Land Use Change on Potential Landslide Vulnerability in Palolo Sub-district Sigi Regency

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ABSTRACT

Natural damage as a result of changes in land use can trigger erosion, landslides, and floods that impact the social and economic life of the population. This study aims to determine the large extent of land-use change that occurred in the District of Palolo within 13 years (2003-2016), as well as determine the Potential for landslides in the District of Palolo due to land-use changes that occur. The research location is in the District of Palolo, Sigi Regency. Research data included LANDSAT 8 imagery, RBI Palolo map, DEM slope data, rainfall, geological type, oil type, and population density. The method of data collection is done by indirect observation and calculation by Geographic Information System (GIS) analysis, as well as using the Quantum GIS application and documentation study. The method of data analysis is done using image interpretation analysis, scaling, Coding, overlay techniques, and des descriptive analysis. The results of the study show the land-use changes that occurred from 2003 to 2016 covered. 47,366.81 hectares of the total area of Palolo Subdistrict, which was 64,710.21 Ha or 73.2%. Areas with moderate and high levels of potential landslide disasters are more prevalent in areas that experience less intense land-use change (IC). The area referred to can be seen from the A2-KI-B1 land unit covering 18,013,279 ha or 38.02%, and the A3-KI-B1 land unit covering 10,491,693 ha or 22.15% of the total area that has changed, i.e., 47,366.81 ha.

1. Introduction

Land use activities often change the existing land use, such as the conversion of natural vegetation into built-up areas. These changes will have an impact on the shape and function of the land from the previous one. Forest land, for example, functions as a water catchment area and productivity, especially forest resources and ecosystem biodiversity. The decrease in the number of infiltration areas has an impact on changes in hydrological conditions, such as an increase in runoff or surface water, which can trigger natural disasters, namely floods and landslides, especially in mountainous areas that have sloping land. Land use change, according to Muiz (2009) in Landoala (2013), is a process that occurs from land use into another land use as a consequence or impact of population growth and changes in the socioeconomic structure of developing communities, the land cover index, especially forests in Indonesia for the period 2011-2015, is decreasing. The declining condition of forest cover is followed by the distribution and frequency of floods, landslides, droughts, and forest and land fires (Ministry of Environment and Forestry, 2016). Bakornas Penanggulangan Bencana (PB) (2007) concludes that disasters occur if there are threats that arise with existing vulnerability conditions. In simple terms, the relationship between threats and vulnerability can be described as follows.

Threat + Vulnerability = Disaster

Hirnawan (1994:1) understands landslide as one of the dynamic system behaviors of slope stability of hilly morphology in a geological mandala that is integrated with its physical environment. The system is scattered as macro zones of landslide disaster with its level in a certain area, better known physically in the field as slope body morphology, having stability or safety factor (FS) changes determined by the interaction and interrelation of factors involved. The purpose of this study is to determine the extent of land use change that occurred in the Palolo sub-district from 2003 to 2016. The next objective is to determine the physical and social conditions of land use change that affect the level of potential landslide vulnerability in Palolo Sub-district, Sigi Regency.

2. Method

2.1 Type of Research

This research is a type of descriptive combined qualitative and quantitative research because the analysis uses qualitative data and quantitative data. This type of descriptive research aims to collect data or information to be compiled, explained, and analyzed.

The geographical approach used is the spatial approach, which is an analysis that emphasizes the existence of space with regard to the elements and the process of space formation. The spatial approach is always related to the temporal dimension; in this study, there are two points of time used as the basis for analysis, namely the period between 2003 and 2016.

2.2 Location and time of research

The location of the research conducted was in Palolo Sub-district, Sigi Regency. The time used in research was started at the time of initial observation and initial data collection related to disaster conditions and an overview of the community of Palolo District, namely from February 2017 to February 2018.

2.3 Data Types And Sources

The types of data used in this research are primary data and secondary data. Primary data is data

obtained directly during observation or from the community at the research location. Secondary data is obtained from various sources or agencies related to research needs. Secondary data was taken from various sources, including the Village Head's office, Palolo Sub-District Office, Sigi Regional Disaster Management Agency (BPBD), Central Sulawesi Bappeda, Central Sulawesi Public Works

Office, Library, and literature from various sources, including books, journals, documents, newspapers, and internet web pages.

Secondary data used in this research are literature data, Landsat TM 8 image data, rainfall data, disaster recapitulation data, slope map (topography), soil type map, and RBI map including sheet 2114-431 Makmur; sheet 2114-411 Wongkodono, sheet 2114-433 Bunga; sheet 2014-644 Bora; sheet 2114-434 Bulu Masomba; sheet 2014-64 Maranat, as well as documentation of landslide disaster in Palolo sub-district.

2.4 Re-search Variables

The variables used in this study are land use change as the influencing variable and landslide potential as the influencing variable. Physical and social land conditions that have implications on landslide potential are used as indicators of the influenced variable. Indicators of physical aspects include slope, rainfall, rock type, and land cover type. Indicators on social aspects are related to the characteristics and behavior of the community in utilizing and cultivating the existing land. The two variables used will show whether or not there is an influence or impact of land use change that occurred for 13 years on the condition of land with landslide potential in Palolo Sub-district, Sigi Regency.

2.5 Research Materials and Tools

The materials used in this study include:

- RBI map of Sigi sheet 2013, scale 1:250,000
- Palolo sub-district monthly/annual rainfall data 2013-2016
- Landsat TM 8 images in 2003 and 2016
- Palolo sub-district soil type map e. Slope map of Palolo sub-district
- Population data of Kecamatan Palolo g. List of interview questions

Tools are needed to process data and assist in observation activities as well as storing documentation of research activities, including Global Position System (GPS), Hardware (Laptop PC), QGIS software, Microsoft Word and Microsoft Excel software, Camera, and Stationery.

2.6 Data Processing and analysis analysis

Data processing is carried out with the data editing stage to adjust the data obtained so that the data remains focused on the research objectives. After that, the Coding stage. The data that has been obtained is then classified according to the instrument consisting of:

a. Attribute data from spatial analysis (mapping)
b. Observation, measurement (indirect observation), and field testing (land use) data
c. Socioeconomic data of the study area population

The data analysis carried out is Geographic Information System (GIS) analysis, namely map overlay and weighting system. In addition, Descriptive analysis is also used as a depiction of the results of the analysis in the study in detail and more clearly.

3. RESULTS AND DISCUSSION

3.1 Results

a. Geography of Kecamatan Palolo

Palolo sub-district, located at 0°58′53″-1°14′31″ N and 119°57′46″-120°21′26″ E, is one of the sub-districts in Sigi Regency. Sigi Regency has its capital in Bora, about 16 km from Palu City. Palolo sub-district is divided into 22 villages, and the sub-district government center is located in Makmur Village. The area of Kecamatan Palolo is 64,710.21 hectares or 12.05% of the area of Kabupaten Sigi. The largest village in this Kecamatan is Desa Sejahtera, with an area of 12,397 hectares.

Based on data from the Central Bureau of Statistics of Palolo Sub-district in 2016, the Population of Palolo Sub-district continues to grow. In 2013, the Population of Palolo Sub-district was 28,549 people, while in 2014, it increased to 28,888 people, and in 2015 to 29,183 people. The largest population was in Ueneni Village, with 2,793 people, while the lowest population was in Sarumana Village. The population of each village and the size of the village area in Kecamatan Palolo can be seen in Table 1 below.

Table 1 Area, Population, and population density per village of Palolo Sub-district

No.	Village Name	Area (Km)^2	Total Population	Populaction Density (people/km$^{2)}$
1	Lembant Ongoa	122,74	1.989	16
2	Ueneni	5,48	2.763	510
3	Tongoa	54,87	2.542	46
4	Happy	15,16	993	66
5	Grace	14,05	1.496	106
6	Pprosperous	123,87	956	8
7	Sintuvu	44,47	1.603	36
8	Ranteleda	3,63	855	236
9	Land of Hope	1,94	770	397
10	Berdikari	35,58	1.420	40
11	Fortune	36,20	1490	41
12	Ampera	3,17	1.009	318
13	Pprosperous	6,98	1.967	282
14	Petimbe	16,18	1.029	64
15	Kapiore	18,95	1.130	60
16	Flowers	23,64	1.113	47
17	Bobo	23,25	1.126	48
18	Baku Bakulu	31,32	1.444	46
19	Sigimpu	44,61	754	17
20	Karunia	-	1.224	-
21	Uerani	-	781	-
22	Saruman	-	699	-
	Total	**2015**	**29.153**	**29**

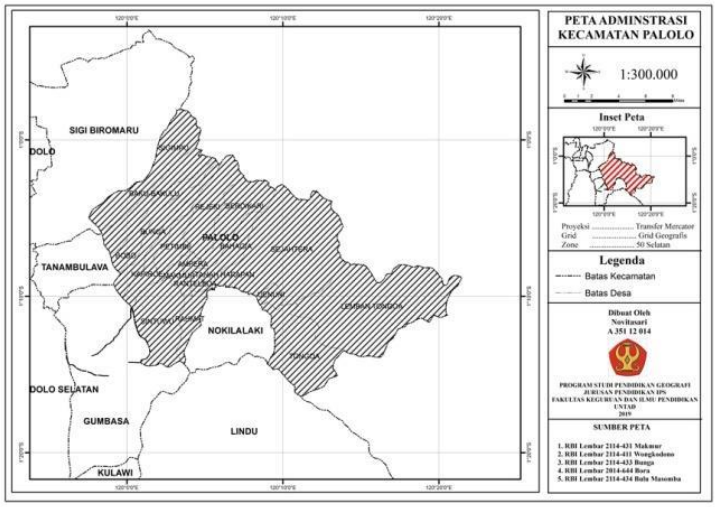

Fig.1. Administrative Map of Palolo Sub-district

b. Slope

The slope in the Palolo Sub-district, with a rather steep category, is the most extensive area compared to other categories in the Palolo Sub-district. The area of the flat category with a slope level of <8% is 13,580.010 Ha, the sloping category with a slope level of 8-15% is 15,711.732 Ha, rather steep with a slope level of 16-25% is 16,311.19 Ha, steep with a slope level of 26-25% is 12,780.602 Ha, and very steep with a slope level of >45% is 6,326.674 Ha. The level of slope in the Palolo Sub-district and its area can be seen in Table 2.

Table 2. Theslope of the Palolo Sub-district

No.	Slope class	Category	Score	Area (Ha)
1	< 8 %	Flat	1	13.580,0103
2	8 - 15 %	Ramps	2	15.711,7323
3	16 - 25 %	Somewhat Steep	3	16.311,1898
4	26 - 45 %	Steep	4	12.780,6017
5	> 45 %	Very steep	5	6.326,6744
		Total		**64.710,2085**

Source: Palolo Slope Map Analysis (2018)

c. Geological Type

The arrangement of rock types from each rock name in the Palolo Sub-district includes:

1. Tineba Mountain Rocks

The rock consists of hornblende andesite lava, basalt lava, quartz latite lava, and breccia. The andesite lavas are gray to greenish in color, porphyritic with plagioclase and hornblende as primary crystals; some of the plagioclase is transformed into crisis, calcite, and epidote, while some of the hornblende is transformed into chlorite. Basalt lavas generally have altered primary crystals, with basic masses of plagioclase, sericite, silicate, glass, and clay; quartz latite lavas are gray and porphyritic, showing altered minerals of clay, sericite, and chlorite. Andesite-basalt component breccia, up to 10 m in size moderately compressed. This unit was produced by the melting of a submarine volcano. Its age is thought to be middle-late Miocene because it is intruded by Pliocene-Pleistocene age granite. The unit is 500 Meters thick at maximum.

2. Lake Deposits

Lake deposits consist of clay, silt, sand, and gravel, showing horizontal layering, several meters to tens of meters thick.

3. Napu Formation

The Napu Formation consists of sandstone, conglomerate, siltstone with clay inserts, and peat; its age is thought to be Pliocene-Plistocene, with a shallow to brackish, marine depositional environment; the unit is less than 1000 m thick; it is thought to overlie the Puna Formation, and is unconformably overlain by lake deposits.

4. Granit Kambuno

Kambuno granite rocks consist of granodiorite granite types. Granite is white with black spots, medium to coarse grained, consisting of biotite granite, biotic horenblenda granite, microleukogranite and micro horenblenda-biotite granite. Granodiorite contains the mafic minera l horenblenda. The granite at the peg. Takolekaju shows an age of 3.35 million years (Sukamto, 1975), so the age of the Kambono granite is thought to be Pliocene.

5. Metamorphic rock complex

The Metamorphic Rock Complex consists of mica schists, amphibolite schists, gebes, and alabaster
(mainly Genes).

6. Gumbasa complex

The Gumbasa complex consists of the rock types Genesan granite, genes diorite, genes, and schists. The dominant geological type in the Palolo Sub-district is Kambuno Granite rock, with an area of 530,891,311.250 m2 or 53,089.13 Ha. The distribution of geological rock types in the Palolo Sub-district area is described in Table 3.

Table 3. Rock Types and Their Distribution Area in Palolo Sub-district

No.	Rock Type	Area (Ha)
1	Granit Kambuno	5.308,91
2	Napu Formation	162,13
3	Lake Deposits	755,87
4	Tineba Mountain Rocks	42,34
5	Gumbasa Complex	189,73
6	Metamorphic Rock Complex	12,04
	Total Area (Ha)	64.710,21

Source: secondary data of Geological map of Palolo sub-district (2016)

d. Soil type

The soil in the Palolo Sub-district consists of three soil types: lithosol, red-yellow Mediterranean, and red-yellow podzolic. The dominant soil type is yellow-red podzolic.

1. Lithosols

Lithosol soils are characterized by brown, yellow to reddish color, very shallow soil solum (<50 cm), variable soil color, loose structure, pair (coarse) texture, low BOT content, pH value, and nutrient content, and permeability vary but tend to be low (pH 4.5-5.0), and parent material from solid rock. Lithosols are also commonly called laterites (USDA soil designation).

2. Red yellow Mediterranean

Mediterranean soil, or another name for Alfisol, has a developmental profile, medium to shallow solum, and brown to red color. This soil type has a fairly thick solum layer; the texture is rather variable clay loam, with a stockyangular structure, while the consistency is firm to firm. The permeability of this soil is moderate, and the sensitivity to erosion hazard is moderate to great (USDA, in Mulyanto, 2013:12).

3. Yellow red podzolic

This soil is found in many areas that are choppy to hilly with an altitude of 0 to 400 meters above sea level. Podzolic Red Yellow soils or, commonly abbreviated as PMK, are the largest part of dry land in Indonesia that has not been used for agriculture. Podzolic soils are a group of soils that have developed profiles with clear horizon boundaries, red to yellow in color, with a Depth of one to two meters. These soils have a firm-to-lose consistency (the lower, the firmer), slow to medium permeability, blocky structure in the B horizon (the lower, the firmer), diverse textures, and clay-coated aggregates.

e. Rainfall

Rainfall in the Palolo Sub-district area is dominant with high rainfall, namely 2000 to 2500 mm/year. The area with high rainfall is 29,404.952 hectares. The area with moderate rainfall is 1500 to 2000 mm/year, covering an area of 20,700.924 hectares. Low rainfall with 1000 to 1500 mm/year covers 14,604.3327 hectares. The description of the rainfall area of the Palolo Sub-district can be seen in Table 4 and the following map.

Table 4. Rainfall of Palolo sub-district

No.	Rainfall (mm/year)	Category	Area (ha)
1	1000-1500	low	14.604,3327
2	1500-2000	M	20.700,9238
3	2000-2500	high	29.404,9520
Total			**64.710,2085**

Source: Palolo sub-district secondary rainfall data (2014)

f. Land use in 2003

Land use in Palolo Sub-district in 2003 was dominated by shrubland with an area of 22,923.22 Ha, then forest land with an area of 20,498.7 Ha, while the least land use was moor land with an area of 1,996.93 Ha. The area and type of land use of the Palolo sub-district in 2003 are described in Table 5 and can be seen in the following map.

Table 5 Land Use of Palolo Sub-district in 2003

No.	Land Use Genre	Area (m)^2	Percentage (%)
1	Forest	204.987.092,58	31,68
2	Garden	79.488.333,43	12,28
3	Shrubs	229.232.235,98	35,42
4	Tegal/Field	19.969.392,30	3,09
5	Sawah	17.854.366,77	2,76
6	Settlements	28.212.675,08	4,36
7	Clouds	67.357.989,26	10,41
	Total	**647.102.085,41**	**100**

Source: Landsat 8 Image Analysis results

g. Land Use in 2016

Land use in the Palolo sub-district in 2016 was dominated by shrubland covering an area of 17,799.15 Ha, followed by garden land covering an area of 12,614.87 Ha. The least land is rice fields, covering an area of 2,311.22 Ha, while there is land that cannot be detected because there is cloud cover on the processed image covering an area of 1,000.42 Ha or 1.55%. The area and type of land use in the Palolo sub-district in 2016 are described in Table 6 and can be seen in the attached map.

Table 6. Land use of Palolo sub-district in 2016

No.	Land Use Genre	Area (Ha)	Percentage (%)
1	Forest	14.681,4	22,69

2	Garden	12.614,9	19,49
3	Shrubs	17.799,2	27,51
4	Tegal/Field	11.211,4	17,33
5	Ricefiled	2.311,2	3,57
6	Settlements	5.091,8	7,87
7	Clouds	1.000,4	1,55
Total		64.710,2	**100**

h. Land Use Change

The total land area of Palolo Sub-district that has changed is 47,366.81 hectares out of the total area of 64,710.21 hectares. The area of each land use change of Palolo Sub-district is described in Table 6 and can be seen in the attached map, while the area and difference in land use in 2003 and 2016 are described in Table 7.

The land that experienced the most changes was forest land, consisting of forest land into gardens covering an area of 7,134.916 Ha and forest land into shrubs covering an area of 7,690.567 Ha. In contrast, the least experienced land change is from paddy fields to settlements covering an area of 28.341 Ha.

Table 7. Type and Area of Land Use in 2003 and 2016 Palolo sub-district

No.	Land Use Ttype	Land Area (Ha)		The difference in land area (m2)
		2003	2016	
1	Forest	20.498,71	14.681,35	5.817,36
2	Garden	7.948,83	12.614,87	4.666,04
3	Shrubs	22.923,22	17.799,15	5.124,07
4	Settelements	2.821,27	5.091,80	2.270,54
5	Sawah	1.785,44	2.311,22	525,78
6	Tegal/Field	1.996,94	11.211,38	9.214,44
7	Clouds	6.735,80	1.000,43	5.735,37
	Total	64.710,21	64.710,21	33.353,60

Source: secondary data (Landsat 8 Image Analysis results)

3.2 Discussion

a. Analysis of Landslide Potential of Palolo Sub-district

Landslide potential in this analysis is limited to 3 (three) classes of landslide potential based on the accumulated score or weight of each landslide parameter as the basis of the map. The results of the map overlay include the low-class area of 22,762.528 Ha, medium-class area of 14,844.245 Ha, and high-class area of 9,760.032 Ha. The area of landslide potential is described in Table 8 and on the map.

Table 8. Area Classification of Landslide Potential in Palolo Sub-district

No.	Classification of Landslide Potential.	Area (Ha)	Percentage (%)
1	Low	22.762,528	48,06
2	Medium	14.844,245	31,34
3	High	9.760,032	20,61
	Total	**47.366,806**	**100**

Source: Analysis of Landsat 8 imagery

b. Analysis of Land Use Change, Landslide Potential Level, and Population Density

The result of the analysis between land use change, landslide potential, and population density, it can
be concluded that the largest land unit is land with moderate landslide potential with less intensive land use change rate and low population density (A2-KI-B1) with an area of 18,013.279 ha. The land unit with the most potential landslide impact is A3-SI, covering an area of 1,762.588 ha with low population density.

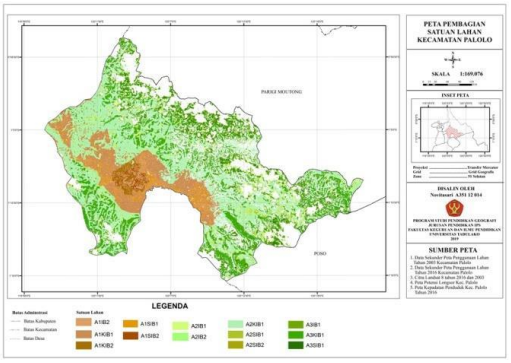

Fig.2 Land Unit Map

Fig 3. Residential Land Samples

Figure (2) shows Settlement Land Use in Ampera Village, Palolo Sub-district; this area is a sample of Land Unit Point A3-SI-B1. The A3 code indicates that the area has a high landslide potential level, while the SI code indicates the level of land use change that occurs is Very Intensive, and the B1 code indicates the area has a Low-density level. The very intensive land use change in this land sample can be seen in the increasing permanent residential land, while the surrounding land is still in the form of rice fields shrubs, and mixed plantations. The high rainfall condition and soil type in this topographically diverse area can also trigger the high level of landslide potential in this area.

It should be noted that this research was conducted before the natural disaster of earthquake, liquefaction, and tsunami in Palu, Sigi, and Donggala or better known as the PASIGALA Earthquake Disaster on September 28, 2018, which changed several landforms and land uses in the affected areas such as Palu City, Siigi Regency, and Donggala Regency. Palolo sub-district itself is located in Sigi Regency but is not among the areas with a major impact, especially on land change, as happened in Sigi Biromaru and Jono Oge sub-districts. Meanwhile, this research was conducted from mid-2017 to early 2018, so the results of the appearance of the image at the time of the research with the post-earthquake and after the earthquake did not experience significant changes.

4. ConclusionConclusion

The conclusions of this study include the extent of land use change in Palolo Subdistrict that occurred in the span of 13 years, from 2003 to 2016, was 47,366.81 hectares of the total area of Palolo Subdistrict of 64,710.21 hectares or with a percentage of 73.2%. The type of land use that has experienced the most changes is forest land use consisting of forest land into gardens covering an area of 7,134.916 hectares and forest land into shrubs covering an area of 7,690.567 hectares. While the

least experienced land change is from paddy fields to settlements covering an area of 28.341 Ha.

The results of the analysis of the influence of land use change using the map overlay technique in this study concluded that areas with low, medium, and high landslide potential levels are mostly found in areas with less intensive land use change (KI). The area in question can be seen from land unit A1-KI-B1 covering 5,218.710 ha or 11.2%, land unit A2-KI-B1 covering 18,013.279 ha or 38.02%, and land unit A3-KI-B1 covering 10,491.693 ha or 22.15% of the total area undergoing changes which are 47,366.81 ha. Meanwhile, the areas with high landslide potential, with intensive (I) and very intensive (SI) land use change are A3-I-B1 covering 2,589.965 ha or 5.4%, and A3-SI-B1 covering 1,762.588 ha or 3.72%. The results also show that all three land units with high landslide potential, whether less intensive, intensive, or very intensive, are located in areas with low population density. This means that the potential impact of landslides in the Palolo Sub-district is still relatively low, and the influence of land use activities is still low and has not really influenced the increase of landslide potential.

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