50	46,245	44,405	Moderate
5	Loa Janan		34,219	28,652	Moderate
6	Loa Kulu		45,004	124,448	High
7	Marang Kayu	1,564	66,989	44,415	Moderate
8	Muara Badak	17,479	28,989	14,840	Moderate
9	Muara Jawa	18,480	18,689	8,232	Moderate
10	Muara Kaman	63,503	225,175	45,272	Moderate
11	Muara Muntai	22,428	38,382	24,890	Moderate
12	Muara Wis	31,027	77,078	40,633	Moderate
13	Sanga-sanga	1,395	8,511	2,082	Moderate
14	Sebulu		22,778	44,320	High
15	Semboja	5,576	41,824	23,686	Moderate
16	Tabang		35,963	726,832	High
17	Tenggarong		12,416	14,671	Moderate
18	Tenggarong Seberang		14,406	37,096	High
	Kutai Kartanegara	**248,787**	**901,841**	**1,367,936**	**Moderate**

The comparison between the slope class and hazard class is made in the Table 2. From the comparison, the area that has more plain slope (<15%) or gentle sloping the Kutai Kartanegara Regency also has lowest hazard class which identified in Anggana sub-district. The area with moderately steep and steep slope also associated with moderate hazard occupied most of the sub-district in the research area. The extremely steep slope (50 – 70%) associated with high hazard class which has distribution in Loa Kulu, Sebulu, Tabang, and Tenggarong Seberang.

The geological analysis was done by collecting regional data and confirmed with field observation. The geological map in the Figure 4 showing Kutai Kartanegara Regency consists of three types lithology namely volcanic rocks, sedimentary rocks, and alluvial deposit. The sedimentary rocks have the largest distribution which spread throughout the research area. The volcanic rocks occur concentrated in the northwest research area. The youngest lithology unit is alluvium deposit concentrated in the middle of the research area and delta at the southeasternmost of Kutai Kartanegara Regency.

Table 2. The result slope class and hazard class.

Slope	Class	Hazard Class	Sub-district
<15%	Gentle Sloping	Low	Anggana
15-30%	Moderately Steep	Moderate	Kembang Janggut, Kenohan, Kotabangun, Loa Janan, Marang Kayu, Muara Badak, Muara Jawa, Muara Kaman, Muara Muntai,
30-50%	Steep		Muara Wis, Sanga-Sanga, Semboja, Kota Tenggarong.
50-70%	extremely Steep	High	Loa Kulu, Sebulu, Tabang, Tenggarong Seberang

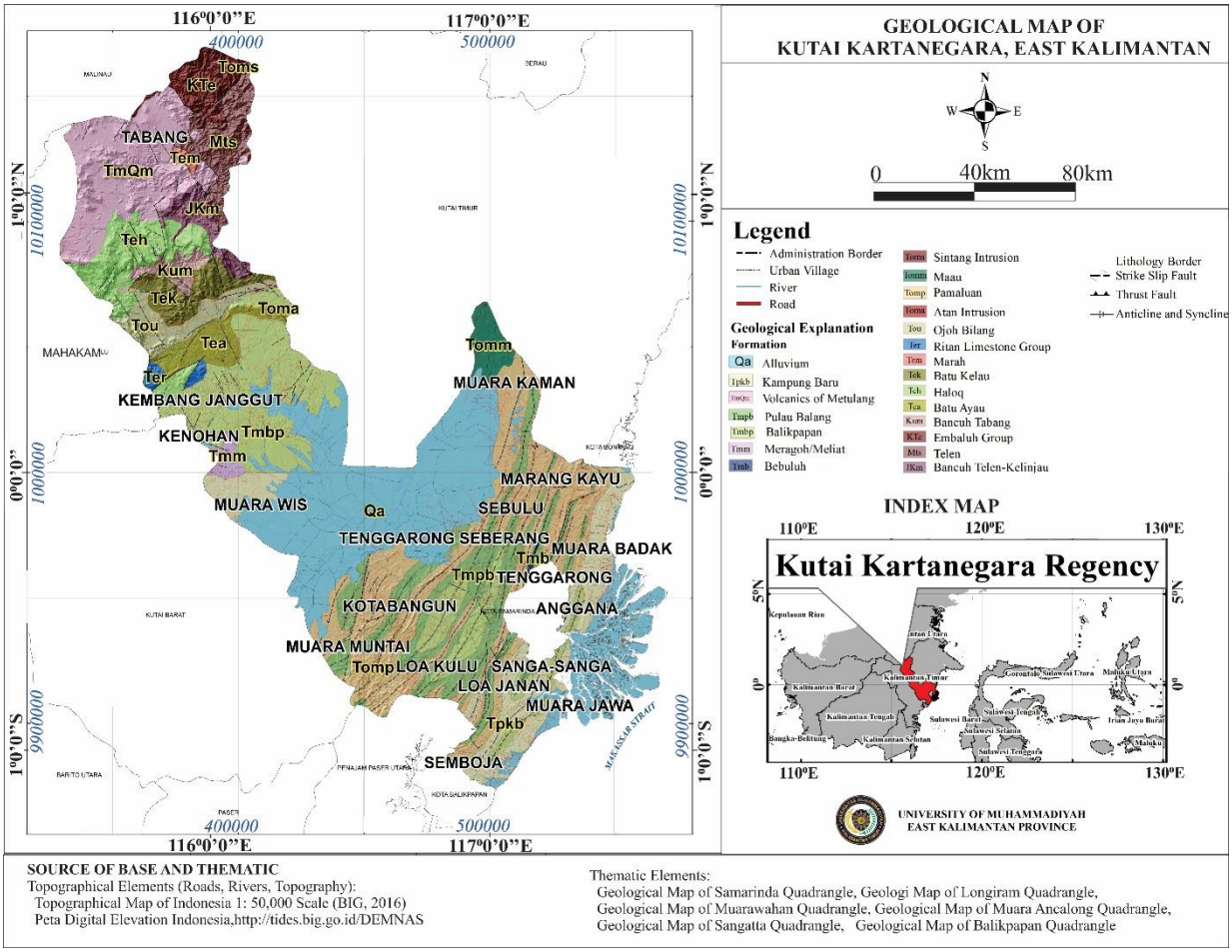

Figure 4. The geological map of Kutai Kartanegara Regency.

The analysis of geological factors of the landslide including lithological characteristics and geological structure is made. The resumed analysis in the Table 3 showing the landslide hazard classification calculated from the lithology, the distance from the fault as the discontinued plane, and the length or the dimension of the slope.

Table 3. Data analysis of the distance of faults and length of slope.

Districts	Landslide Hazard Classification	Description Area				
		Lithology	Fault Distance (m)	Slope Direction	Slope Dimension (length) (m)	Total Hazard Area (Ha)
Anggana	Low - High	Alluvial (F: Qa) Sediment (F: Tpkb, Tmbp, Tomp)	> 400	Plain- Southeast	< 200 - 500	105.963
Kembang Janggut	Low - High	Alluvial (F: Qa) Volcanic (F: Tea, Tmm) Sediment (F: Ter, Tmbp)	> 400	Plain - Northeast	< 200 - 1000	188.060
Kenohan	Low - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tpkb) Volcanic (F: Tmm)	> 400	Plain - Southwest	< 200 - 1000	121.876
Kota Bangun	Low - High	Alluvial (F: Qa) Sedimen (F: Tmpb, Tomp)	> 400	Plain - Northwest	< 200 - 1000	90.700
Loa Janan	Moderate - High	Sediment (F: Tmbp, Tmpb, Tomp, Tpkb)	> 400	Plain - Northwest	< 200 - 500	62.871
Loa Kulu	Moderate - High	Sediment (F: Tmbp, Tmpb, Tomp)	> 400	Strike slip - Southeast	< 200 - 1000	169452
Marang Kayu	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmb, Tmpb, Tomp, Tpkb)	> 400	Strike slip - Northwest	< 200 - 1000	113.004
Muara Badak	Low - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tomp, Tpkb)	> 400	East - North	< 200 - 1000	61.294
Muara Jawa	Low - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tomp, Tpkb)	> 400	East - North	< 200	45.401
Muara Kaman	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmpb, Tomp)	> 400	East - North	< 200 -> 1000	333.950
Muara Muntai	Low - High	Alluvial (F: Qa) Sediment (F: Tmpb, Tomp)	0 -> 400	East - North	< 200 -> 1000	85.700
Muara Wis	Low - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tpkb, Tomp) Volcanic (F: Tmm)	0 -> 400	East - North	< 200 -> 100	148.737
Sanga-Sanga	Low - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tpkb)	0 -> 400	Strike slip - North	< 200	11.988
Sebulu	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tomp)	> 400	Datar - Utara	200 -> 1000	67.097
Semboja	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tomp, Tpkb)	> 400	Strike slip - North	< 200 - 500	71.086
Tabang	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmbp, Toma, Tou, Tek, Jkm, Kte, The, Tem, Ter, Kum, Mts, TmQm, Toms) Volcanic (F: Tea)	0 -> 400	Strike slip - North	< 200 -> 1000	762.795
Tenggarong	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tomp)	0 -> 400	Strike slip - North	< 200 - 1000	27.086
Tenggarong Seberang	Moderate - High	Alluvial (F: Qa) Sediment (F: Tmbp, Tmpb, Tomp)	0 -> 400	Strike slip - North	< 200 - 100	51.502

F = Formation

The analysis of the landslide hazard supported by the stream flow map (Figure 5) of the Kutai Kartanegara Regency showing that the research area predominantly controlled by rectangular river.

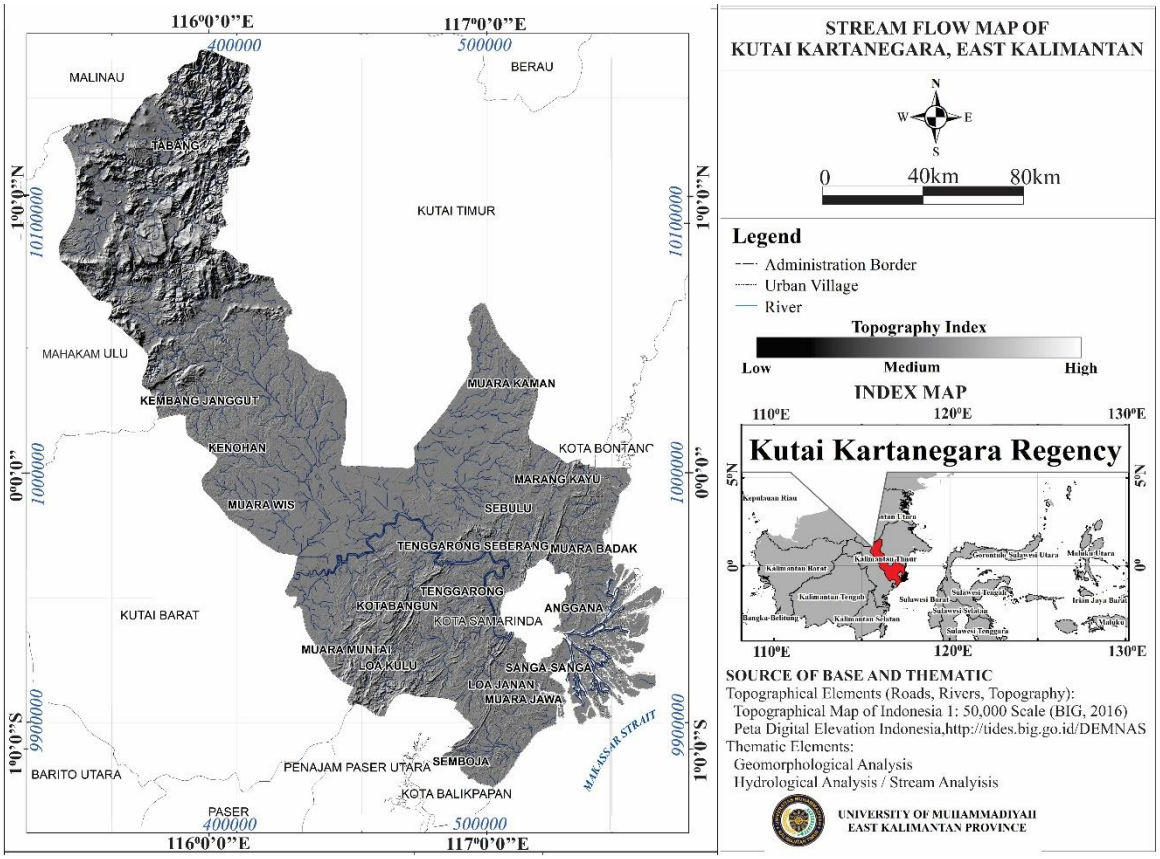

Figure 5. The stream flow map of the Kutai Kartanegara Regency.

The landslide hazard map is made to identify the distribution of the hazard in the research area. The landslide hazard index is analyzed from geomorphological and geological parameters which the steps explained in the methodology section. The landslide hazard map shown in Figure 6 the divided into three categories associated with the slope percentage that divided into four class namely:

- The green color, has slope class <15% (gentle slope) categorized as low hazard class only occurs in Anggana District.
- The yellow color, has slope class 15 – 30% (moderate steep slope) categorized as moderate hazard class, which occupied almost all the area in Kutai Kartanegara Regency.
- The orange color, has slope class about 30 – 50% (steep slope) and red color has slope class about 50 – 70% (extremely steep) categorized as high hazard index.

5. Discussion

Based on the result that shown on the geomorphological and geological map the geological structure has important role to the morphology of the Kutai Kartanegara Regency. The evidence of structural controls showed in the topographic lineament which has characteristic high topography, elongated, than cut suddenly. Another morphological feature that shows structural control is the rectangular type drainage pattern which have characteristic the smaller drainage make relatively perpendicular to the main drainage (Van Zuidam) [11] (Figure 5). Based on classification of slope (Van Zuidam) [11], Kutai Kartanegara covered with 35.41% of gently sloping area, 44.71% area is categorized as moderately steep area, 4.94% categorized as steep area, and 0.14% as extremely steep area. Kutai Kartanegara area is divided into 3 zones of landslide hazard based on BNPB classification [10] which are low hazard zone covering 9.88% area, moderate hazard zone covering 35.81% area, and 54.31% area is high hazard zone of landslide (Figure 6).

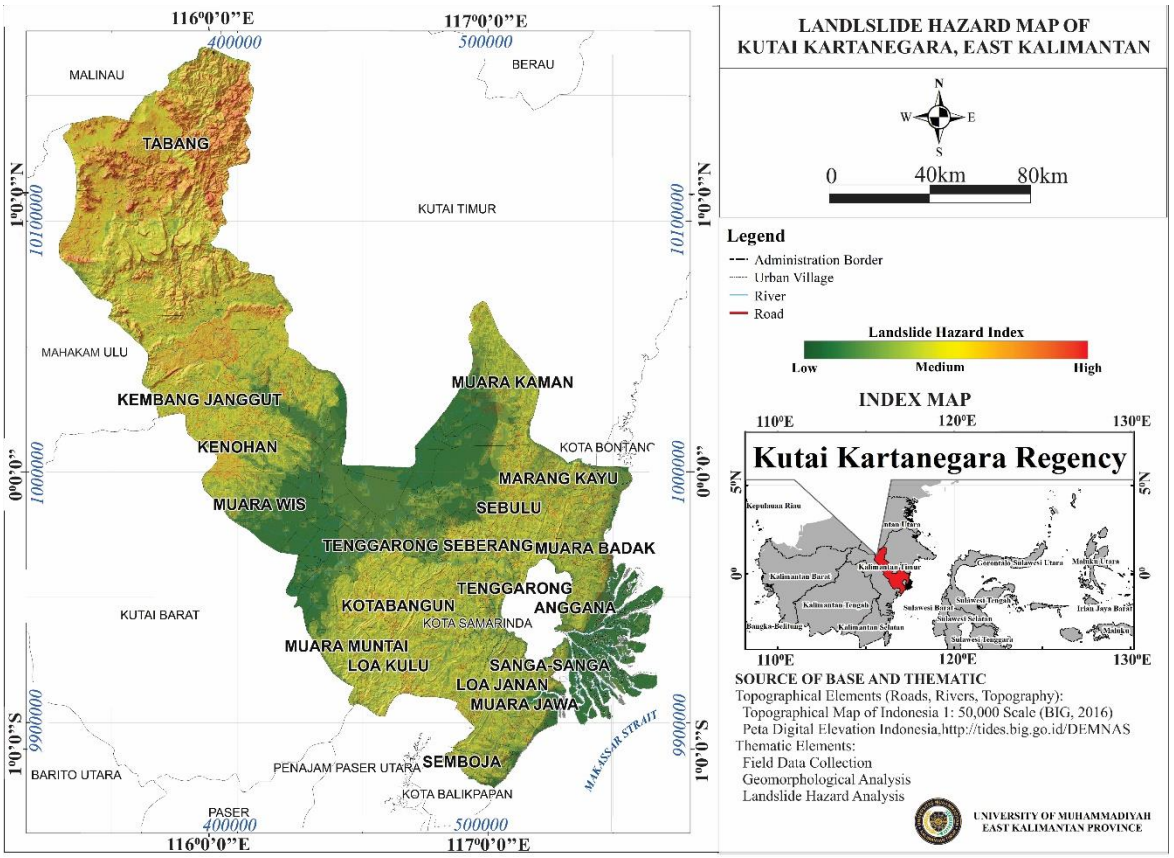

Figure 6. The landslide hazard map of the Kutai Kartanegara Regency.

From the result, it can be identified that the landslide in the research area is not just triggered by the slope, but also geological characteristics including lithology and structural geology. It corresponds to two factors that influence the landslide stated by Karnawati (2005) which are conditioning factors and triggering factors [12]. The conditioning factors are the components in the slope that can cause landslide or soil movement namely morphology, lithology type and stratigraphy, geological structure, geohydrology, and land use [12]. BNPB divided lithology into three types: alluvial, sedimentary rocks, and volcanic, and each lithology has different strength or resistivity so it will influence their resistance to other factors which are structural geology as internal factor and climate as external factor.

The area presentations of each lithological type in the Kutai Kartanegara Regency are alluvial occupied 25.29% area, sedimentary rocks occupied 60.04% area, and volcanic rocks occupied 14.61% area. From those data, it can be identified that the research area predominantly consists of sedimentary rock. The sedimentary rocks considered have low resistance to the pressure from geological structure which has destructive characteristic. The evidence showed in the geological map of the research area in the Figure 4 most of area of the Kutai Kartanegara effected by geological structures, only at the middle of Kutai Kartanegara the geological structure cannot be detected due to covered by alluvial deposit. The geological structures that developed in research area are thrust fault, strike slip fault, and fold which included in Anticlinorium Samarinda [9].

6. Conclusion & Recommendation

Kutai Kartanegara Regency is area that relatively prone to landslide. The analysis of landslide hazard, the research area divided into three landslide hazard class namely low, moderate, and high hazard class. The low hazard zone only identified in Anggana district. The moderate hazard class has the widest spread in the research area including in district Kembang Janggut, Kenohan, Kotabangun, Loa Janan,

Marang Kayu, Muara Badak, Muara Jawa, Muara Kaman, Muara Muntai, Muara Wis, Sanga-Sanga, Semboja, and Kota Tenggarong. The high hazard class has the largest area, but only four districts categorized in this class namely Loa Kulu, Sebulu, Tabang, and Tenggarong Seberang. The factors control the landslide hazard are the slope along with geological features such as geological structures and lithology. The area with steeper slope associated with higher hazard class and vice versa. Kutai Kartanegara dominated consists of sedimentary rocks which has relatively low resistance to the pressure from geological structure that destructive and make the landslide hazard class higher.

The mitigation of the potential landslide disaster that may happen in the research area is recommended to be done. The more data analysis such as vulnerability and capacity to calculate the landslide risk of the research area is suggested. The risk analysis will identify the potential loss that may happen due to landslide disaster. The risk management is one of methods in disaster mitigation.

References

[1] RPIJM 2018 *RPIJM Kabupaten Kutai Kartanegara*. Kutai Kartanegara.
[2] Syamsidar, S M and Alam F 2019 *Memahami Bencana Banjir dan Longsor* (Samarinda: RV Pustaka Horizon)
[3] Moss S, Chambers J, Cloke I R, Nas D S 1997 *New observations on the sedimentary and tectonic evolution of the Tertiary Kutai Basin, East Kalimantan*
[4] Satyana A H 1999 *Kalimantan An Outline of The Geology of Indonesia* (Indonesian Association of Geologist) p.69-89
[5] Van Bemmelen R W 1949 The Geology of Indonesia Vol IA (The Hague: Netherlands, Govt. Printing Office) p.732.
[6] Nuay 1985 Kerangka Tektonik Pulau Kalimantan: *Peta Geologi Lembar Kotabaru*
[7] Allen G P and Chambers J L 1998 Sedimentation In The Modern and Miocene Mahakam Delta (Indonesia: IPA)
[8] https://tanahair.indonesia.go.id/demnas/#/ accessed 19 April 2021
[9] Supriatna, S. Sukardi, R, and R. Rustandi. (1995). Peta Geologi Bersistem, Lembar Samarinda, Kalimantan sekala 1:250.000, Pusat Penelitian dan Pengembangan Geologi Bandung.
[10] Badan Nasional Penanggulangan Bencana 2019 *Petunjuk Teknis Kawasan Rawan Bencana Tanah Longsor* Jakarta
[11] Van Zuidam (1985). A*erial Photo – Interpretation in Terrain Analysis and Geomorphologic Mapping*, The Hague: Netherlands, Smith Publisher
[12] Karnawati, D. (2005). Bencana Alam Gerakan Massa Tanah di Indonesia dan Upaya Penanggulangannya, Jurusan Teknik Geologi Fakultas Teknik Universitas Gadjah Mada, Yogyakarta

Acknowledgments

Spirit of Muhammadiyah for science, gratefulness for UMKT Rector, research partner, and especially experts team on the Samarinda City disaster have provided input and case samples so that they can be applied in the Tenggarong city area, finally hopefully we can fight together again in more challenging research.