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Analysis of flood vulnerability in the lawo watershed Soppeng Regency

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Abstract. The Lawo Watershed (DAS) is a watershed located in Soppeng Regency and every year during the rainy season it is prone to flooding. Other factors that cause flood vulnerability are slope, rainfall, soil type, altitude, and inappropriate land use. This study aims to determine the distribution of the level of flood vulnerability in the Lawo watershed, Soppeng Regency. The type of research used is descriptive quantitative. The method of making maps uses overlays and scoring between variables. Each variable will be given a score by giving weights and values according to the classification. Variables that have gone through the scoring stage will be overlaid with other variables using the ArcGIS application so as to produce a map of the level of flood vulnerability. The data analysis technique used descriptive method. The result of the research is a map of the level of flood susceptibility with four levels of vulnerability. There are two dominant levels of flood vulnerability in the Lawo watershed, namely not prone to flooding and prone to flooding. The flood-prone level is located downstream of the Lawo watershed with an area of 13,172 ha or 34.33% of the total watershed area, while the non-flood prone level is located in the upstream part of the watershed with an area of 13,923 ha or 36.28% of the total watershed area. The dominant factor that causes flooding in the Lawo watershed is the slope and land use. Most of the area of the Lawo watershed has a slope of 0-8% with a presentation of 57.22% of the total watershed area, and 32.97% of land use is in the form of rice fields and swamp shrubs.

Introduction

Flood is one of the natural disasters that often occurs in various areas, both urban and rural areas. The National Disaster Management Agency (BNPB) said that from 2015 to September 2019, floods took second place in the list of natural disasters that often occur in Indonesia. The condition of the various morphological forms of Indonesia and having many rivers, causes Indonesia to experience frequent floods every rainy season. Flood is a condition where a land is submerged by puddles because the volume of water increases due to heavy rains, overflows of river water or a broken river embankment.

The causes of flooding in Indonesia generally occur due to deforestation without reforestation, garbage disposal in river flow, and construction of houses on riverbanks [1]. These factors will result in a decline in the function of the watershed and can cause severe flooding. The phenomenon of critical watersheds can cause the ability to decrease the watershed, during the rainy season there will be floods and during the dry season there will be drought because they cannot store water reserves [2]. The increase in watershed damage can be seen from an increase in flood disasters, especially in downstream areas due to the large amount of sedimentation carried from the upstream due to extreme changes in land use.

The Lawo River Basin with an area of 38.372 ha is one of the watersheds in South Sulawesi which has serious problems to be addressed due to the ever-increasing and uncontrolled forest degradation and transformation. The forms and patterns of degradation that occur are very diverse, including: a decrease in vegetation density, a change in the type of vegetation cover of land, impermeability, namely the change of cultivated land to watertight residential areas and conversion of forest land to non-forest designations [3].

The classification of flood-prone areas can use a Geographic Information System (GIS). GIS can provide a comprehensive picture of spatial data phenomena, in terms of location, linkages with other spatial phenomena and changes over time to spatial phenomena [4]. Data that can be used to support map making can be in the form of data on slope, altitude, soil type, land use, and rainfall.

The increasing number of forest conversion to non-forest land and the number of flood occurrences in Soppeng Regency, especially in the Lawo watershed that occurs every year, has prompted researchers to conduct research with the aim of mapping flood-prone areas.

2. Method

This type of research is descriptive quantitative. Researchers describe the characteristics of flood vulnerability in the Lawo watershed of Soppeng Regency by using the geographic information system (GIS) as a means of processing data. Quantitative descriptive data are the numbers obtained from the calculation process. The object of this research is the flood disaster that occurred in the Lawo watershed. The research subject is a map obtained from related agencies in Soppeng.

The data used in this research is secondary data. Secondary data is obtained through data analysis studies, archives, books and other forms of documentation owned by related agencies. Rainfall data from 2010 to 2019 were obtained from the Pompengan Jeneberang River Basin. The variables used to measure the level of flood vulnerability consist of six variables, namely, slope, soil type, rainfall, altitude, land use and distance from rivers. The classification of slopes in the Lawo watershed is presented in the following Table 1.

Table 1. Slope Classification.

Slope	Description	Information	Score
0-8%	Flat	Very Prone	5
8-15%	Sloping	Vulnerable	4
15-25%	Slightly Steep	Enough Prone	3
25-45%	Steep	Less Prone	2
>45%	Very Steep	Not Prone	1

Source : [5]

Table 1 shows the classification of slopes divided into 5 parts. The highest score is on a slope of 0-8% while the lowest score is on a slope of > 45%. Soil type classification can be seen in the following Table 2.

Table 2. Classification of Soil Types.

Soil Type	Description	Information	Score
Aluvial, Planosol, Hidromorf, Laterik	Slow	Very Prone	5
Latosol	Slightly Slow	Vulnerable	4
Tanah Hutan Coklat, Tanah Mediteran	Moderate	Enough Prone	3
Andosol, Laterik, Grumosol, Podsol, Podsolic	Rather fast	Less Prone	2
Regosol, Litosol, Organosol, Renzina	Fast	Not Prone	1

Source: [5]

Table 2 shows that the highest score is on soil types that have slow infiltration, and low scores on soil types that have fast infiltration. The classification of the distribution of rainfall in the Lawo watershed can be seen in the following Table 3.

Table 3. Classification of Rainfall.

Rainfall	Description	Information	Score
>3000	Very wet	Very Prone	5
2501-3000	Wet	Vulnerable	4
2001-2500	Moderate	Enough Prone	3
1501-2000	Dry	Less Prone	2
<1500	Very Dry	Not Prone	1

Source : [6]

Table 3 shows that the greater the rainfall intensity the greater the score, and the smaller the rainfall intensity, the smaller the score. The land use classification in the Lawo Watershed can be seen in the following Table 4.

Table 4. Land Use Classification.

Land Use	Information	Score
Settlement	Very Prone	5
Rice field / pond	Vulnerable	4
Field / Moor	Enough Prone	3
Shrubs	Less Prone	2
Forest	Not Prone	1

Source: [7]

Table 4 shows that residential land use has the greatest level of vulnerability compared to other land uses such as rice fields, shrubs and forests. The altitude classification can be seen in Table 5.

Table 5. Classification of Altitude.

Altitude (mdpl)	Description	Information	Score
<20	Very low	Very Prone	5
20 – 75	Low	Vulnerable	4
75 – 130	Moderate	Enough Prone	3
130 – 200	High	Less Prone	2
>200	Very high	Not Prone	1

Source: [7]

Table 5 shows that the higher a place is, the lower the flood hazard level. Classification of distance from the river can be seen in the following Table 6.

Table 6. Distance classification from rivers.

Distance from river (m)	Information	Score
0 – 50	Very Prone	5
50 – 100	Vulnerable	4
100 – 250	Enough Prone	3
250 – 500	Less Prone	2
>500	Not Prone	1

Source: [8]

The technique for making a flood hazard map consists of 2 stages, namely:

2.1. Data processing

2.1.1. Attribute analysis. Providing information is done to edit the open attribute Table. The attribute analysis process consists of 2 stages, namely, scoring and weighting. The score for each parameter is in accordance with the classification Table that has been made. The more vulnerable in this parameter class, the higher the score. The weighting is done for each parameter. The greater the influence of the parameters on flood hazard, the greater the weight and the smaller the effect of the parameters on flooding, the smaller the weight. The classification of parameter weights is presented in the following Table 7.

Table 7. Weighting Classification of Flood Prone Parameters.

Parameter	Weight
Slope	25
Type of soil	15
Rainfall	10
Land Use	20
Altitude Place	15
Distance from river	10

Source : [8]

2.1.2. Overlay. This analysis was carried out using the tumpeng stacking / overlaying technique of maps that already had scores and weights in the Table attributes. The overlay process is carried out by combining six flood hazard parameters. After the overlay process is complete it will produce a flood hazard map.

2.2. Vulnerability Level Analysis

The value of flood hazard is obtained by adding up the scores of the 6 parameters using the following equation:

$$K = \sum_{i=1}^{n} (Wi \times Xi)$$

Information:
K = the value of vulnerability
Wi = Weights for the parameter to – i
Xi = parameter class score to-i
n = lots of data

Table 8. Classification of Flood Hazard Level.

Classification	Score
Not Prone	100 – 199
Enough Prone	200 – 299
vulnerable	300 – 399
Very Prone	400 – 499

Source: [8]

3. Result and discussion

3.1 Slope

The slope of the slope is the angle formed between the vertical distance of the land and the horizontal distance of the land, in percentage units or degrees. The slope of the slope is a factor that has an influence on the size of an area entering the flood-prone zone. The slope in the Lawo watershed can be seen in the following Figure 1.

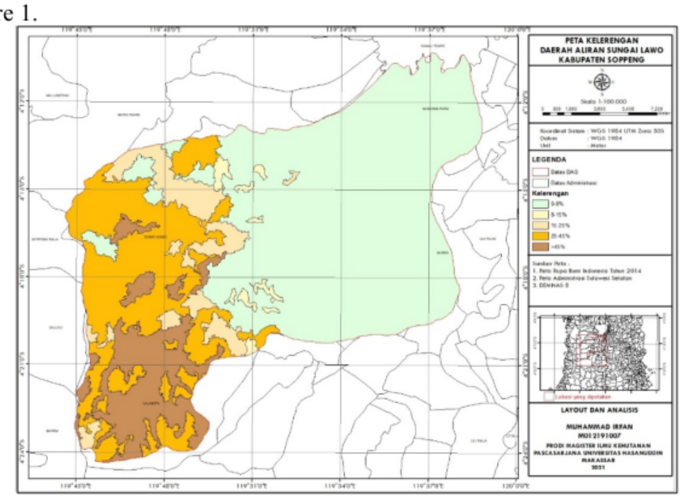

Figure 1. Slope Map Lawo Watershed.

Figure 1 shows that the flat slope (0-8%) has the widest distribution focused on the downstream area of the watershed. Very steep slopes (>45%) are spread over the upstream area of the watershed. The results of the scoring and weighting of the slope parameters can be seen in Table 9.

Table 9. Slope Classification Score.

Slope	Score (S)	Weight (W)	Total (SxW)	Large (ha)	Percentage (%)
0-8%	5	25	125	21,957.19	57.22
8-15%	4	25	100	527.08	1.37
15-25%	3	25	75	2,769.70	7.22
25-45%	2	25	50	8,784.56	22.89
>45%	1	25	25	4,334.34	11.30
Amount				38,372.87	100

Source : Secondary data processed in 2020

Table 9 shows that the slope of 0-8% has the widest distribution of 21,957.19 ha (57.22%) with a total score of 125.The flatter an area is, the greater the potential for flooding, this is because falling rainwater will flow. to a lower or flatter area.

3.2 Soil type

Soil is a layer of earth formed by weathering of the parent rock material and formed as a result of interaction with the climate, living beings, and the parent material. Soil type will have a relationship with soil texture. Soil texture will affect the process of water infiltration. Infiltration is the process of water flow into the soil [4]. The more finely textured ground, then the slower the rate of water into the ground. The type of soil in the Lawo watershed can be seen in the following Figure 2.

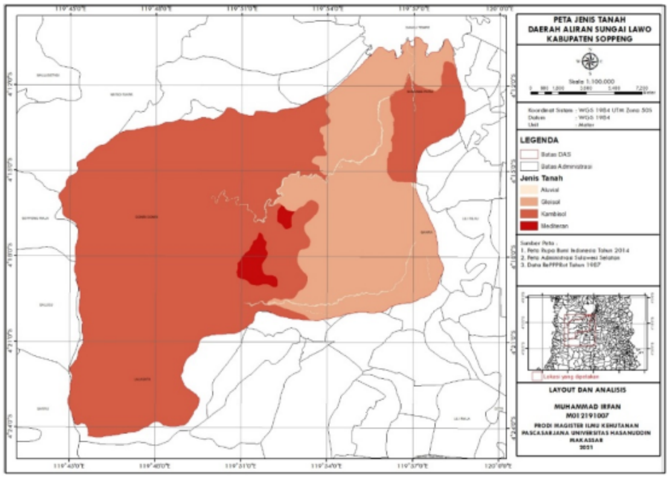

Figure 2. Lawo watershed soil type map.

Figure 2 shows that the dominant type of cambisol soil in the Lawo watershed area. Cambisol soil is another soil that shows hydromorphic properties within a depth of 50 cm from the surface, does not have a characteristic horizon (unless> 50 cm of new material is buried) other than A horizon, H horizon, B horizon cambic, calcic or gypsic. The results of scoring and weighting for soil types can be seen in Table 10.

Table 10. Soil Type Classification Score.

Soil Type	Infiltration	Score (S)	Weight (W)	Total (SxW)	Large(ha)	Percentage (%)
Alluvial	Slow	5	15	75	215.11	0.56
Gleisol	Slow	5	15	75	11,290.90	29.42
Kambisol	Rather fast	2	15	30	26,293.26	68.52
Mediteran	Moderate	3	15	45	573.61	1.49
Amount					38,372.87	100

Source : Secondary data processed in 2020

Table 10 shows that the distribution of gleisol soil types that are prone to flooding has an area of 11,290,90 ha or 29% of the total area of the Lawo watershed with the largest number of values being 75. Kambisol soil has a rather fast infiltration sensitivity level, while for alluvial soil types and gleisols are sensitive to slow infiltration.

3.3 Rainfall

Rainfall is the amount of water that fell from the sky in an area within a certain time. The higher the average rainfall, the higher the potential danger of flooding, and vice versa. The lower rainfall, the more secure from the threat of flooding. Distribution of the average rainfall in the watershed Lawo during the years 2010 - 2019 are presented in the following Figure 3.

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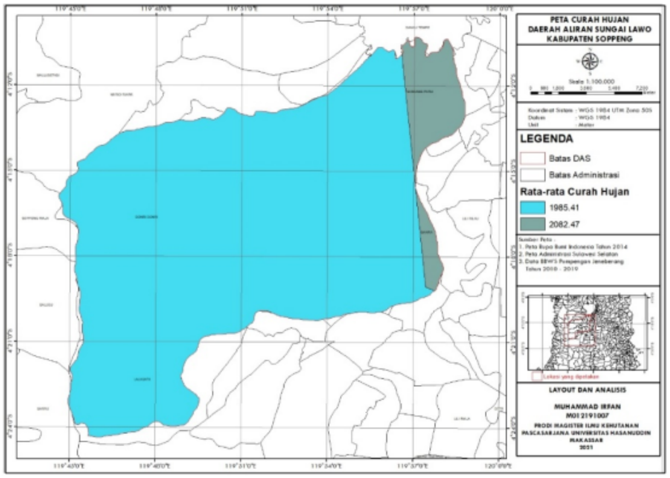

Figure 3. Lawo Watershed Rainfall Map.

Figure 3 shows that most of the Lawo watershed area has an average rainfall of 1,985.41 mm / year. The results of the scoring and weighting of the rainfall parameters can be seen in the following Table 11.

Table 11. Rainfall Classification Score.

Rainfall (mm/year)	Score (S)	Weight (W)	Total (SxW)	Large (ha)	Percentage (%)
2,082.47	3	10	30	2,770.16	7.22
1,985.41	2	10	20	35,602.71	92.78
Amount				38,372.87	100

Source : Secondary data processed in 2020

Table 11 shows that rainfall of 1,985.41 has an area percentage of 92.78%. This rainfall is included in the dry category, so the Lawo watershed when viewed from the rainfall factor has a less prone level of flood vulnerability.

3.4. Land use

Land use is a manifestation of human activity in utilizing its natural environment to meet needs in supporting life and success [9,10]. Human activities on earth are dynamic, so every year there will be changes in land use on the earth's surface. The distribution of land use in the Lawo watershed is presented in the following Figure 4.

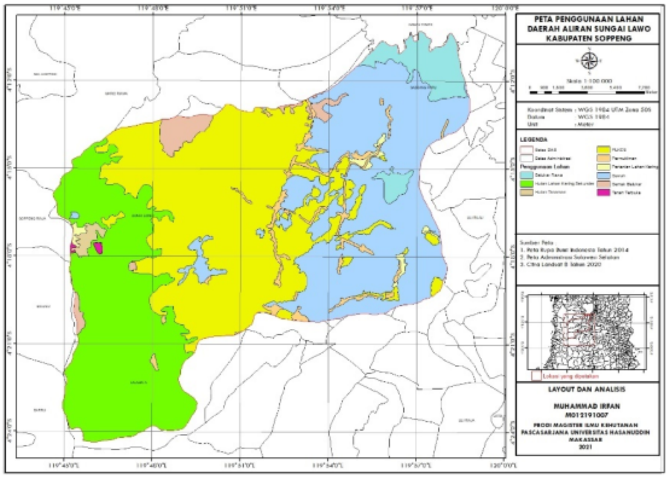

Figure 4. Lawo Watershed Land Use Map.

Figure 4 shows that the dominant land use in the Lawo watershed is dryland agriculture mixed with shrubs and rice fields and secondary dryland forest. The distribution of secondary dry land forest is located in the upstream part of the watershed, rice fields are located in the downstream part of the watershed, while dryland mixed bush agriculture is located between secondary dry land forest and rice fields. The results of the scoring and weighting of land use parameters can be seen in Table 12.

Table 12. Land Use Classification Score.

Land Use	Score (S)	Weight (W)	Total (SxW)	Large (ha)	Percentage (%)
Secondary Dryland Forest	1	20	20	9,853.46	25.68
Plantation Forest	1	20	20	206.75	0.54
Dry Land Mixed Shrub Farm	2	20	40	13,572.47	35.37
Open Land	3	20	60	44.84	0.12
Dryland Agriculture	3	20	60	259.47	0.68
Shrubs	2	20	40	835.72	2.18
rice field	4	20	80	11,011.29	28.70
Settlement	5	20	100	949.12	2.47
Thicket Swamp	4	20	80	1,639.74	4.27
Amount				38,372.87	100

Source : Secondary data processed in 2020

Table 12 shows that the Lawo watershed, 35% of its area, is dominated by dry land mixed with shrubs. In addition, there are rice fields with a total weight of 80 which dominate the Lawo watershed with an area of 11,011.29 ha (28.7%) of the total watershed area. The large area of rice fields increases the potential for flooding in the Lawo watershed. The vegetation in the rice fields is not strong enough to withstand the flow of surface water and increase the occurrence of erosion. The forest area in the Lawo watershed is 9,853.46 ha or 25.68%. The existence of forests can reduce the risk of flooding in the Lawo watershed.

3.5. Altitude

Altitude is the elevation level location measured from the lowest point is sea level. Altitude is one of the factors or parameters to measure the danger of flooding. The elevation of the Lawo watershed is shown in the following Figure 5.

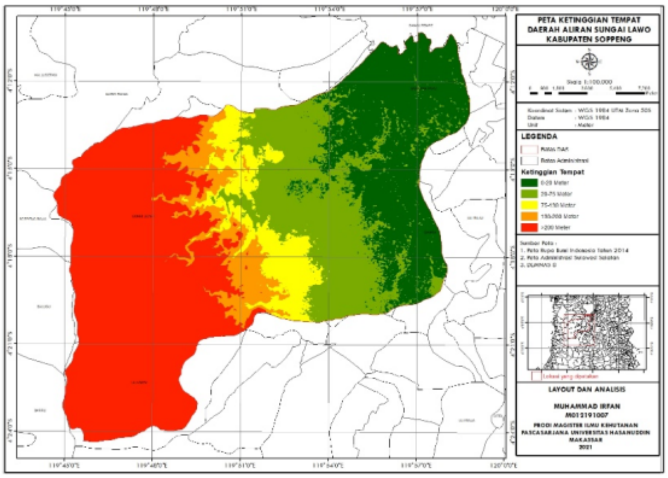

Figure 5. The Lawo Watershed Elevation Map.

Figure 5 shows the widest distribution of altitude in the Lawo watershed, with an altitude of more than 200 m spread over the upper watershed. The results of the scoring and weighting of the altitude parameters can be seen in Table 13.

Table 13. Place Altitude Classification Score.

Place Altitude	Score (S)	Weight (W)	Total (SxW)	Large (ha)	Percentage (%)
0 - 20 Meter	5	15	75	8,551.60	22.29
21 - 75 Meter	4	15	60	7,855.84	20.47
76 - 130 Meter	3	15	45	3,068.82	8
131 - 200 Meter	2	15	30	2,593.90	6.76
> 200 Meter	1	15	15	16,302.71	42.48
Amount				38,372.87	100

Source : Secondary data processed in 2020

Table 13 shows that the Lawo watershed is dominated by an altitude of > 200 meters with an area of 16,302.71 (42.48%) of the total watershed area. The higher a place, the lower the level of vulnerability to flooding. Surface water flow will move from a high surface to a low surface due to gravity and water will tend to pool in that place before heading to the sea or lake.

3.6. Distance from river

Rivers affect the occurrence of flooding. When the river's capacity is not able to accommodate the water discharge, the water will stagnate in the area around the river. The distance from the river in the Lawo watershed can be seen in the following Figure 6.

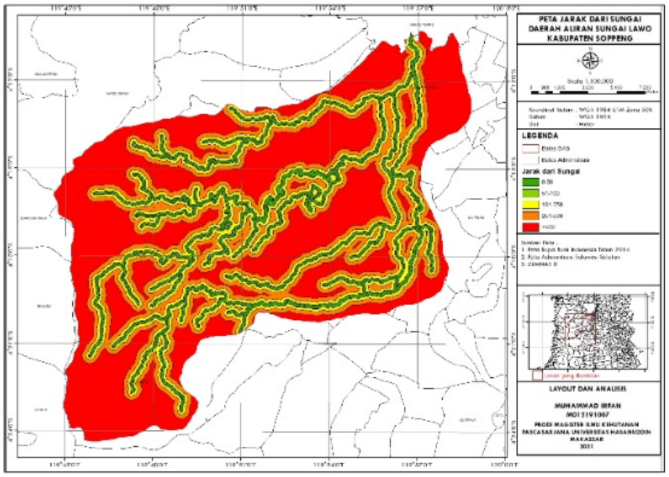

Figure 6. Distance map of the Lawo river basin.

Figure 6 shows that the flow pattern of the Lawo River Basin is rectangular. The pattern of rectangular flow is the flow pattern found in areas that have structural faults, either in the form of the actual fault or just joints (cracks). This pattern is a right-angled flow pattern. The results of the scoring and weighting of the distance parameters from the river can be seen in the following Table 14.

Table 14. Classification score of Distance from River.

Distance from river (m)	Score (S)	Weight (W)	Total (SxW)	Large (ha)	Percentage (%)
0 - 50	5	10	50	2,480.27	6.46
51 - 100	4	10	40	2,299.30	5.99
101 - 250	3	10	30	6,394.78	16.66
251 - 500	2	10	20	8,587.72	22.38
> 500	1	10	10	18,610.80	48.50
	Amount			38,372.87	100

Source : Secondary data processed in 2020

3.7. Flood Vulnerability

Maps that have gone through the scoring and weighting stages will be overlaid gradually so as to produce a flood vulnerability map. The results of the flood susceptibility map are presented in the following Figure 7.

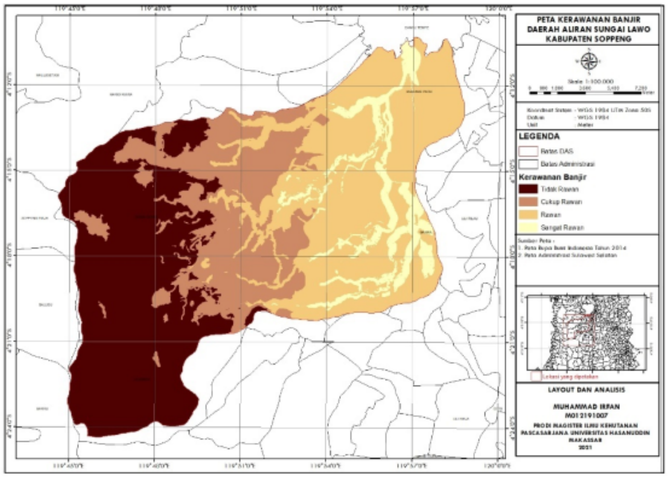

Figure 7. Lawo watershed flood vulnerability map.

Figure 7 shows that in the Lawo watershed there are two levels of flood hazard that dominate, namely not prone to flooding and prone to flooding. The non-prone category is found in the upstream watershed area, while for the flood-prone area there is a downstream watershed area. The level of vulnerability in the Lawo watershed can be seen in Table 15.

Table 15. Flood Vulnerability Level in the Lawo Watershed.

Level of vulnerability	Large (ha)	Percentage (%)
Not Prone	13,923.35	36.28
Enough Prone	8,574.72	22.35
vulnerable	13,172.35	34.33
Very Prone	2,702.45	7.04
Amount	38,372.87	100

Source : primary data processed in 2020

Table 15 shows that the non-flood-prone category has an area percentage of 36.28% and the flood-prone category is 34.33%. This category of not prone to flooding must be maintained both from the vegetation contained in it and other factors that cause flooding. For the category of flood-prone, the level of vulnerability will increase to become very prone to flooding if repairs or disaster migrations are not carried out immediately.

4. Conclusion

The distribution of flood-prone areas in the Lawo watershed is divided into four categories, namely very flood-prone, flood-prone, moderately flood-prone, and not flood-prone. The level not prone to flooding is the widest area with an area of 13,923.35 ha (36.28%) of the watershed area, while the flood-prone level has an area of 13,172.35 ha (34.33%), the level is quite prone to flooding with an area of 8,574.72 ha. (22.35%), and the level is very prone to flooding with an area of 2,702.45 ha (7.04%). Areas that are included in the flood-prone category are located in the lower reaches of the Lawo watershed while the area for the non-flood-prone category is located in the upstream part of the Lawo watershed.

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