Flood Hazard Zoning-mapping in Sigi District Central Sulawesi Using Geographic Information System

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Original Research Article

ABSTRACT

Flooding is a disaster that every year occurred in Sigi District. The research purpose is finding out the flood hazard zoning in the Sigi District. The type of research is descriptive qualitative, with a region complex approach. The variables used are slope, soil type, rainfall, and land use. Data analysis used overlay, scoring, and layout techniques. The result showed that Mapping of flood hazard zoning in Sigi Districts is divided into four zones, namely; 1) Zone IV is a zone with a very high level of flood hazard category, this zone has an area of 24505.62 Ha or 4.82%; 2) zone III, namely the zone with Danger flood hazard category has an area of 131587.86 Ha or 25.91%; 3) zone II, which is in the less dangerous category has an area of 350605.76 Ha or 69.03%; zone I with the non-hazardous category has an area of 1193.62 Ha or 0.24%.

Keywords: Flood; mapping; flood hazard zone; geographic information system.

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1. INTRODUCTION

Flooding, one of the hydro-meteorological phenomena, is caused by heavy rainfall resulting in an abundant amount of runoff from upstream to downstream. Flooding, like a major natural disaster in Indonesia, occurs each year in the seasonal rainfall [1]. The major causes of flood disasters include heavy rainfall in the river catchments caused by climate change, blockage of drainages with refuse, inadequate drainage networks, and population increase in urban areas. The increase in population in urban areas needs more land for housings. They cause land-use change, conversion of natural vegetation, agricultural land, and wetlands. All of that can be threatening the lives of people living in flood vulnerable areas such as flood plains and river beds [2]. Flood harms human life, environments, and socioeconomics [2,3].

Sigi Regency is a district in Central Sulawesi Province [4]. The area is flood-prone. Floods that occurred in Sigi Regency from 2012 to 2018 were recorded as much 57 times. The highest frequency was in South Dolo District as much 13 times in the last seven years. In South Dolo, The recent flash flood was in Bangga Village which claimed casualties and damage to infrastructures such as breaking up village roads, buildings and many houses destroyed by floodwaters.

One of the weaknesses in anticipating floods is the lack of availability of detail comprehensive and up-to-date spatial data and information, both in the form of paper maps and digital maps (GIS) [5]. Reducing the impact of flood hazards need the availability of information and knowledge of areas that are vulnerable to flood hazards [6]. Inadequate information results in inaccurate handling. Identifying risk areas requires an overall picture of flood hazards to help build information infrastructure for emergency management in the area. Thus, one way to reduce the impact of floods is to ensure that all vulnerable areas are identified and adequate precautions are taken to ensure adequate preparedness, effective response, rapid recovery and effective prevention [7]. The hazards and losses can be prevented and reduced by providing reliable information such as flood hazard maps [6,8]. A flood hazard map is the first step to assess flood risk and to find out mitigation for residents in each flood zoning [9,10]. Mapping of flooded areas can be done using GIS techniques. GIS can be used to classify damage

information, monitor rapid damage assessments, and post-disaster census in-formation, site evaluation for reconstruction, as well as emergency response and efficient relief work [11,12,13,14].

2. MATERIALS AND METHODS

The type of research was descriptive qualitative. Mapping uses Geographic Information Systems (GIS) to manage spatial data (satellite imagery) in the Sigi Regency. The final result is a map of zoning disasters. The approach used in this study is a regional (regional) complex approach. The mapping unit is by overlapping several maps namely administration, slope, land, rainfall and land use maps.

A flood hazard map is obtained by combining imagery and field data. The images obtained are from USGS sources, the type of image is Landsat 8. The process of image interpretation is done using digitization on the screen, then scaling or weighting the map of the digitization results. The weighting is based on the influence of flood hazard criteria, namely rainfall, slope, soil type and land use. Each parameter will be assessed based on the division of values determined in three levels of categories, namely: high category with a value of 3, a medium category with a value of 2 and a low category with a value of 1. The assessment results are then weighed, the weighting measure is carried out based on the size of the factors that influence disaster risk. The value of the biggest factor to the weighted threat is higher and the smallest factor is the vulnerability to be weighed smaller. All parameters selected will be calculated total score and total weight score and overlap with spatial data (land type maps, rainfall maps, land use, slope maps, and administrative maps). Overlay maps are then printed again to determine flood hazard areas.

2.1 Criteria for Flood Hazards

The risk criteria used in this study are using interval class calculations. A threat score is given to determine the level of flood threat in an area, this score is based on the level of flood hazard. Categories for flood hazard are calculated based on frequency data using the Sturgess formula [15].

k = 1 + 3.3 log n
k = number of classes
n = amount of data / amount of data

The vulnerability criteria used are:

Rainfall: The purpose of rainfall assessment is to see the intensity of rainfall in Sigi Regency. The higher the rain, the higher the danger of flooding. Table 1 presents the rainfall scores.

Slope: The scoring on the slope aims to see how much the level of flood danger in Sigi Regency. The flatter, the more danger to flooding, because water is difficult to flow. Table 2 presents the slope score.

Land use: Scoring on land use aims to find out the level of flood hazard in Sigi District, land use in Sigi Regency varies, land use affects flooding. Table 3 presents the slope score.

Soil: Scoring on soil types aims to determine the level of flood danger and the type of soil affecting floods. Table 4 presents the slope score.

2.2 Research Location

Sigi Regency is a district in Central Sulawesi Province with an astronomical location between 0°52'16"- 2°03'21" South Latitude and 119°21'24"- 120°38'45" East Longitude as shown in Fig. 1. The area of Sigi Regency is 519,602 ha [4]. The topography consists of mountainous and lowland areas.

Table 1. Rainfall score

No.	Criteria (mm/Year)	Classification	Score
1	<1500	Very low	1
2	1500 - 2000	Low	2
3	2000 - 2500	Moderate	3
4	2500 - 3000	High	4
5	>3000	Very high	5

Source : [16]

Table 2. Scoring for slope

No.	Class (°)	Classification	Score
1	0 – 2	Flat	7
2	2 – 4	Gently slope	6
3	4 – 8	Sloping	5
4	8 - 16	Moderate steep	4
5	16 - 35	Steep	3
6	35 - 55	Very Steep	2
7	>55	Extremely steep	1

Sources : [16]

Table 3. Scoring for land use

No.	Type of land use	Score
1	Forest	1
2	Shrubs	2
3	fields, rice fields, dry fields, livestock	3
4	settlement	4
5	Lake, pond, open space, Irrigation Channels	5

Source : [16]

Table 4. Scoring for soil

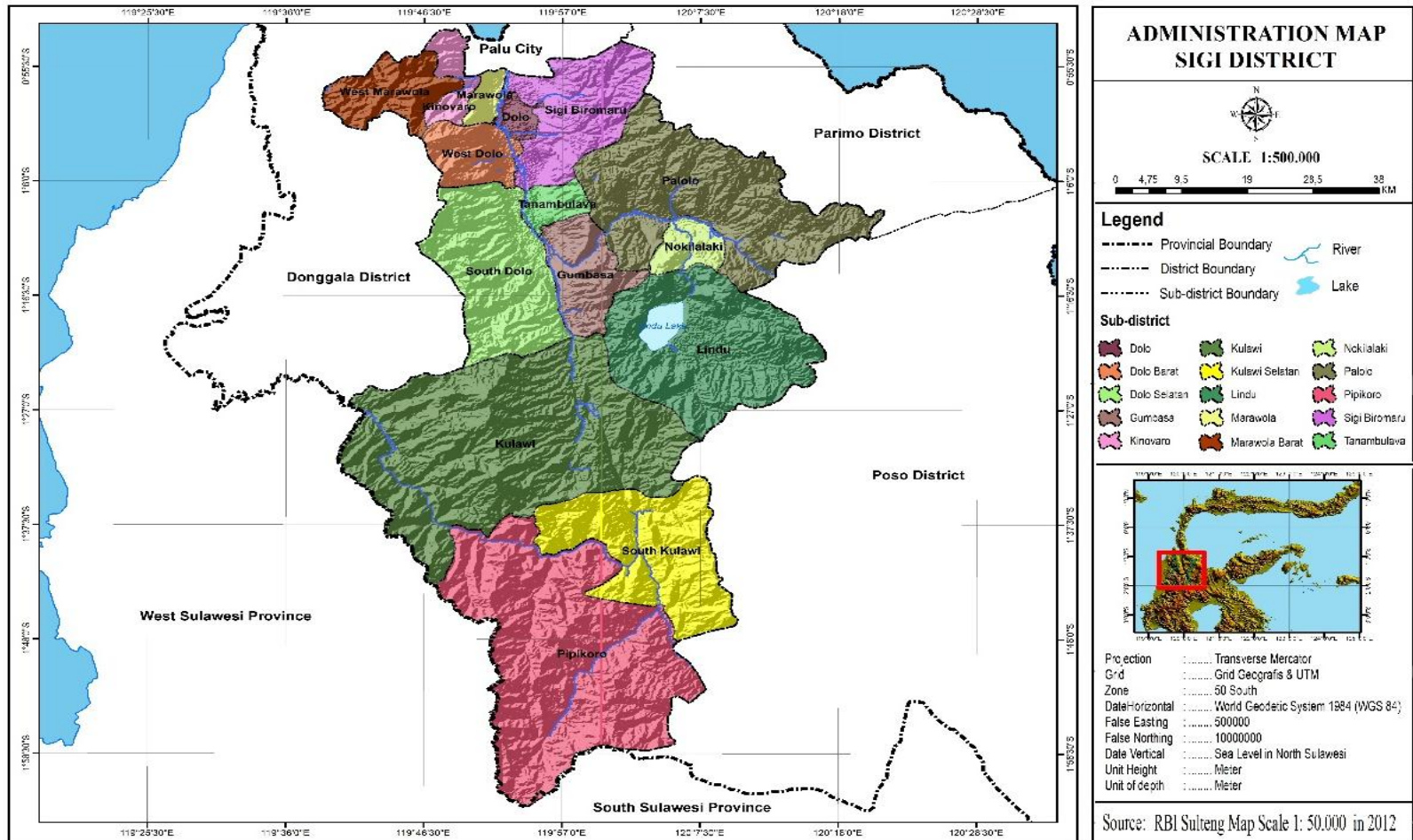| No	Type of soil	Classification infiltration	Score
1	Regosols	High	1
2	Alluvial, Andisols	Rather high	2
3	Latosols	Moderate	3
4	Latosol Medittera	Rather slow	4
5	Gromusol	slow	4

Source : [16]

Fig. 1. Administrative map in Sigi District

3. RESULTS AND DISCUSSION

3.1 Geological Conditions

Sigi Regency has a quite complex geological condition. According to Rab Sukamto (1975) in [17], They can be divided into 2 Geological Mandalas, namely:

1. Mendala West Sulawesi is characterized by the spread of rubble and genes, which are then crushed by sedimentary rocks and volcanoes. Another characteristic is the presence of granite breakthrough rocks, granodiorite and others which among them cause the process of mineralization. Mandala West Sulawesi has a wide distribution in the area of Central Sulawesi including the Districts of Kinovaro, West Marawola, West Dolo, South Dolo, Kulawi, South Kulawi and Pipikoro.
2. Mendala East Sulawesi, the characteristic of this men-dala is the extent of the spread of base and ultramafic rocks and schist as a base, which is then suppressed by

sedimentary and volcanic rocks. Its distribution covers the areas of Lindu and Palolo Districts.

3.2 Soil

Soil can absorb water into the soil, and hence the amount of water that is not absorbed into surface water. The structure and capacity of soil infiltration have an impact on soil efficiency in absorbing water. When the soil has a lower infiltration capacity, an increase in surface runoff results in flooding.

The types of soil are alluvial, latosol and litosol. Litosol is around 88.45%, found in the districts of Pipikoro, South Kulawi, Kulawi, West Marawola, Kinovaro, someThe partly of Sigi Biromaru, Palolo, Nokilalaki, Lindu, South Dolo, Tanambulava, West Dolo and Gumbasa. Alluvial is found in Dolo, part of Marawola, part of West Dolo, part of Tanambulava, part of South Dolo, part of Gumbasa, part of Palolo, part of Nokilalaki, part of Lindu and part of Sigi Biromaru. Latosol with a percentage of 0.01% or 71 ha is found in some Lindu Districts (Fig. 2).
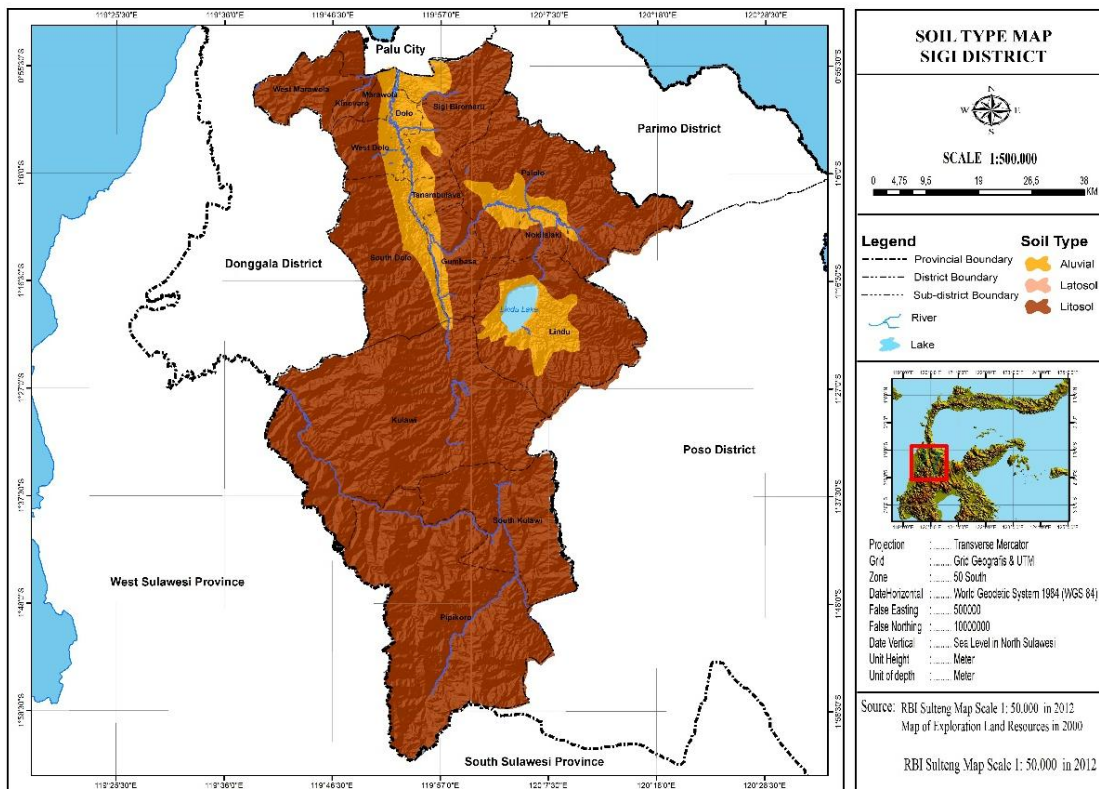

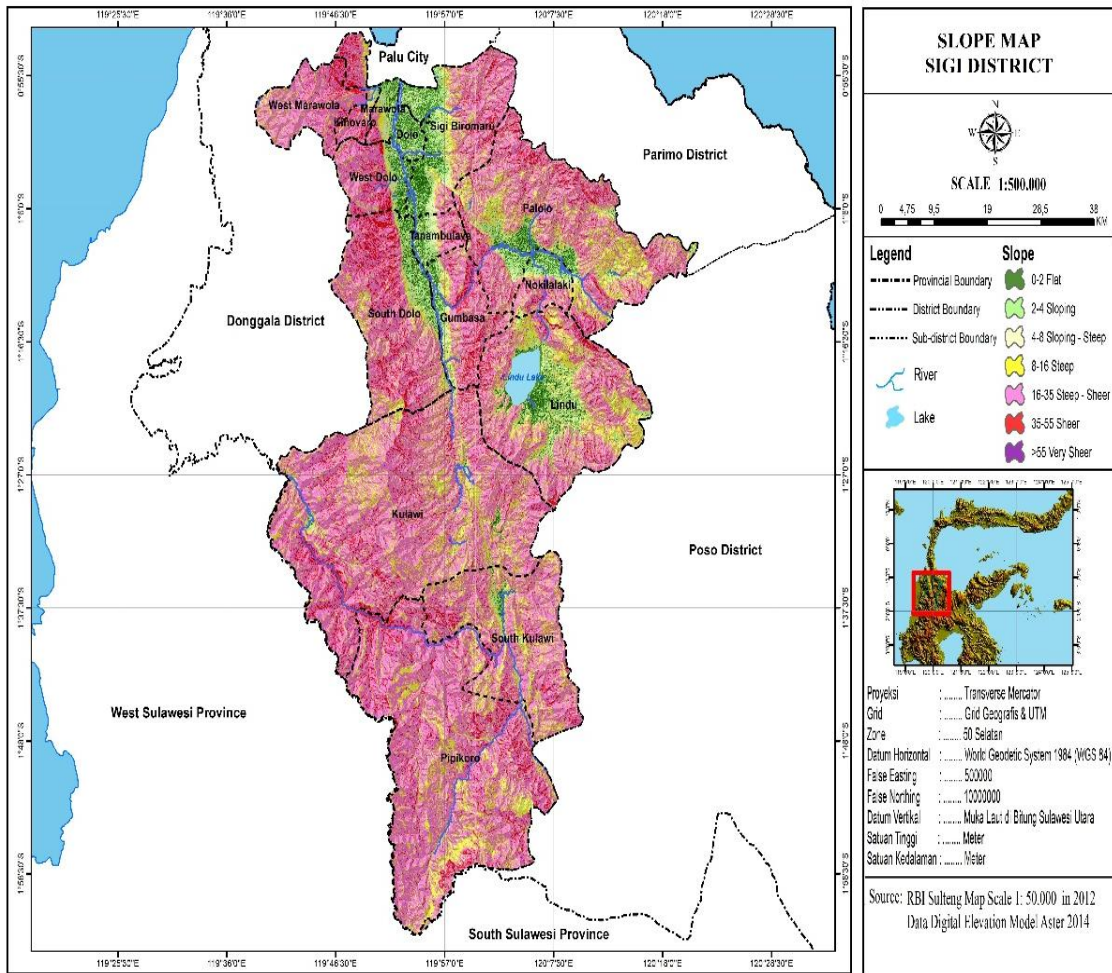Fig. 2. The type of soil map in Sigi district

Fig. 3. Slope map in Sigi district

3.3 Slope

The slope is classified by the Van Zuidam classification and resulted in 7 slope classes, namely; flat, gently slope, sloping, moderately steep, steep, very steep, and extremely steep. The steep category with 16° -35° found in Pipikoro, South Dolo, West Dolo, West Marawola, South Kulawi, Kulawi, Gumbasa Palolo, Sigi Biromaru. Areas with a flat slope of 0° -2° include Dolo, Marawola, part of South Dolo, part of Gumbasa, part of Sigi Biromaru, part of Palolo, part of South Kulolo, and Lindu as shown in Fig. 3.

3.4 Weather and Climate

Rainfall is divided as Rainfall <1500 mm / year with a rain area of 2680.37 ha or around 0.51%

only occurs in West Marawola District, while rainfall with an intensity of 1500-2000 mm/year cover area of 518208.73 ha or around 99,49% occurred starting from Dolo, Pipikoro, South Kulawi, Kulawi, Lindu, Nokilalaki, Palolo, Gumbasa, South Dolo, West Dolo, Tanambulava, Sigi Biromaru, Marawola, and Kinovaro Districts (Fig. 4).

3.5 Landuse

Land use in Sigi Regency based on the results of data processing is classified into 5 land use classes. The use of for-est land is the largest land area with an area of 3,988.9 ha and many are in the southern region of Sigi Regency; land use for gardens with an area of 618.64 ha; the use of fields, paddy fields, dry fields, animal husbandry covering an area of 510.63 ha; the
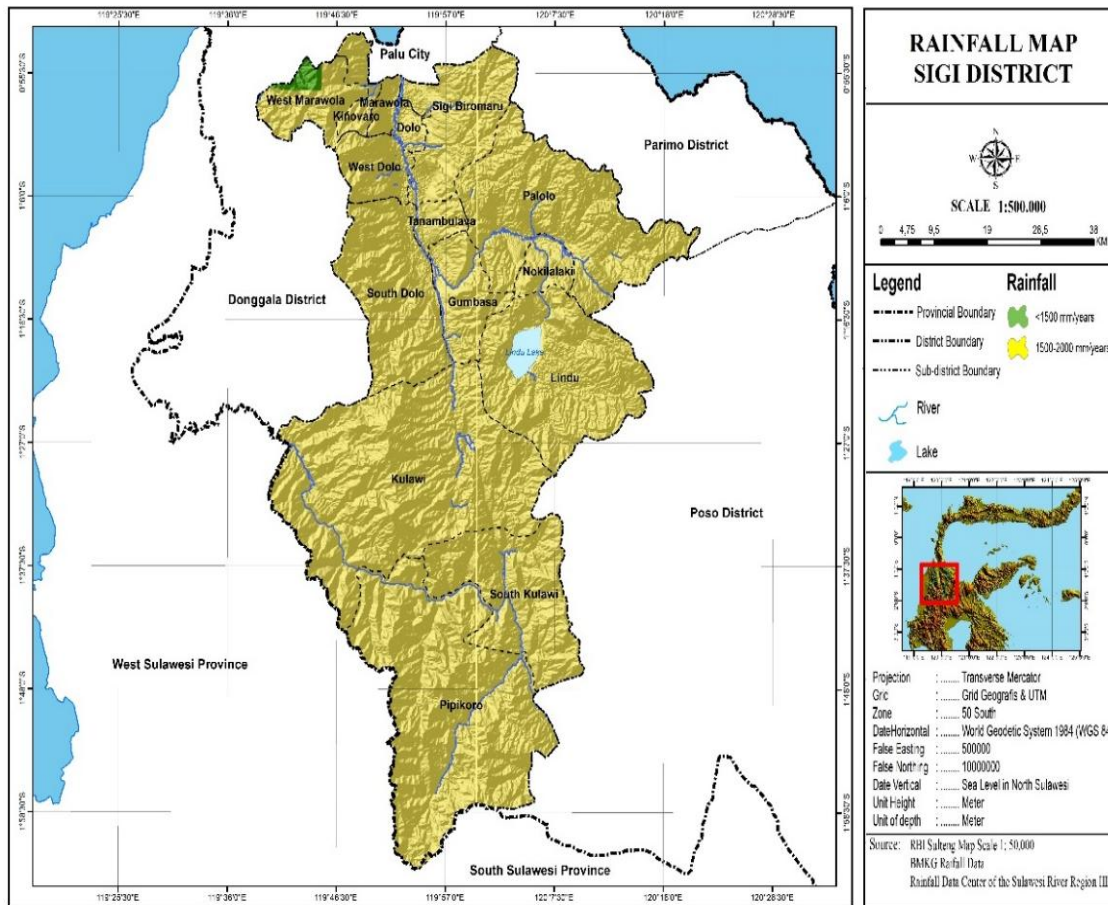
Fig. 4. Rainfall map in Sigi district

use of residential land covers an area of 29.94 ha; and land without vegetation (lakes, ponds, fields, irrigation channels) covering an area of 57.52 ha.

3.6 Zoning of Flood Hazard Level

The magnitude of the threat of flooding in this study was seen based on the distribution of floods on the flood hazard map. Flood hazard maps were done by overlay rainfall, slope, soil type and land-use maps. The Areas with a very vulnerable level are given the highest score and areas with a vulnerable level are given the lowest score.

Based on the analysis of flood hazard maps, The flood hazard levels in Sigi Regency divides as 4 levels namely: no danger, less danger, danger and very dangerous. Zone IV (very dangerous) has an area of 24505.62 ha or around 4.82% of the area of Sigi Regency. Zone III (danger) has

an area of 131567.86 ha or around 25.91%. Zone II (less danger) has an area of 350605.76 ha or around 69.03%. this zone is the widest in Sigi Regency. Zone I (no danger) has an area of 1193.62 ha or around 0.24% and this zone is the smallest zone of the flood hazard zone in Sigi Regency.

The results of the analysis for Zone IV which is a very hazard or high hazard zone area that has a wide potential for flood hazard is Lindu District, which is 7,038.66 ha or around 28.72%. The land cover in Lindu District is mostly land without vegetation (Lake Lindu), the rainfall is in the medium category of 1500- 2000 mm / year. The area is mostly located on a flat slope or 0° -2° so that the rate of runoff is very less which can cause inundation water and flooding.

Zone III and zone II are located in Kulawi District with the area of each zone, namely zone III 2,7705.39 ha or around 17.25% and zone II 89,149.86 ha or around 25.43%. Rainfall is in the

medium category of 1500-2000 mm/year. The slope is on a flat-steep slope. The land use is mostly forest and shrubs.

Zone I is the zone of no-flood hazard zone which has the widest area is Pipikoro District, which is 471.93 ha or around 39.54%. Pipikoro Subdistrict is the second widest sub-district after Kulawi Subdistrict, the land use is mostly forest. Rainfall is in the medium category, 1500-2000 mm / year and the slope is 8° -35° or from steep slopes, almost no land is found with a slope of 0° -2°. This resulted in the water flowing from the ground surface did not inundate. So that most Pipikoro areas are safe from flood hazards.

The results obtained in this study are similar to those obtained by Matoddang et.al, 2013. Their result showed that the coast of Kendal region is an area that is very vulnerable to flooding because it is dominated by land use without vegetation (fishponds) and alluvial soil types.

whereas in areas not prone to flooding, land use is dominated by forests and plantations [18].

The slope in the Zone IV is flat while in Zone I is Steep. Slope controls the rate of infiltration of groundwater into the subsurface. When the slope of an area is flat or gentle, the surface runoff is slow so the raindrops infiltration into the ground is slow and as a result, the area will be highly susceptible to flooding or the area can be the area inundation. Similarly, Similarly, when the slope is steep, the rainfall slowly percolate into the ground thereby making the area to be less susceptible to flood. the soil is alluvial soils whose infiltration is rather high [19].

The flood susceptibility map will help to a quick assessment of the potential impact of the flood hazard so it can be taking a positive and in time steps during pre-disaster and post-disaster [20].
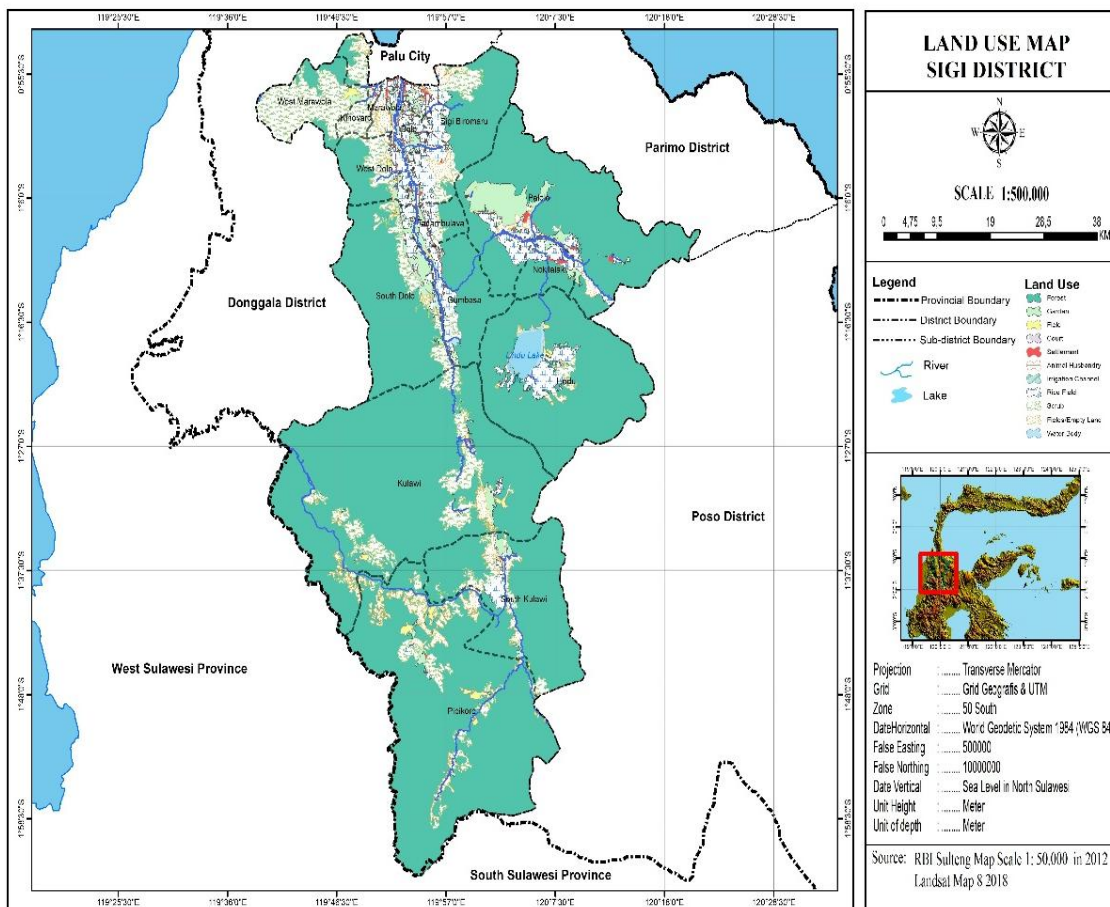

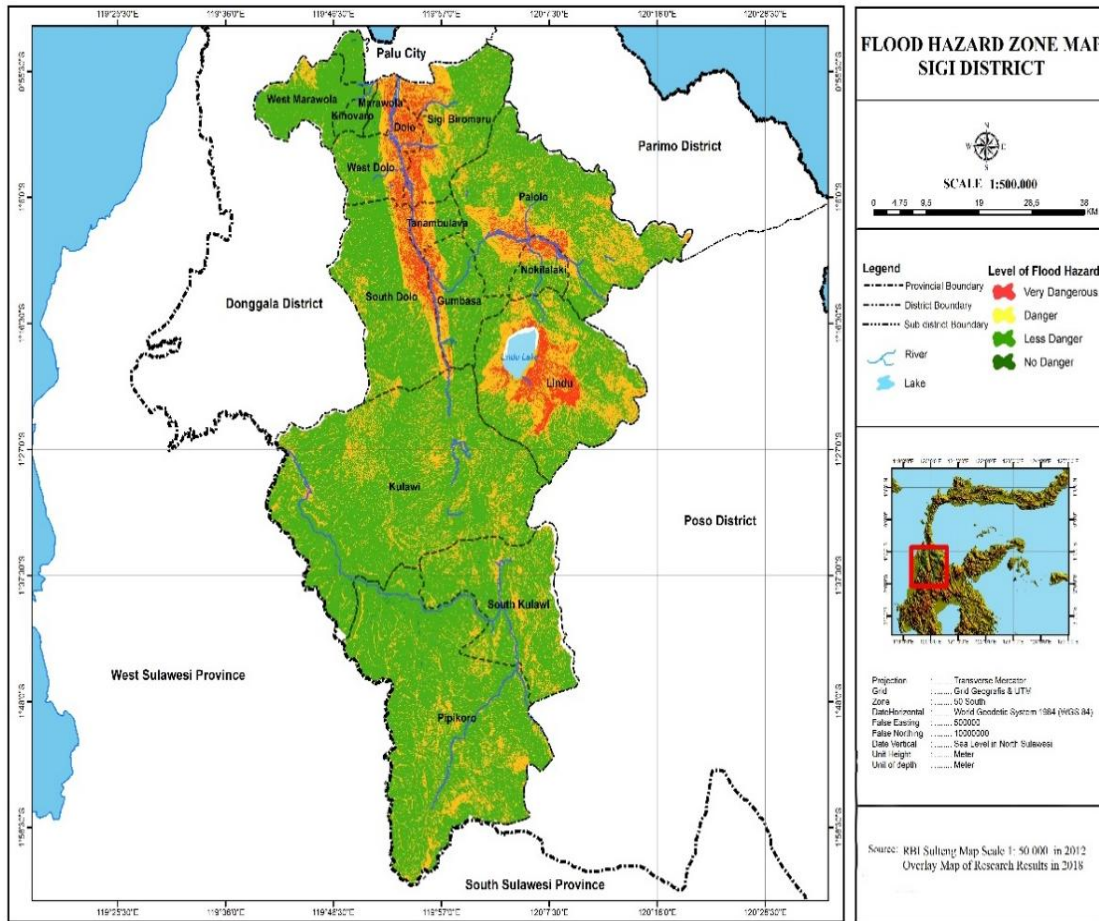**Fig. 5. Landuse map in Sigi District**

Fig. 6. Flood hazard zoning map in Sigi District

4. CONCLUSION

Factors that cause floods are rainfall, slope, soil type and land use. The biggest factor that causes flooding is the slope, due to the compilation of rain that occurs on the flat slope will become an inundation area, Then the type of soil that also affects the process of water infiltration in these areas. The Zonage flood hazard mapping in Sigi Regency is divided into four zones, namely; 1) Zone IV is a zone with a category of very dangerous flood level, this zone has an area of 24505.62 ha or 4.82%; 2) zone III, namely zone with danger flood hazard category has an area of 131587.86 ha or 25.91%; 3) zone II, namely the category of less hazard has an area of 350605.76 ha or 69.03%; zone I in, not danger category has an area of 1193.62 ha or 0.24%.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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