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ANALYSIS OF FLOOD-PRONE AREAS USING GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

Tolitoli Regency is an area that often experiences regular floods every year, one of the areas that are often affected by flooding is the Lampasio District, flood disasters that often occur in the District of Lampasio have many impacts on the community and the environment. Based on this background, flood-prone research was carried out in Lampasio District to mitigate disasters. This study uses primary data and secondary data in the form of topographic data, slope, geology, and soil types, as well as rainfall data and land use data. The purpose of this research is to be able to get the level of flood vulnerability with a Geographical Information System. The results of the analysis show that Lampasio District has an area with the highest level of flood vulnerability covering an area of 1,274.31 Ha or 2.04%, then in the area that is included in the moderate flood vulnerability level is 18,765.93 Ha or 30.03% of the total area. , and areas that are included in the low level of vulnerability are 2,444.60 Ha or 67.93% of the total area in Lampasio District.

Keywords: flood, geographical information system, region, Lampasio.

1. INTRODUCTION

Flood disaster is a natural occurrence that is difficult to predict because it comes suddenly with uncertain periodicity, except for areas where annual floods are regularly affected. There are at least five important factors that cause flooding in Indonesia, namely the factor of rain, the factor of destruction of retention of river basins, the factor of development planning errors, river flow, river silting factors, and factors of errors in zoning and construction of facilities and infrastructure (Matondang *et al*., 2013).

Flood-prone areas are usually located in flat areas, close to rivers, basins, and tidal areas. While the formation of floods is generally found in low areas as a result of repeated flooding, this area usually has a high soil moisture level compared to other areas that are rarely affected by flooding. This high soil moisture condition is caused by the shape of the land consisting of fine material deposited from the flooding process and poor drainage conditions so that the area is prone to water inundation(Pratomo, 2008).

Flood is water runoff that exceeds the normal water level so that it overflows from the riverbed which causes inundation on low land on the side of the river. Floods are usually caused by rainfall that is higher than normal (Harto, 1993) and the influence of surface runoff, which can cause erosion (Naharuddin *et al*., 2019; Naharuddin *et al*., 2021). As a result, the water drainage system consisting of naturalist rivers and tributaries as well as the existing artificial flood drainage and canal systems is unable to accommodate the accumulated rainwater so that it overflows (Kusumasari, 2014). In this research, the flood in question is the flood that occurs in Lampasio District.

The incidence of flooding in the District of Lampasio is increasing along with the increase in land use activities in the District of Lampasio. In addition, the flood that occurred in Lampasio Sub-district also inundated hundreds of houses and caused 4 people to die, and Emergency Response Status was issued by the Tolitoli Regent and was valid for 14 days (BPBD, 03/06 2017) and according to (Dwiputra, 2018) it needs improvement awareness of all parties.

There are currently many GIS applications for flood-prone mapping (Primayuda, 2006), (Purnama, 2008), (Prasetyo, 2009), (Damanik and Restu, 2012), (Haryani, 2012), (Renwarin *et al*., 2014) (Hamdani *et al*., 2014), (Santosa *et al*., 2015), (SINAGA, 2016), (Darmawan and Suprayogi, 2017), (Nurdiawan, 2018), (Samela *et al*., 2018), (Iskhak and Putra, 2019), (Ujung *et al*., 2019), (Hamdikatama, 2020), but no one has conducted evaluation-based zoning mapping to minimize flooding.

2. MATERIALS AND METHODS

2.1 Formulation of the Problem

Based on the above background, it turns out that flood disasters that often occur in the District of Lampasio have many impacts on the community and the environment and because the availability of maps of flood-prone areas is one of the mitigation efforts in minimizing disasters. Based on the results of observations that have been made at the research location, the formulation of the problem in this study is how wide the distribution of flood hazard levels using GIS in Lampasio District, Tolitoli Regency, Central Sulawesi Province as an effort to mitigate disasters.

2.2 Goals and Usage

This study aims to determine the extent of distribution of flood hazards using GIS in Lampasio District, Tolitoli Regency, Central Sulawesi Province as an effort to mitigate disasters.

This research is expected to provide an overview and information to the wider community, especially those in the Lampasio District area and it is hoped that it will be able to become a reference for the government in handling

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floods in Tolitoli Regency, especially in the Lampasio District, Tolitoli Regency, Central Sulawesi Province.

2.3 Tools and Materials

The research tools used are as follows:

a) Global Positioning System (GPS) For determining the position of observation points in the field.
b) Cameras, for taking documentation in the field.
c) ArcGis program version 10.4.1 for processing spatial data (making digital maps) and analyzing Landsat images.
d) Microsoft Word 2013 program for compilation and reporting
e) Microsoft Excel 2013 program for spatial data calculations
f) Computer, for operating data processing software.

The materials used in this study are used scale 1: 250.000 as follows:

a) Rainfall data for the last 5 years (2014-2018)
b) Visible Map of Indonesia (RBI).
c) Map of soil types in Lampasio District.
d) Map of land use in Lampasio District.
e) Map of the Lampasio District Watershed.
f) Map of the slope of the slopes of the Lampasio District.

2.4 Method of Research

The method used in this research is the scoring method and the overlap (overlay). The stages of the research procedure that will be carried out are as follows:

a) Collecting data and maps related to the object of research. The maps needed are slope maps, soil type maps, altitude / topographic maps, and rainfall maps.
b) Equalizing the projection system for each map.
c) Scoring.
d) Overlay the slope map, rainfall map, soil type map, land use map, elevation map, and river buffer map.
e) Sum the score of each parameter, which is then entered into the criteria to determine the area based on its function.
f) Field checks at several location points are the object of research.
g) Finalize the map.

2.5 Data Collection Technique

Data collection is aimed at analyzing the flood-prone areas that occur in Lampasio District, starting from land use and so on. The data collection includes:

A. Secondary Data Collection

Secondary data, namely, data obtained not directly from the object or subject. Secondary data were obtained from BMKG Meteorology Class III Lalos Toli-Toli, BPS Tolitoli Regency, BAPPEDA. Starting from the rainfall data for the last 5 years, the RBI map, the district administration map, the land use map, the river map, and the slope map.

B. Primary Data Collection

Primary data is data that is directly taken or collected from the field, namely in the form of survey data and field observations.

C. Analysis of Data

The method used in this research is the scoring and overlay method. Through this method, an overlapping system is carried out on the parameters required in the study. The parameters used are maps of soil type, land slope, land use, river density, and rainfall data.

D. Flood Hazard Analysis with Scoring

Scoring is a method of scoring or scoring each parameter value to determine its level of ability. This assessment is based on predetermined criteria.

The parameters used in flood vulnerability according to (Kusumo and Nursari, 2016) can be seen in the following table:

a. Slope (L)

The slope class has 5 classes, each of which will be one of the criteria for determining flood hazard. The criteria for slope class can be seen in the following Table-1:

Table-1. Criteria and scoring of sloping.

Class	Slope (%)	Classification	Score
1	0%-8%	Flat	9
2	8%-15%	Sloping	7
3	15%-25%	Slightly Steep	5
4	25%-40%	Steep	3
5	>40%	Very Steep	1

Source: (Kusumo and Nursari, 2016)

b. Type of soil (T)

Soil type is used to determine soil types based on their level of sensitivity to erosion. Soil type is one of the factors in determining flood-prone. The criteria can be seen in Table-2 below:

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Table-2. Criteria and scoring type of soil.

Class	Criteria	Remark	Score
1	Regosol	Fast	1
2	Alluvial	Rather fast	3
3	Andosol	Rather fast	3
4	Latosol	Moderate	5
5	Cytosol Mediterat	Slightly	7
6	Grumose	Slow	9

Source: (Kusumo and Nursari, 2016)

c. Rainfall (CH)

Rainfall is the amount of water that falls in a certain area. The lower the rainfall, the safer it will be from floods. The classification used can be seen in Table-3 below:

Table-3. Criteria and scoring rainfall.

Class	Description	Average Rainfall	Score
1	Very low	0-1.000	1
2	Low	1.000-1.500	3
3	Moderate	1.500-2.500	5
4	Light	2.500-3.500	7
5	Very Light	3.500-5.000	9

Source: (Kusumo and Nursari, 2016)

d. Landuse (L)

Land use will affect the flood vulnerability of an area land use will play a role in the amount of runoff from rain that has exceeded the infiltration rate. The classification used can be seen in Table-4 below:

Table-4. Criteria and scoring land use.

Class	Criteria	Remark	Score
1	Wooded	Very good	1
2	Plantation, Shrubs	Good	3
3	Agriculture, Rice Fields	Moderate	5
4	Settlement	Not good	7
5	Land Without Vegetation	Very Poor	9

Source: (Kusumo and Nursari, 2016)

e. Area Distance to River (S)

The closer an area is to a river (Buffer), the higher the chance of flooding. The scoring parameters can be seen in Table-5 below:

Table-5. Criteria and scoring parameter Buffer.

Class	Distance (m)	Score
1	0-25	9
2	25-50	7
3	50-75	5
4	75-100	3
5	>100	1

Source: (Kusumo and Nursari, 2016)

f. Elevation (E)

Elevation affects the occurrence of flooding, because based on the nature of water, water flows from high areas to low areas. The scoring for the height class can be seen in Table-6 below:

Table-6. Criteria and scoring parameter of elevation.

Class	Elevation (m)	Score
1	< 100	1
2	100-500	3
3	500-1.000	5
4	1.000-2.000	7
5	2.000-3.000	9

Source: (Kusumo and Nursari, 2016)

A. Weighting

While the weighting method or also called weighting is a method used when each character has a different role or if it has several parameters to determine land capability or the like.

The weighting values used in the flood hazard parameters can be seen in Table-7 below:

Table-7. Weighting of flood prone.

No	Parameter	Weight (%)
1	Rainfall	15
2	Slope	10
3	Type of soil	10
4	Landuse	25
5	Elevation	20
6	Buffer River	20
Amount	100	

Source: (Kusumo and Nursari, 2016)

B. Determination of Vulnerability Value

The value of an area's vulnerability to flooding is determined from the total score of the six parameters that affect flooding (rainfall, slope, soil type, land elevation,

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and land use). According to Kingma, 1991 in (Kusumo and Nursari, 2016) the value of vulnerability is determined using the following equation:

$$K = \Sigma Wi \times Xi$$

Where:

K = Vulnerability Value
Wi = Weights For Parameters to-i
Xi = Score Class Parameters to-i

C. Determination of Total Score

Determination of the Total Score is carried out to obtain the total value of all parameters that have been evaluated. The formula used in the overlay process with the arithmetic method is as follows:

$$KB = 2 \times CH + 1 \times KL + 1 \times JT + 2.5 \times PL + 1.5 \times E + 2 \times BS$$

Where:

KB : Flood Hazard
CH : Rainfall
KL : Slope of the Slope
JT : Soil type
PL : Land Use
E : Elevation / Altitude
BS : Buffer River

D. Class Interval Determination

Class intervals are used to classify overlay results into levels of flood hazard. The class interval can be calculated using the Sturgess formula, i.e.:

C_i =

Where:

Ci = Class Interval
Xt = Biggest Score
Xr = Smallest Score
K = Number of Classes

3. RESULTS AND DISCUSSIONS

Parameters for Determination of Flood Prone Areas.

Mapping of flood-prone areas and risks in Lampasio Sub-district, Toli-Toli Regency, was obtained through the scoring and overlay results of 3 hazard parameters and 3 risk parameters. For more details, see the following tables:

3.1 Rainfall

Based on the rainfall data obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) of the Sultan Bantilan Toli-Toli Class III Meteorological Station for the last 5 years, the following classification results are obtained:

Table-8. Result of criteria and according to rainfall.

No.	Criteria (mm /year)	Remark	Score
1	1.500-2.500	Moderate	5

Source: Data Processing Results 2019

Rainfall is one of the factors in determining flood-prone areas. Prone or not an area, depending on the intensity of rainfall and slopes in the area. The higher the rainfall in an area, the higher the potential for flooding. Based on the results of the classification and processing of rainfall data in Lampasio District, it is known that the rainfall around Lampasio District is moderate rainfall with an area of 62,484.84 Ha.

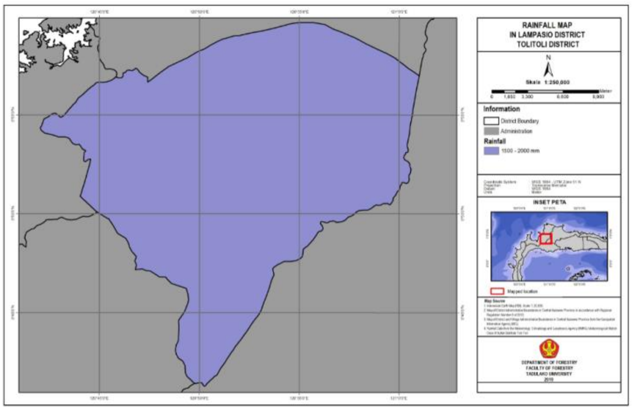

Figure-1. Rainfall map.

3.2 Slope

The slope of the slope greatly affects the process of flooding. The flat slope has a high level of flood vulnerability, while the steep slope does not significantly affect the occurrence of flooding. For more details, see the following table:

Table-9. Results of classification and scoring slope.

No.	Slope (%)	Description	Score
1	0-8	Flat	9
2	8-15	Sloping	7
3	15-25	Slightly steep	5
4	25-40	Steep	3
5	>40	Very steep	1

Source: Data Processing Results 2019

Based on the classification results table above, it can be seen the score of each slope unit. The size of the score is based on the characteristics of the slope and its effect on flooding. Flat slopes have a higher level of flood vulnerability than very steep slopes. In Lampasio District, the widest slope of the slope, which is steep, has a percentage of 25 - 40% with a land area of 17,702.38 Ha, while the smallest slope is 8-15% with a land area of 2,940.34 Ha. Based on these data,

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it can be seen that gentle slopes are spread over residential and weaving areas while steep slopes are scattered in forested areas.

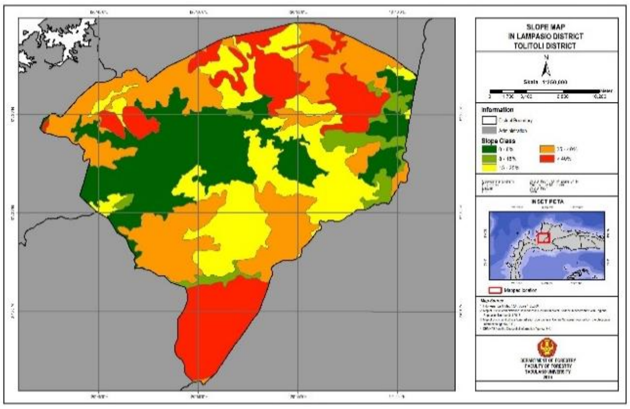

Figure-2. Map of land slope.

3.3 Land Use

Land use will affect the amount of runoff water resulting from rain that has exceeded the infiltration rate.

Table-10. Results of classification and scoring land use.

No	Criteria	Remark	Score
1	Without Vegetation	Very Poor	9
2	Settlement	Not good	7
3	Agriculture, Rice Fields	Moderate	5
4	Plantation, Shrubs	Good	3
5	Wooded	Very good	1

Source: Data processing results 2019

Based on the classification table and scoring of land use parameters, it can be seen the score of each land use unit. The size of the score is based on the characteristics of each type of land use and its effect on flooding. The land use in Lampasio District is dominated by forested areas with an area of 36,354.09 hectares. While the use of existing land in the area which is the center of activity is dominated by plantations and shrubs with an area of 12,635.48 hectares, agriculture, rice fields and moor with an area of 12,414.01 hectares, settlements with an area of 758.79 hectares, and without vegetation with an area of 322.47 Ha.

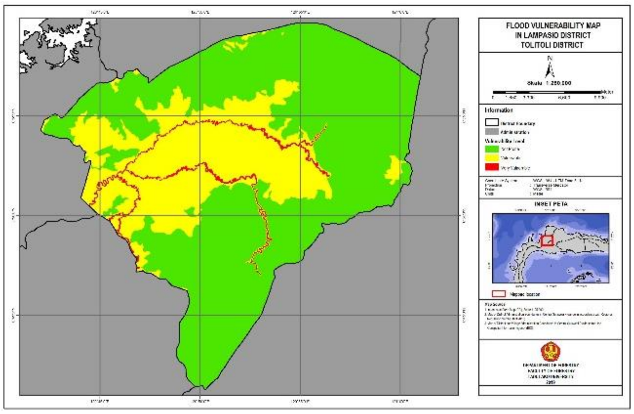

Figure-3. Map of land use.

3.4 Type of Soil

Table-11. Result of classification and scoring type of soil.

No	No Soil Type Texture Score	No Soil Type Texture Score	No Soil Type Texture Score
1	Yellow	Moderate	7
2	Cytosol	Smooth	3

Source: Data processing results 2019

The scoring of soil types is based on the texture of each type of soil. Soils with very fine textures have a high chance of flooding, while coarse textures have a low chance of flooding. This is because the finer the soil texture, the more difficult it is to absorb water into the soil so that inundation can occur in the surface area. Lampasio sub-district has 2 classifications of soil types, namely Podsolic Red Yellow with medium soil texture criteria and Alluvial Hydromorphous, Organosols with fine soil texture. This soil texture also affects the occurrence of flooding because the absorption capacity of water is not very sensitive, allowing water to stagnate above the ground surface.

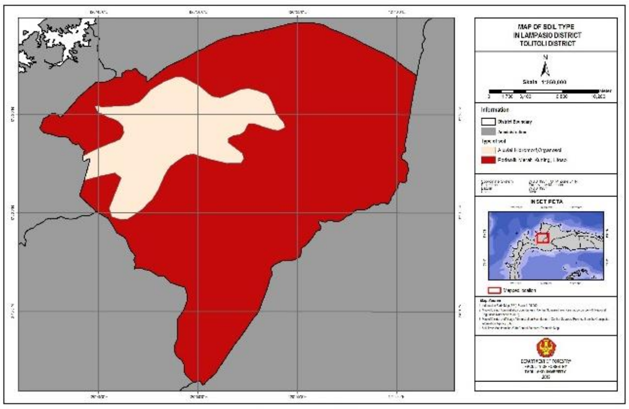

Figure-4. Map of soil type.

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3.5 Elevation

Table-12. Result of classification and scoring elevation.

No. Altitude (masl) Score	Altitude (mdpl)	Score
1	0 -100	9
2	100-500	7
3	500-1000	5
4	1000-2000	3
5	2000-3000	1

Source: Data processing results 2019

Based on the classification table and altitude scoring, it can be seen that the altitude in Lampasio District and its area. The altitude in the Lampasio sub-district is dominated by altitudes ranging from 100 - 500 masl. The assignment of an altitude score based on its effect on flooding. The height affects the occurrence of flooding because based on the nature of the water, water flows from high areas to low areas. Where the higher area has little potential for flooding. Meanwhile, the lower area has a higher potential for flooding. So that the lowest score is given at an altitude of 2,000 - 3,000 MSL because it has a very high altitude. Meanwhile, the highest score is given to the area less than 100 MSL which has a low area, because the possibility of flooding is very high.

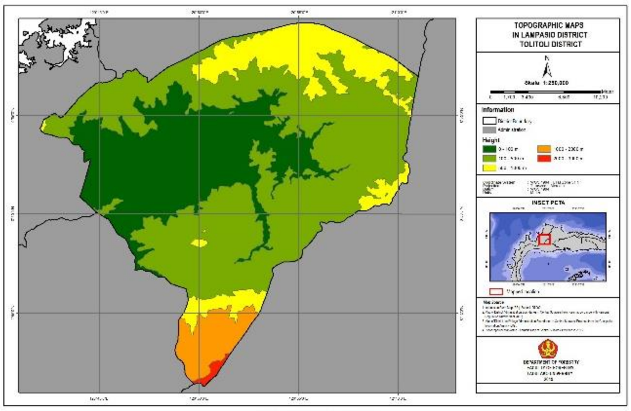

Figure-5. Map of elevation.

3.6 Bufferof River

Table-13. Result of classification and scoring of a parameter of river Buffer.

No.	Class	Score
1	0-25	9
2	25-50	7
3	50-75	5
4	75-100	3
5	< 100	1

Source: Data processing results 2019

Based on the results of river buffer classification, it can be seen that the closer an area is to the river, the higher the chance of flooding. Therefore, the highest score is given to an area that is very close to the river, namely a distance of 25 m with a score of 9 with a land area of 901.32 ha. Conversely, if the distance of an area is further away from the river, the score given will be lower. The proximity of an area to a river greatly affects the occurrence of flooding in an area. Therefore, we must know how far away the area is right to build a settlement that is close to the river. So that we can reduce the chances of flooding that can harm residents.

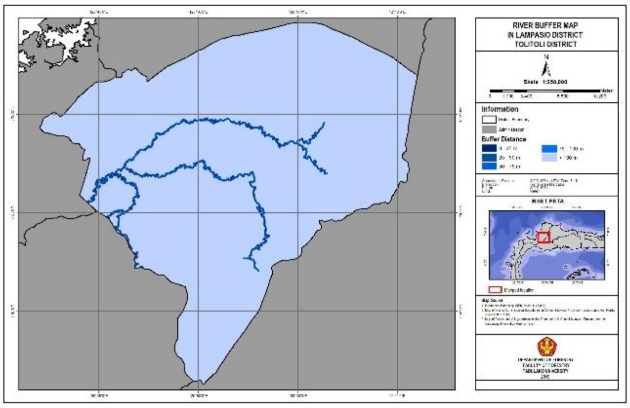

Figure-6. Map of river buffer.

a) Weighting

Weighting using the method of expert judgment, namely the opinions of experts. The weighting value is done qualitatively depending on the "opinion of the experts". Based on the opinion of appointed experts, the highest weight is given to the land use parameter, because whether or not it is prone to flooding in an area is largely determined by land use in the area. Where, the more open the land is, the greater the potential for flooding to occur. Followed by elevation parameters and river buffers. Both have the same weight because both have the same effect, where the lower the height of an area and the closer the area is to the river, the greater the potential for flooding to occur. Furthermore, the parameter of rainfall, the weight of the rainfall is not too high but it is quite influential on flooding. Where, the higher the rainfall in an area, the possibility of flooding will be higher. Then the parameters of soil type and slope, according to the experts' opinion, that the effect of soil type and slope does not have a big effect on flooding compared to other parameters. Thus, the weight given is the lowest compared to other weights (Kusumo and Nursari, 2016).

For weighting the parameters of flood hazard can be seen in the following table:

Table-14. Result of scoring of parameter prone flood.

No.	Parameter	Weight (%)
1	Rainfall	15
2	Slope	0
3	Type of soil	0
4	Land Use	25
5	Altitude / elevation	20
6	Buffer River	20
Total		100

Source: (Kusumo and Nursari, 2016)

b) Flood Hazard Level Analysis

The level of flood vulnerability is an event of sinking land (which is usually dry) due to the increased volume of water in each unit of land obtained based on the value of flood hazard. In most areas where the soil has poor water absorption or the amount of rainfall exceeds the soil's ability to absorb water. When heavy rains fall, what sometimes happens is sudden flooding caused by filling dry drains with water (Suhardiman, 2012)? The formula used in the overlay process with the arithmetic method is as follows:

KB = 1, 5 x CH+ 1 xKL+ 1 x JT+ 2,5 x PL+2 x E+ 2 x BS

Where:

KB : Flood Hazard
CH : Rainfall
KL : Slope of the Slope
JT : Soil type
PL : Land Use
E : Elevation / Altitude
BS : Buffer River

Based on the analysis of the level of flood hazard in Lampasio District, the classification of hazard levels is obtained as follows:

Table-15. Result of classification flood hazard level.

No	Hazard Level	Description of zone	Area(Ha)	(%)
1	Not Prone	100-366	42.444,60	67,93
2	Prone	367-663	18.765,93	30,03
3	Very Prone	664-900	1.274,31	2,04
Total			62.484,84	100

A. Flood-Prone Zone

The zone that is not prone to flooding can be said as a safe area against the possibility of flooding. This is because this area is classified as highland, with land use that is still a lot of vegetation, and the distance is far from the river. The steep slope causes runoff flow to be rapid and does not inundate the area, so the risk of flooding is small. Based on the results of the analysis, the level of flood vulnerability classified as non-prone areas is 42,444.60 Ha or 67.93% of the total area.

B. Flood Prone Zone

This zone is a critical area for flooding. This area is located in the lowlands and is located in the central area of activity. The type of flooding in this area is not very high. Usually, they are temporary inundations due to high rainfall and poor drainage. The area classified as a flood-prone zone is 18,765.93 hectares or 30.03% of the total area.

C. Very Flood Prone Zone

The very flood-prone zone is an area that is categorized as critical to flood vulnerability. Most of the areas classified as very prone to flooding are found in the river area with an area of 1,274.31 hectares or 2.04% of the total area. Areas that are very prone to flooding are areas that have a low surface level, where land use tends to have little or no vegetation so that water flows directly. Most of the very vulnerable areas are built and open areas without vegetation which causes high surface runoff, making them prone to flooding.

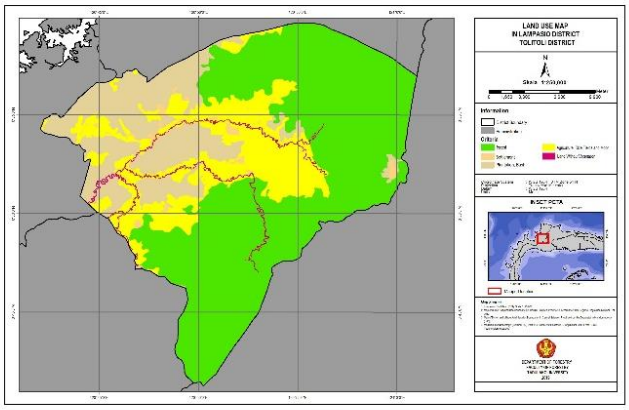

Figure-7. Map of vulnerability level.

4. CONCLUSIONS

From the results of the analysis carried out in the area of Lampasio Sub-district, Tolitoli Regency, it can be seen that the areas included in the low hazard level are 2,444.60 Ha or 67.93% of the total area, then the areas that are in the moderate level of vulnerability are 18,765. 93 Ha or 30.03% of the total area, and areas included in the high level of vulnerability are 1,274.31 Ha or 2.04% of the total area in Lampasio District.

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