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Reducing the Risk of Flood Disasters in Lamongan Regency Using the Geographic Information System (GIS)

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ABSTRACT

Flood disasters cause negative impacts, such as damage to facilities to the onset of fatalities. Reducing the risk of flooding needs to be done to reduce the impact caused by this disaster. Lamongan Regency is one of the regencies in East Java affected by floods every year in most of its areas. This study aims to reduce the risk caused by flooding by using GIS (Geographic Information System). Mitigation is done by determining areas with a high potential risk of being affected by flooding. The study used spatial analysis functions in ArcGIS. Supporting variables used rainfall, land cover, slope, soil texture, and watershed area, and it becomes important in determining flood-prone areas. From the results, the largest soil classification is the Kpl soil type. Litosol Gray Grumosol, The wide distribution of rainfall from 1500-1750 mm has the widest distribution is 66,67 ha. The slope of 0-8% has the widest distribution of 92,257 ha, making Lamongan a very vulnerable high flood area. Laren District is the District with the greatest flood potential, and Irrigated Field is the dominant land cover type affected by the flood. With the flood disaster map generated from this research, local governments can seek prevention in areas with high flood potential. They can carry out socialization based on disaster mitigation, especially for districts with potential flooding.

1. Introduction

Floods are one of the most destructive natural disasters globally, causing more widespread economic and social damage than any other natural phenomenon [1][2]. Several factors, such as the size and nature of the river, the vegetation in and around the river, the water level downstream, etc., determine whether flooding occurs in a particular area [3]. Over

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the past 30 years, flooding has become the most disturbing natural disaster globally, with an average of nearly 80 million people per year [4][5]. The inundation of rice fields, residential areas and agricultural land have caused enormous losses and suffering for the local community. The inundation of national roads will harm residents and road users. In short, flooding will generate significant social and economic damage and significantly change the environment [6].

Lamongan Regency is a district with a high level of flood vulnerability. According to the BNPB of Lamongan Regency, in 2020, Floods occupied the highest number in most disaster events in Lamongan Regency, 115 affected areas. It is necessary to carry out flood disaster management based on the data above. Several areas in Lamongan Regency are flood-prone, especially in areas traversed by the Bengawan Solo River. Areas not crossed by the Bengawan Solo River but are flood-prone include Deket and Turi sub-districts. The flood-prone area in Lamongan Regency is ± 29,273 Ha, or about 16.15% of the total area of Lamongan Regency.

In recent years, non-structural flood mitigation strategies, including land-use planning, forecasting, and applying Geographic Information Systems (GIS) and Remote Sensing, have received increasing attention [7]. Utilizing today's increasingly sophisticated technological developments can prob solve the flood problem [8]. Modeling the distribution of flood-prone areas using remote sensing methods combined with GIS (Geospatial Information System) can help in solving flood problems [9][10]. Flood maps are currently used in disaster management. Can perform accurate flood mapping in calibration and validation with hydraulic models and assist in damage assessment and rescue operations [11]. Geospatial engineering provides a potential solution for rapid and effective flood disaster decision making; It is useful for emergency response and disaster preparedness, Building Information Models, and GIS integration tools used across transboundary areas to develop frameworks for assessing flood damage [12]. Can use the framework for frequently flooded settlements to determine flood risk. This framework provides a three-dimensional view of flooding that helps better understand the most flood-affected areas in settlements [13]. Remote sensing has been widely used in research related to flood disasters worldwide [14]. Geographic Information System (GIS) is one of the methods commonly used in flood-related studies. Its ability to store and access data makes it easier for users to use the system for management and planning [15]. The mapping method is important in this research because it provides visual information that guides the user. GIS can also measure the location of

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inundated areas and estimate the affected land and infrastructure. The main advantages of using GIS can visualize flood-prone areas and analyze potential flood areas. Mitigation can be carried out periodically by knowing the areas affected by flooding and the affected land cover [16].

Several studies have used GIS to assess flood vulnerability by combining multiple criteria, including index-based through investigating the role of factors controlling floods [17][18]. Physical flood vulnerability mapping applying geospatial techniques, e.g., in rainfall, land use, soil, slope, drainage density [19][20][21]. The most commonly used parameters in flood hazard mapping are rainfall, distance to the river, Flood forecasting, a key requirement for disaster reduction, which has been enriched by recent advances from satellite datasets and methods. Multi-spectral images are used for flood forecasting in different parts of the world. Identified three dimensions of spatial planning integration with flood risk management: territorial, policy, and institutional [23].

In this study, the identification of flood-affected areas was determined using GIS. It is important to note that this process cannot replace a comprehensive flood risk assessment of studied areas but is important as a screening tool that can help identify areas that are particularly vulnerable in the event of such a disaster. This study aims to model the distribution of flood-prone areas and flood-affected areas in the Lamongan Regency area map. In this study, GIS (Geographic Information System) imagery was used as the main material in monitoring the Lamongan Regency area to get the best modeling [24] . The processing uses several supporting variables that are no less important, including geology, soil type, rainfall, land cover, slope, and river flow. Determination of the administrative boundaries of Lamongan Regency and several flood-prone and flood-prone sub-districts using the RBI (Rupa Bumi Indonesia) map at a scale of 1:25,000. It is hoped that this research can be used as a determinant of flood-affected areas to help minimize and prevent the occurrence of early flooding in several floods and flood-prone areas in Lamongan Regency by determining maximum flood disaster mitigation.

2. Research Method

The location of this research is in Lamongan Regency with an area of 1,812.8 km^2 or occupies about 3.73% of the total area of East Java Province. Geographically, Lamongan Regency has a very strategic location because it is on the North Coast route that connects Regencies/Cities in the northern region of East Java. Lamongan Regency is located at

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6°51'54" to 7°23'6" South Latitude and 112°33'12" to 112°33'12" East Longitude. The administration of the study area of this research is Lamongan Regency as a whole, Lamongan

Regency has an area of approximately 1,812.80 km², equivalent to 181,280 Ha or + 3.78% of the total area of East Java Province with a coastline of 47 km.

The area of Lamongan Regency is divided by the Bengawan Solo River, and broadly the land is divided into three characteristics, namely:

- The Central South is a relatively fertile lowland that stretches from the Districts of Kedungpring, Babat, Sukodadi, Pucuk, Lamongan, Deket, Tikung, Sugio, Sarirejo and Kembangbahu
- The southern and northern parts are rocky limestone mountains with moderate fertility. This area consists of the Districts of Mantup, Sambeng, Ngimbang, Bluluk, Sukorame, Modo, Brondong, Paciran, and Solokoro.
- The North Central is the Bonorowo area which is a flood prone area. This area includes the Districts of Sekaran, Maduran, Laren, Karanggeneng, Kalitengah, Turi, Karangbinangun and Glagah

2.1 Topography

Can review the topography of the Lamongan Regency from the height of the area above sea level and the slope of the land. The topography of Lamongan Regency can be seen from the elevation of the area with an altitude of 0-20 m with an area of 50.17% of the area of Lamongan Regency, land with an altitude of 25-100 m covering an area of 45.68%. The remaining 4.15% are land with an altitude above 100 m.

2.2 Data Analysis

Collecting data such as SPOT 7 satellite imagery, administrative boundaries from

RBI vector maps of 1:25000 scale, rainfall data, land use data, and watershed area data. Processing Data, at this Stage, the corrected SPOT 7 satellite imagery is processed using administrative boundaries from the RBI vector map of the Lamongan Regency area. Then rainfall data, land use, and watershed area are entered to determine the classification of flood-prone areas. Processing using the NDVI algorithm is also needed to ensure green areas in flood-prone areas. Final Stage, at this Stage, modeling and making maps of flood-prone areas and analyzing data generated from data processing are carried out. Then proceed with making reports and journals.

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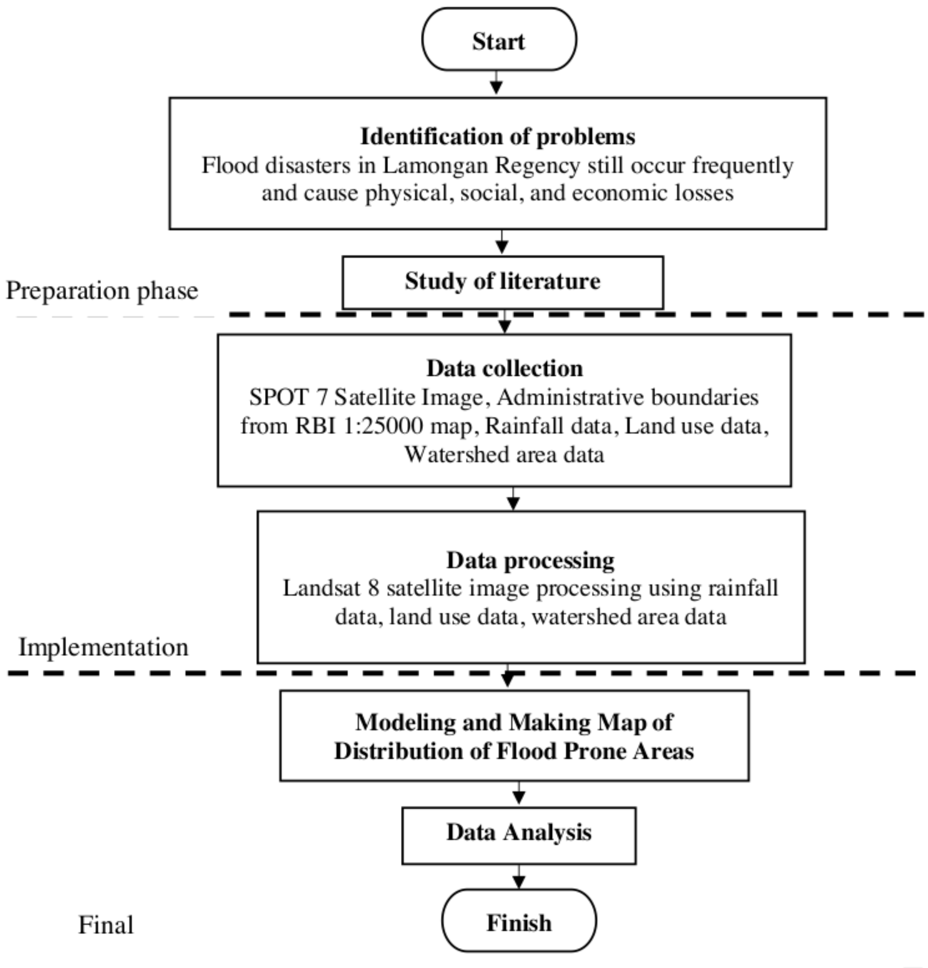
2.3 Research Flow Chart



Source. : Research Results (2021)

Figure 1. The Stages Of The Research

From *figure 1*. The following are the stages of the research: The identification and formulation of the problem in this study are that Lamongan Regency often floods and causes physical, social, and economic losses. It is necessary to map flood-prone areas for flood disaster mitigation. After identifying the problem, a literature study was conducted. Next is data collection. The data used in this study are Image of SPOT 7 Lamongan Regency 2021, the administrative boundary of the Indonesian Earth (RBI) scale 1:25,000, Lamongan

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Regency rainfall data 2016-2020, Lamongan Regenc land use data, and data on the area of the Lamongan Regency Watershed (DAS). After the data preparation stage, data processing to

continue with GIS software. The corrected GIS map was processed using the administrative boundaries of the Lamongan Regency RBI vector map. Analysis of the slope, the steeper the level of the slope, the speed of water flowing on the surface will be greater, the flatter the level of the slope, the speed of water flowing on the surface will be smaller, causing the water absorption process to take longer and cause flooding [25]. At the same time, Overlay or overlap is done to determine the prone area from several parameters that determine the flood-prone area using the scoring method. The patching results show that the area with the highest total score is potentially prone to flooding [26].

3. Results and Discussions

In the Lamongan Regency area, some areas are also frequently flooded, and the area around the Bengawan Solo river. This area has a land level that is low in the surrounding area, including lower than the height of the Bengawan Solo River. The Flood Disaster that occurred in 2021 had an impact on 17 sub-districts. In general, the presence of water in Lamongan Regency is dominated by surface water, where during the rainy season, it is found in abundance, which causes floods.

This is what causes the area to become flooded every year. This area is called Bengawan Jero. Bengawan Jero is a stretch of territory located in 6 sub-districts, namely Turi, Karanggeneng, Kalitengah, Karangbinangun, Glagah and Deket sub-districts which are located to the north of the Gresik - Babat highway. The stagnant water in this area cannot be discharged into the Bengawan Solo River because the water level of the Bengawan Solo River is higher than this area. Hence, the water remains stagnant in this area.

3.1 Type of soil

Soil capability identifies soil elements very influential soil elements in the types of land use on it. The soil capability element in question consists of the aril slope, soil texture, effective soil depth, soil surface drainage, rocky limited factors, and soil erosion.

1) Soil Texture

Soil is the layer of the earth that is form a result of weathering of the parent rock material and formed as a result of interaction with climate, living things, and parent material.

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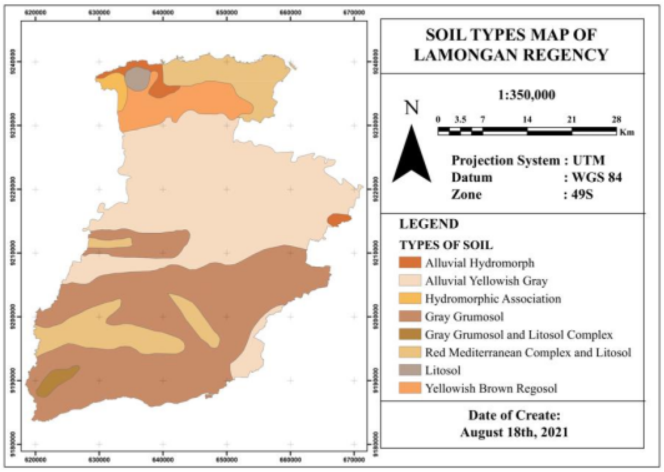
Soil type will be related to soil texture. Texture soil will affect the process of water infiltration.



Source. : Research Results (2021)

Figure 2. Soil Texture Map

In Fig. 2, Most of the areas in Lamongan Regency have a rough texture of 114,884 Ha or 63.37% of the total area. In addition, the area with an area of 63,709 Ha or 35.14% is soil with medium texture, while the soil with fine texture has an area of 2,687 Ha or 1.48% of the total area of Lamongan Regency. From the map, soil texture results are obtained with the following description in Table 1.

Table 1. Area by Land Type in Lamongan Regency

Type of soil	Area		Score	Weight	Amount
	Hektar	%			
Alluvial Hydromorph, Alluvial Yellowish Gray	69,060	38,095	5	15	75
Hydromorphic Association	0,600	0,331	4	15	60
Gray Grumosal	2,125	1,172	3	15	45
Yellowish-brown	0,350	0,193	2	15	30
Litosol, Kpl. Litosal Gray Grumosol, Kpl. Red Meter and Litosal	109,145	60,208	1	15	15
	181,280	100			

Source. : Research Results (2021)

From table 1. There are 8 types in Lamongan Regency, with the largest soil classification being the Kpl soil type. Litosol Gray Grumosol and Alluvial Yellowish Gray. Grumusol is composed of weathered limestone and volcanic tuffa. That's why the organic matter in it is so low that it is not suitable for plants. This soil color is neutral with a dry

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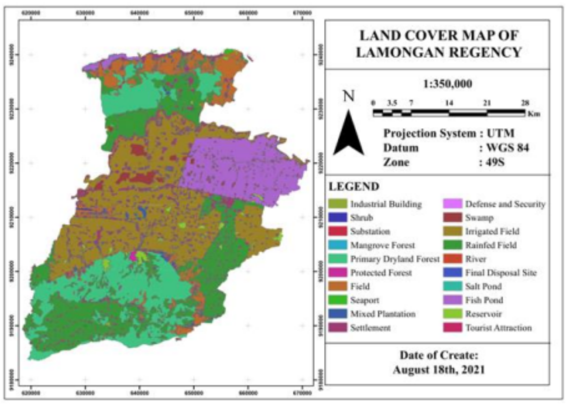
texture and breaks easily, especially in the dry season. Yellowish alluvial soil is a type of soil that has a fine texture so that it has good infiltration slow to make water easy to stagnate.

3.2 Land Cover Map

Land use is an attempt at planning land use in an area that includes the division of areas for the specialization of certain functions, such as residential, commercial, industrial, etc.



Source. : Research Results (2021)

Figure 3. Lamongan Regency Land Cover Map

Fig 3 Land use maps are opened in ArcGIS 10.1 and generated in thematics. Land use data that already has attribute data is then added to the class of vulnerability based on expertise judgment (expert validation). Land use in the Lamongan Regency area can be grouped as shown in table 2 below :

Table 2. Area by Land Use Type in Lamongan Regency

No	Land Use	Area (ha)	Percentages (%)
1	Substation	14,104	0,01
2	Mangrove forest	84,319	0,05
3	Protected forest	255,283	0,14
4	Primary Dryland Forest	31405,78	17,32
5	Industrial Building	594,685	0,33
6	Irrigated rice field	46535,96	25,67
7	Tour	66,257	0,04
8	Reservoir	1729,906	0,95
9	landfill	9,119	0,01
10	Mixed Plantation	4922,439	2,72
11	Seaports	192,461	0,11
12	Settlement	14226,97	7,85
13	Defense and security	5,156	0,00

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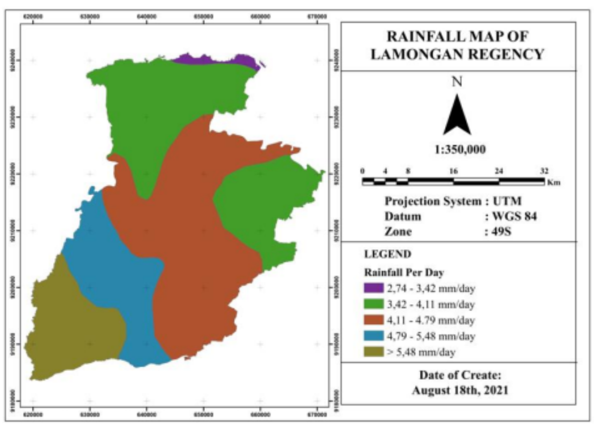
No	Land Use	Area (ha)	Percentages (%)
14	Swamp	2233,811	1,23
15	Rainfed Rice Fields	38322,58	21,14
16	Scrub	82,547	0,05
17	River	919,775	0,51
18	Salt pond	114,562	0,06
19	Fish Pond	20317,31	11,21
20	Field	13052,05	7,20
21	Other Designations	6195	3,42
		181280,1	100

Source. : Research Results (2021)

From table 2. The dominant Land use is Irrigated rice fields(25%), Rainfed Rice Fields (21 %,) and Fish Pond (11%)

3.3 Rainfall Map Analysis

Rainfall is the most important data fundamental in calculating flood discharge plans (design flood). Rain data analysis intended to get the amount of bulk calculated rain and statistical analysis to calculate the design flood discharge.



Source. : Research Results (2021)

Figure 4. Lamongan Regency Rainfall Map

In Figure 4, the digital map for The intensity of rainfall in Lamongan Regency is classified to show the value of the level of rainfall in the city of Semarang, which consists of very low, low, high, and very class tall.

Table 3. Rainfall Classification

No	Rainfall	Area (ha)	Percentages (%)
1	>2000mm/th	22,849	13,05
2	1000-1250 mm/th	1.933	1,11

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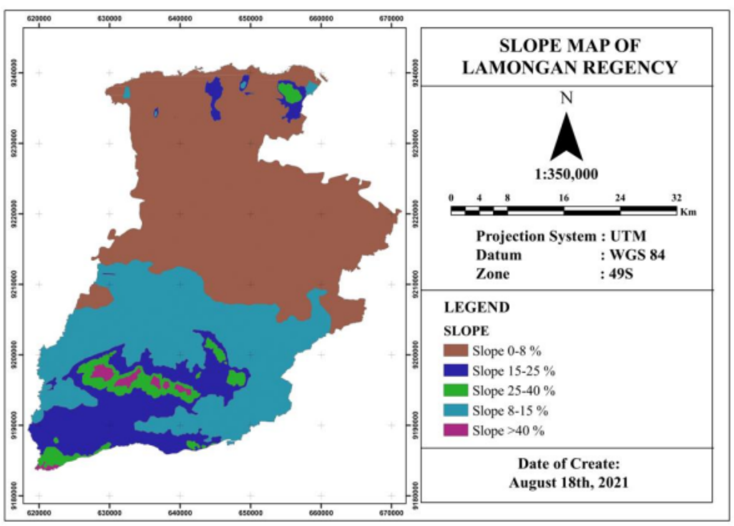
3	1250-1500 mm/th	57,088	32,61
4	1500-1750 mm/th	66,666	38,08
5	1750-2000 mm/th	26,548	15,16

Source: Research Results (2021)

Rain per District classified table 3, Rainfall Intensity per District classified is an attribute of map data digital Rainfall Intensity per District classified in Figure 6. The higher the average rainfall, the higher the potential flood hazard, and vice versa. The lower the rainfall, the safer it is from the threat of flooding. The wide distribution of rainfall from 1500-1750 mm has the widest distribution is 66,67 ha.

3.4 Slope Map

Slope affects the amount and speed of runoff surface, surface drainage, use land, and erosion. It's assumed to be more sloping slope, then the runoff flow the surface will be slow and the possibility of inundation or flooding getting bigger while getting steeper the slope of the slope will cause the flow surface runoff becomes fast so that water the rain that falls will flow directly and not flood the area, so low risk of flooding.



Source. : Research Results (2021)

Figure 5. District Slope Map

Figure 5. shows that the slope is flat (0-8%) has the broadest focused distribution in the central and northern regions. Tilt very steep (>40%) spread over the south of Lamongan Regency. The slope of the slope affects the speed & volume of surface runoff.

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Table 4. Slope Classification

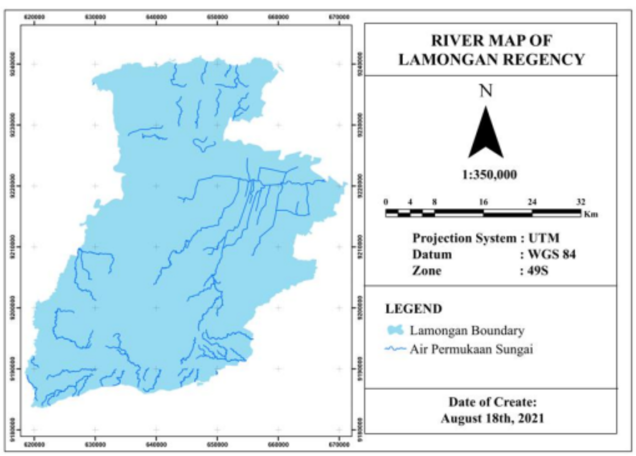
No	Slope	Area (ha)	Percentages (%)
1	>40 %	1,533	0,876
2	0-8 %	92,257	52,694
3	8-15 %	50,949	29,101
4	15-25 %	23,780	13,582
5	25-40 %	6,563	3,7485

Source. : Research Results (2021)

From table 4. The slope of 0-8% has the widest distribution of 92,257 ha. The extent of the area with a slope of 0-8% makes Lamongan have a very vulnerable area high flood.

3.5 River Buffer Map

River buffers are created to determine the distance to the right and left of the river using GIS software and determining the distance to the right and left of the river. River buffer creation is created via the vector taskbar, then select tools buffer and determine the distance between the width of the right and left of the river.



Source. : Research Results (2021)
Figure 6. Lamongan Regency River Buffer Map

Table 5. Lamongan Regency Buffer River

Buffer Distance (m)	Area (ha)	Percentages (%)
0-200	18270,313	14,642
200-500	42672,010	34,198
>500	63836,712	51,160
	124779,035	100,000

Figure 6 and Table 5, show the density of the river is in Lamongan Regency, focusing on the region Central District, namely Karanggeneng District, Kalitengah,

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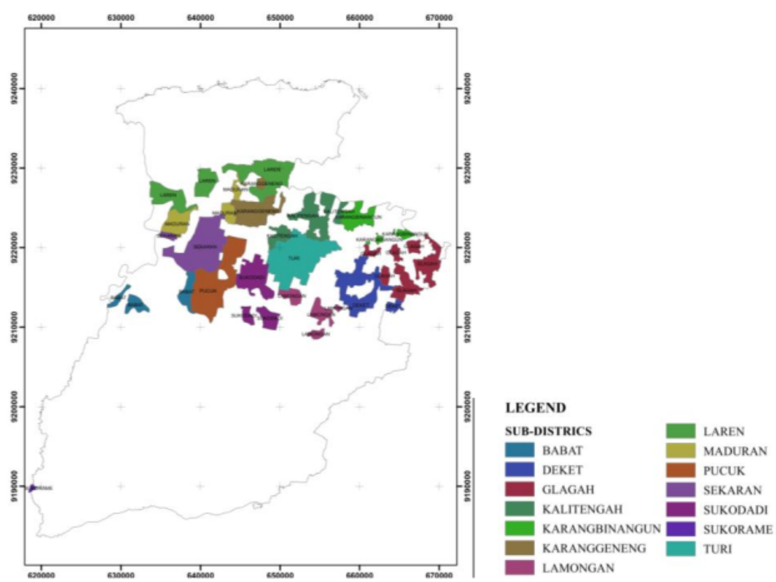
Karangbinangun, Turi, Deket, and Glagah. Rivers affect the occurrence of flooding. This shows that the flow pattern of rivers is focused on the southern and central regions. Rivers affect the occurrence of flooding. When river capacity cannot accommodate water discharge,

the water will stagnate in the area around the river so that the River Buffer Map will show a flow map. It will be easier to know the area affected by the overflow when the river overflows.

3.7 Flood Hazard Map

Using the scoring method, overlays or overlaps are carried out to determine vulnerable areas from several parameters that determine flood hazard areas. From the patching results, the area with the highest total score is an area with the potential to be a flood hazard. The overlay process is carried out in stages: done in pairs. Slope maps with elevation, soil type, rainfall, river buffer maps, and land use.

Map A and map B are overlaid. After that, generate map AB. Map AB overlaid with map C produces a map of the Flood Vulnerability Level.



Source. : Research Results (2021)

Figure 7. Lamongan Regency Flood Hazard Map

The results of the flood susceptibility map are presented in Figure 7 below. The results of overlaying land cover maps, rainfall maps, soil texture maps, slope maps, and river

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buffer maps obtained a map of flood-prone areas in Lamongan Regency with the flood area of each District.

Table 6. Lamongan Regency Flood Hazard

No	District	Area (Ha)	Percentages	Rank
1	Babat	12137,1902	3,9%	12
2	Deket	24869,6145	7,9%	6
3	Glagah	27605,9871	8,8%	5
4	Kalitengah	24612,0225	7,8%	7
5	Karangbinangun	12677,1975	4,0%	11
6	Karanggeneng	17905,1299	5,7%	9
7	Lamongan	11918,6332	3,8%	13
8	Laren	40976,9556	13,0%	1
9	Maduran	14842,1975	4,7%	10
10	Pucuk	32947,3391	10,5%	4
11	Sekaran	33150,0980	10,5%	3
12	Sukodadi	23206,8686	7,4%	8
13	Sukorame	570,5223	0,2%	14
14	Turi	37033,0904	11,8%	2
		314452,8465		

Source. : Research Results (2021)

From Table 5. Percentages Lamongan Regency Flood Hazard Map, districts that are prone to flooding include: Laren District (13%), Turi District (11,8%), Sekaran District (10,5%), Pucuk District (10,5%), Glagah District (8,8%), Deket District (7,9%), Kalitengah District (7,8%), Sukodadi District (7,4%), Karanggeneng District (5,7%), Maduran District (4,7 %), Karangbinangun District (4%), Babat District (3,9%), Lamongan District (3,8%), and Sukorame District (0,2%).

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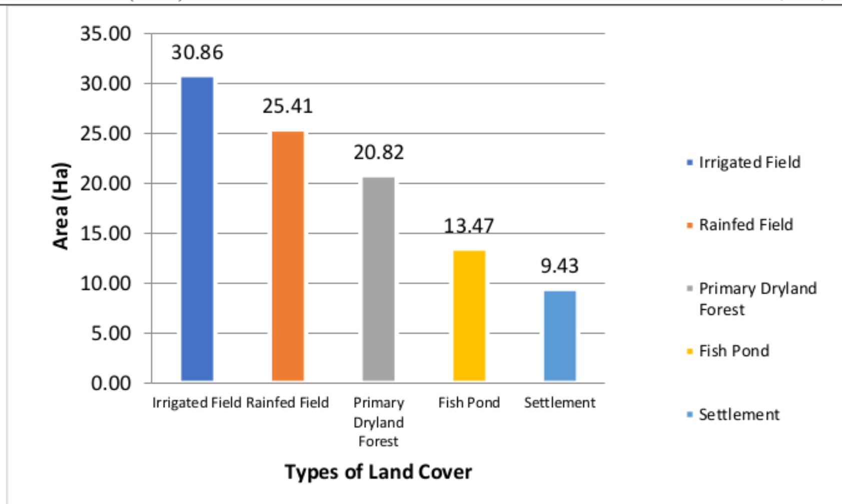

Source. : Research Results (2021)

Figure 8. Presentation of Land Cover Types Affected by Flood

Figures 8 show the land cover types affected by the flood. Meanwhile, the dominant land cover types affected by the flood were Irrigated Field (30.86%), Rainfed Field (25.41%), Primary Dryland Forest (20.82%), Fish Pond (13.47%), and Settlement (9,43%). From the results above, with the flood disaster map generated from this research, local governments can seek prevention in areas with high flood potential and carry out socialization based on disaster mitigation, especially for districts with potential flooding. To minimize victims and affected areas as well androach to disaster preparedness and planning throughout Lamongan Regency.

4. Conclusion

From the research that has been done, it is found that the highest level of potential flooding occurs in the Laren District. Lamongan has the type of soil type Kpl. Litosol Gray Grumosol has a wide rainfall distribution 1500-1750 mm and has the widest distribution of 66.67 ha. The slope of 0-8% has the widest distribution of 92,257 ha, so that Lamongan is a highly flood-prone area. The five most vulnerable sub-districts are Laren District (13%), Turi District (11.8%), Sekaran District (10.5%), Pucuk District (10.5%), and Glagah District (8.8%). At the same time, the dominant types of land cover affected by the flood were Irrigated Rice Fields (30.86%), Rainfed Rice Fields (25.41%), Primary Dry Land Forests (20.82%), Ponds (13.47%), and Settlements (9.43%). With the flood disaster map generated from this research, local governments can seek prevention in areas with high flood potential

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and carry out socialization based on disaster mitigation, especially for sub-districts that have the potential for flooding. To minimize victims and affected areas and the approach to disaster preparedness and planning throughout Lamongan Regency.

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