Mapping of Flood-Prone Areas and Its Compatible with Actual Site Condition in Latambaga District, Indonesia

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Abstract. Flood-prone of Latambaga District Mapping can reduce the impact of flood disasters and improve disaster preparedness. The first objective was to determine the distribution of flood-prone areas and the occurrence of flood disasters based on GIS in the Latambaga District. The second objective was to determine the suitability of the potential flood disaster distribution map to the actual conditions in the Latambaga District. This research is a quantitative descriptive research, including survey research. Data collection techniques using observation, questionnaires and documentation. The data analysis technique for the first objective uses map overlay and scoring. The second research objective uses weighting and percentages. The results in first objective show that 85.5% of the area in Latambaga District is included in the non-flood risk category with a size of 185.38 km² and areas in the flood-prone category have an area of 31.53 km² or 14.5%. The results in second objective show that the level of conformity of the map of flood-prone areas with actual conditions is 85%, which shows that the map resulting from the spatial analysis can be used as information.

Keywords: flood-prone mapping, GIS flood analysis, disaster preparedness, flood risk assessment

1 Introduction

A flood disaster in Latambaga District is an event where inundation occurs in a flat area around a river Ulu Wolo that cannot accommodate. Flood disasters are natural disasters that almost happen every time the rainy season arrives in Latambaga District. It condition as a result of overflowing or increasing river water discharge due to the rainy season, poor drainage and ineffective waste processing according to [1]. Floods result from interactions between humans and nature and natural systems that arise from trying to use land for various activities according to [2].

Flood disasters are a common problem in Latambaga District in densely populated areas. The flood disaster in Latambaga District caused by many factors. One of the factors that cause flooding is high-intensity rainfall according to [3].

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According to [4], Latambaga District, Kolaka Regency, is included in the list of areas with a higher risk of flooding. Based on BNPB Perka Number 02 of 2012 concerning Guidelines for Disaster Risk Assessment, 13 disasters must be analyzed for their disaster risk level. This research will analyze a disaster in Latambaga District, namely flooding. On Saturday, July 21 2018, at 05.30-09.00 WITA, there was a flood in Sakuli Village, Latambaga District, Kolaka Regency, with a water level of around 1 meter. On Tuesday, April 30 2019, several points were hit by flooding up to 130 cm, including Sakuli sub-district and Mangolo sub-district.

For these flood conditions, it is necessary to carry out research focused on mapping the flood disaster in Latambaga District, Kolaka Regency, by the regulations of the Head of the National Disaster Management Agency (Perka BNPB). Flood mapping can also provide mitigation information to the community and government according to [5]. Mapping is also an effort to reduce the impact of natural disasters, and disaster preparedness can be carried out quickly and precisely according to [6].

Research related to flood mapping [7] examines the suitability of overlay mapping of potential flood-prone areas with the actual conditions in Kendari City. Almost all areas in the city of Kendari, or 95%, are prone to flooding, varying from somewhat vulnerable, quite vulnerable, vulnerable and very vulnerable. The level of suitability of the map reaches 95%, meaning that the spatial analysis results can be used in mapping the level of flood vulnerability in the city of Kendari. Research [8] mapped floods and calculated their accuracy using optical and SAR satellite data. The accuracy results are above 70% and are relevant information. Research [3] integrates VGI and 2D hydraulic models into flood data mapped and accessed using social media.

There is a difference with previous research in that research [7] mapping and conformity was not carried out simultaneously. In contrast, this research was carried out together between mapping and conformity. Research [3, 8] uses remote sensing to examine suitability, while this research uses direct regional surveys. Geographic information systems research can be disseminated in lectures and secondary schools on geography geografi [9]. The first objective of this research is to determine the distribution of flood-prone areas and the occurrence of flood disasters based on Geographic Information Systems in Latambaga District, Kolaka Regency. The second research objective was to determine the suitability of the distribution of flood-prone areas to actual conditions in Latambaga District, Kolaka Regency.

2 Method

This type of research is quantitative and descriptive, including survey research. It was conducted in 2020 in the Latambaga District, Kolaka Regency. The research subjects were the environmental heads of each sub-district in the Latambaga District. The research objects were flood-prone locations, the extent of flooding, and the most dominant factors that cause flooding in the Latambaga District.

Flood mapping indicators include soil type, rainfall, land use, and slope. The weighting of each parameter used to prepare the flood threat map is as follows.

To determine the number of classes of flood-prone levels, we search using the Sturgges formula [12] as follows:

Table 1. Soil Type Score

Indicator of Soil Type	Score	Description
Aluvial, Planosol, Glay Hodromorph, Lateric Groundwater	5	Insensitive Infiltration.
Latosol	4	Slightly Sensitive Infiltration
Brown Forest Soil, Mediteran Soil	3	Medium Sensitivity Infiltration
Andosol, Laterik, Grumusol, Podsol, Podsolic	2	Sensitive Infiltration
Organosol	1	Very Sensitive Infiltration

Source:[10]

Table 2. Rainfall Description

Indicator of Rainfall (mm/year)	Score	Description
2001-2500	1	Light
2501-3000	2	Currently
3001-3500	3	Heavy
¿3501	4	Very Heavy

Source:[11]

$$K = 1 + 3.3 \log N \tag{1}$$

Dengan N as the number of observational data, and K as the number of classes. Here is the calculation:

$$\begin{aligned} K &= 1 + 3.3 \log 4 \\ &= 1 + 3.3 \times 0.60 \\ &= 1 + 1.98 \\ &= 2.98 \approx 3 \end{aligned}$$

In this way, the number of classes of flood risk levels is categorized into three categories: very vulnerable, moderately vulnerable and not vulnerable. Then, to determine the length of the class interval, it is necessary first to know the range, namely the difference between the highest and lowest scores. The class interval size can be found using the formula:

$$\text{Interval class} = range/numberofclasses \tag{2}$$

Range for the highest value minus the lowest value. Here is the calculation.

$$K = (20–4)/3 = 16/3 = 5.33(6) \tag{3}$$

In this way, the interval for flood risk levels, firstly, floods were very vulnerable if the score ¡14.Second, floods were vulnerable if the score was 9-13. Third, floods were not vulnerable if the score was 4-8.

Table 3. Land Use Scoring

Indicator Land Use Scoring	Score	Description
Water (Revier, Swamp, Pond)	5	Very High
Settlement	4	High
Fields, Rice Fields, Gardens	3	Moderate
Bush, Moor	2	Low
Forest	1	Very Low

Source:[10]

Table 4. Slope Score

Indicator Slope Score%	Score	Description
0-8%	5	Flat
8-15%	4	Sloping
15-25%	3	Somewhat Steep
25-40%	2	Steep
¿45%	1	Very Steep

Source:[4]

The validation process was carried out to determine the accuracy of the flood disaster threat map's result with the situation in the field. This validation process compares the results of hazard mapping with disaster history by interviewing sub-district officials, visiting a sample of points in the sub-district that occur in the field, taking coordinate points and documenting all activities in the field, and checking the validation results from the Kolaka Regency BPBD.

Collecting primary data by surveys and direct observations in the field, in the process of collecting data in the field, is carried out using interviews and documentation related to areas affected by flooding. Collecting secondary data from administrative maps, soil type maps, rainfall maps, land use maps, and slope maps in related agencies. The data analysis technique for the first research objective is map overlay and scoring. The second research objective is quantitative descriptive with percentages.

3 Result and Discussion

Latambaga district has seven sub-districts and has an area of 219.46 km². The names and areas of sub-districts can be seen in Table 5 below.

The soil characteristic that influences the infiltration rate is soil texture. Soil texture is the condition of the level of soil fineness that occurs due to differences in the composition of the sand, dust and clay fractions contained in the soil. Soil with an excellent texture has a high chance of flooding, while a coarse texture has a low probability of flooding. The finer the soil texture, the more difficult it is for surface water from rain or river overflows to seep into the soil, resulting in puddles according to [13].

The type of soil in Latambaga District is dominated by Podzolic soil with an area of 195.60 km² with a percentage of 89.1%. In detail, soil types can be seen in Table 6 below.

Table 5. Adminstration of Latambaga District

Administration	Area (Km²)	Percentage
Latambaga sub-districts	0.295703	0.1%
Sea sub-districts	0.475673	0.2%
Mangolo sub-districts	16.724219	7.6%
Induha sub-districts	54.622658	24.9%
Sakuli sub-districts	17.424842	7.9%
Kolakaasi sub-districts	38.334848	17.5%
Ulunggolaka sub-districts	91.583865	41.7%
Amount	219.461808	100%

Table 6. Soil Type of Latambaga District

Soil Type	Area (Km²)	Percentage
Latosol	0.00003	0.00%
Kambisol	0.475673	0.2%
Mangolo sub-districts	20.37869	9.29%
Organosol	3.476757	1.6%
Podsolic	195.606331	89.1%
Amount	219.461808	100%

The soil type in an area greatly influences the water absorption process or what we usually call the infiltration process. Infiltration is the process of water flowing vertically in the soil due to gravitational potential. Physically, several factors influence infiltration, including soil type, soil density, soil moisture and the plants above it. The infiltration rate in the soil is getting smaller over time because soil moisture is also increasing according to [14].

The Latosol soil type in Latambaga District has an area of 0.00003 km². The mineral content of silicate clay (clay) makes latosol relatively low in plasticity (sticky) and very brittle. As a result, water will quickly enter this soil according to [15]. Latosol can only be found in warm and humid areas. This soil is very suitable for the type of climate in equatorial areas. This soil type is quite sensitive in contributing to flooding in the Latambaga District.

The Cambisol soil type in Latambaga District has an area of 20.37 km² or 9.38%. Cambisol usually has a texture that varies from coarse to fine. In this case, it can depend on the parent material's weathering level. The soil fertility is high, and the adequate depth varies from shallow to profound. The lowlands are generally thick, while the solum is thin in steep slope areas according to [16]. This soil type has moderate sensitivity in contributing to flooding in the Latambaga District

Podzolic soil type in Latambaga District has an area of 195.60 km² or 89.1%. Podzolic soil type is a type of soil that is classified as poor in nutrients and has an acidic reaction. The natural fertility of this soil only depends on the top layer of organic material, which is not stable. Hence, this soil is problematic, but the cross-section of the soil is still quite deep, and the clay content is high, making it suitable for developing rice fields, which require a dense bottom layer according to [17]. This soil type is sensitive in contributing to flooding in the Latambaga District.

The Organosol soil type in Latambaga District has an area of 3.47 km² or 1.6%. Organosol soil is soil whose formation process results from the decomposition of organic materials. Organosol soil is usually in swampy areas or places constantly flooded with water. Organosol soil is very moist and can even be muddy because of its presence in a watery environment according to [10]. This soil type is very sensitive to flooding in the Latambaga District. The greater the water absorption or infiltration capacity, the lower the level of flood vulnerability. Vice versa, the smaller the water absorption or infiltration capacity, the greater the potential for flood vulnerability according to [10, 18].

Latambaga District is dominated by rainfall of 1500–2000 mm/year, which is included in the low-class category with an area of 132,262 km² or 60.27%. Rainfall is the amount of rainwater in an area at a certain time. The rainfall required for flood control planning is the average rainfall throughout the area concerned. Rainfall at a certain point is usually called regional or regional rainfall. The higher the rainfall, the greater the potential for flooding, and vice versa. The lower the rainfall, the greater the risk of flooding according to [6].

Latambaga District has rainfall ranging between 1500-2000 mm/year, so it is in the low category and rainfall of 2500 - 3000 mm/year is in the medium category. Indonesia has high rainfall between 1500 – 2000 mm/year. Flooding easily occurs during the rainy season between October and March according to [19].

Land use will influence the flood vulnerability of an area. Land use will play a role in the amount of runoff resulting from rain that has exceeded the infiltration rate. If the land is heavily planted with vegetation, the rainwater will be greatly infiltrated, and the runoff will take longer to reach the river. Hence, the possibility of flooding is smaller than in areas where the community does not plant vegetation according to [20]. Areas, where trees dominate make it difficult to channel surface runoff water because trees can absorb water. The roots and trunks of trees can also hold back surface runoff water.

Most land use in Latambaga District is primary dry land forest with an area of 112.86 km² or 51.4%. Then, mixed dry land farming with an area of 85.25 km² or 38.8%. Then, bushes with an area of 8.41 km² or 3.8%. The rest comprises settlements, open land, ponds, secondary mangrove forests, secondary dry land forests and rice fields. Land use data can be seen in Table 7 below.

Land use will influence the flood vulnerability of an area. Land use will play a role in the amount of runoff resulting from rain that has exceeded the infiltration rate. Suppose the land is heavily planted with vegetation. In that case, rainwater will be infiltrated a lot, and it will take more time for runoff to reach the river, so the possibility of flooding is smaller than in areas that are not planted with vegetation according to [7, 21].

Most land use in Latambaga District is primary dry land forest with an area of 112.86 km² or 51.4%. Forests play a significant role in the amount of runoff resulting from rain, which will be infiltrated a lot, and the runoff will take more time to reach the river. Hence, the possibility of flooding is smaller than in water areas, residential areas and rice fields.

Table 7. Land Use

Land Use	Area (Km²)	Percentage
Primary Dryland Forest	112.866566	51.4%
Mixed Dry Land Agriculture	85.258392	38.8%
Thicket	8.414715	3.8%
Settlement	3.695527	1.7%
Open Land	2.837678	1.3%
Pond	2.980653	1.4%
Secondary Mangrove Forest	1.151887	0.5%
Secondary Dryland Forest	1.254263	0.6%
Ricefield	1.002127	0.5%
Amount	219.461808	100%

The slope of the land is a percentage ratio between the vertical distance (height of the land) and the horizontal distance (length of the flat land). The steeper the slope, the greater the potential for flooding to occur. Vice versa, the steeper the slope, the safer the flood disaster will be. The slope of an area shows the speed of water flowing. The steeper the slope, the faster the water flows and the flatter the slope, the slower the water flow, making it possible for inundation. The higher the slope, the higher the water flow. Water on a high slope will be transferred more quickly to a lower area so that there is a possibility of inundation or flooding in areas where the slope of the land is smaller according to [10].

The majority of slopes in Latambaga District are in the Steep category (25–45%) with an area of 112.70 km² or 51.4%, and the minority are in the Flat category (8–15%) with an area of 13.91 km² or 6.3%. Slope slope data can be seen in Figure 1 below.

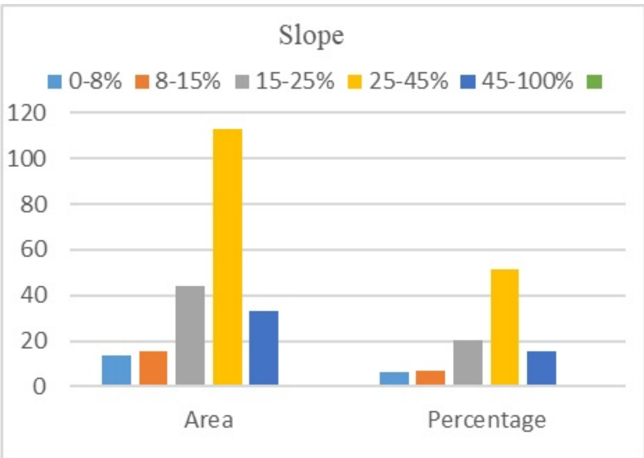

Fig. 1. Diagram of Slope Area and Percentage in Latambaga District

The close relationship between the level of infiltration and the level of the slope of the slope becomes a parameter as one of the main determining factors in the occurrence of flooding. The slope of the slopes in the minority Latambaga District is in the flat category of 8–15%. In the flat category, it contributes greatly to flooding on sloping and flat land. Inundation occurs more easily, which can ultimately cause flooding. On the other hand, the steep category of 25–45% plays a crucial role in reducing the potential for inundation, which results in flooding.

Flood-prone areas in Latambaga District can be categorized into three levels of vulnerability: not, vulnerable, and very vulnerable. Areas classified as not prone to flooding are located in areas with slopes ¿ 25%. Areas not prone to flooding have an area of 185.38 km² or 85.5%. The distribution of non-vulnerable areas is almost all sub-districts, including Induha sub-district, Mangolo sub-district, Ulunggolaka sub-district, Kolakasi sub-district and Sakuli sub-district (marked in light green on the map).

Areas that are categorized as prone to flooding in the Latambaga District are areas with a slope of 8–15%. Flood-prone areas have an area of 30.22 km² or 14.1%. The distribution of flood-prone areas is mostly in every sub-district in Latambaga District, including Induha Subdistrict, Mangolo Subdistrict, Ulunggolaka Subdistrict, Kolakasi Subdistrict, Sea Subdistrict, Latambaga Subdistrict and Sakuli Subdistrict (marked in yellow on the map).

Areas categorized as very prone to flooding in the Latambaga District are found in areas with a 0–8% slope. Areas highly prone to flooding have an area of 0.84 km² or 0.4%. The distribution of very vulnerable areas, a small part of which is in Mangolo Village and Kolakasi Village (marked in red on the map). The Flood Hazard Map is presented in Figure 2 below.

Flood-prone areas are easily or tend to be hit by floods. These areas can be identified using a geomorphological approach, especially the morphogenesis aspect, because of features such as river terraces, natural embankments, flood plains, back swamps, alluvial fans, and deltas which are repeated flood formations, which are detailed landforms that have flat topography. Flood-prone areas are areas that frequently or have a high potential for experiencing flood disasters according to the characteristics of the causes of floods according to [19]. Flood-prone areas are areas with high rainfall, rocky areas with low water absorption capacity, areas around rivers where river water flows, dense residential areas and areas that have experienced flood disasters according to [22].

Validation efforts are important in determining the quality of GIS maps produced by researchers and determining the suitability of flood hazard maps to actual conditions. The validation process was carried out by comparing the results of the hazard mapping with the history of disasters in the Latambaga District. Field validation in this research was carried out at 28 observation location points; the observation location points can be seen in Figure 3 below.

The results of this field observation were carried out over three days. On the first day, they visited Induha Village with three neighbourhood heads and Mangolo Village with five neighbourhood heads. On the second day visited two sub-districts, including Ulunggolaka Village with five neighbourhood heads and Kolakasi Village with five neighbourhood heads. On the third or final day, they visited three sub-districts, includ-

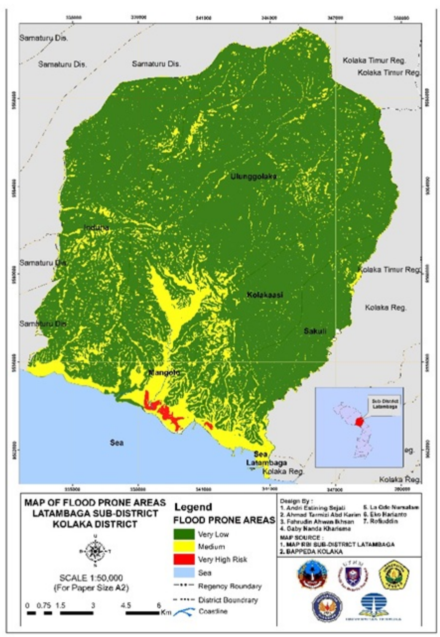

Fig. 2. Flood Prone-area Map of Latambaga District

ing the Latambaga sub-district with two neighbourhood heads, the Sea sub-district with five neighbourhood heads and the Sakuli sub-district with five neighbourhood heads.

Based on the results of field interviews in Induha Village, areas prone to flooding are areas two and three. The cause of the flooding is mostly lowland areas and surrounded by mountainous areas and narrow rivers. If moderate and heavy rain comes, it can cause flooding from the river's overflow, Induha Village. Some areas are categorized as flood-prone.

The results of field interviews in Mangolo Village have lowlands and mountains; one neighbourhood in Mangolo Village is prone to flooding. The flood in 2019 was the worst in Mangolo Village, which was caused by heavy rain for 24 hours and resulted in the river overflowing, which submerged neighbourhoods one, two and three, where Mangolo Village is categorized as a very flood-prone area.

The results of field interviews in Ulunggolaka sub-districts one, two and three are that flooding is common if heavy (heavy) rain comes, which causes rivers to overflow and submerge most of the areas in neighbourhoods one, two and three, which are in the flood-prone category. Neighbourhoods four and five are mountainous areas where most of the area is categorized as not prone to flooding.

Based on field interviews, the Kolakasi Subdistrict has steep and low topographic areas, so if heavy rain comes, the low areas will automatically be submerged due to dense population in the lowlands and poor drainage and fall into the flood-prone category. The results of field interviews in Latambaga Village have areas prone to flooding due

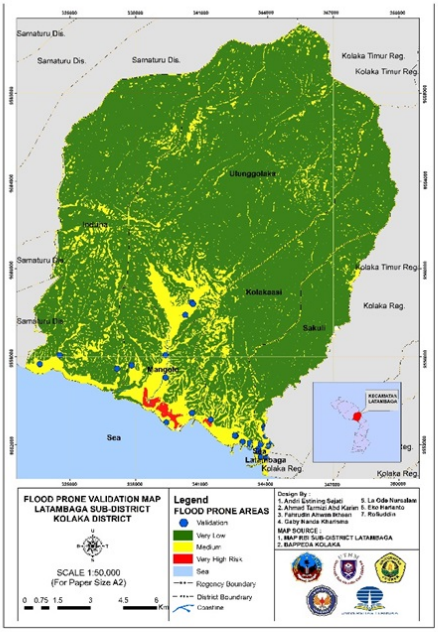

Fig. 3. Validation of Flood Prone Area Map

to population density, low land and poor drainage and are included in the flood-prone category.

The results of field interviews in Sea Village have flood-prone areas due to the dense population in the sub-district and the poor drainage in Sea Village, and the local community's lack of attention to the importance of cleanliness around the house and it is included in the flood-prone category. Sakuli Subdistrict some of the environments in the Sakuli Subdistrict have lowlands and riverbanks, where these areas have areas that are prone to flooding due to drainage and rivers overflowing if heavy rain comes and are included in the flood-prone category.

Validation of flood-prone areas in Latambaga District, Kolaka Regency, was obtained from visual observations and interviews with environmental heads in each Latambaga District Kolaka Regency sub-district. Based on these observations and interviews, the level of vulnerability and capacity at that point is determined by whether the point is classified as not vulnerable, vulnerable or very vulnerable. Map validation is important to determine the accuracy of the map according to [17, 23].

Several factors allow discrepancies to occur between processing results and field survey results. One is secondary data, the main material for processing flood hazard maps, which are not updated enough. Government efforts in mitigation are also factors in reducing flood risk, such as normalizing rivers, improving public facilities, socializing disasters, and improving health facilities according to [7]. The results of field observations and interviews from the 28 validation sample points above show that four locations do not match the map, while 24 locations do. This data shows that the suitability of the flood hazard map with actual conditions in Latambaga District is 85%.

4 Conclusion

First conclusion, the map of flood-prone areas using the GIS in Latambaga District, Kolaka Regency, is 14.5% area categorized as a flood-prone area with 34.06 km^2. That area dominated in the settlement. Second conclusion, the level of suitability of the map of flood-prone areas using the GIS in Latambaga District, Kolaka Regency, with actual conditions is 85%, which shows that the map is the result of spatial analysis and can be used in mapping the level of flood vulnerability in Latambaga District, Kolaka Regency. This research recommendations for massive dissemination of flood prone area map for information to the people as a mitigation effort.

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