JOURNAL OF GREEN SCIENCE AND TECHNOLOGY

ANALYSIS OF MAPPING OF THE LEVEL OF FLOOD PRONECTION IN BOJONEGORO REGENCY BASED ON GEOGRAPHIC INFORMATION SYSTEM

Mushthofa[1*], Muhammad Chandra[1], Mochammad Qomaruddin[2], Fathur Roehman[3]

[1*]) *Civil Engineering Department, Universitas Bojonegoro, Bojonegoro.*
Corresponding Author's Email : zainmushthofa01981@gmail.com
No.HP Corresponding Author : 081330673990
[2]) *Civil Engineering Department, Universitas Islam Nahdlatul Ulama, Jepara.*
[3]) *Civil Engineering Department, Universitas Sultan Fatah, Demak*

ABSTRACT

Floods are natural disasters that often occur in various parts of the world, especially in flood-prone areas. Floods occur when water from rivers, lakes or seas overflows beyond its holding capacity. Floods can cause great damage to infrastructure, plants, animals and people. To overcome floods that occur frequently every year, it is necessary to map areas prone to flooding accurately and quickly using GIS which can be used to accurately monitor the location and area of the area that is experiencing flooding. This study aims to analyze flood-prone areas and compile maps of flood-prone areas and describe the conditions of flood-prone areas in Bojonegoro Regency based on Geographic Information Systems (GIS). Data processed using GIS include: RBI Map of Bojonegoro Regency, River Map, Soil Type Map, Rainfall Data, Landsat Imagery Data, Flood incident data in Bojonegoro Regency. From the results of data processing, the results of the analysis are as follows: The level of flood-prone areas in Bojonegoro Regency is divided into 3 classes, namely: very vulnerable class of 49,963.671 Ha or around 21.66% of the sub-districts in Bojonegoro including the District: Margomulyo , Ngraho, Padangan, Kasiman, Malo, Purwosari, Trucuk, Kalitidu, Ngasem, Bojonegoro, Kapas, Dander, Balen, Kanor, Baureno, Sumberrejo, Kepohbaru and Gondang. The vulnerable class of 173,162.171 Ha or around 75.05% is in sub-districts including: Margomulyo, Ngraho, Tambakrejo, Kedewan District, Malo, Trucuk, Sekar, Ngambon, Ngasem, Gondang, Bubulan, Dander, Temayang, Sugihwaras and Kedungadem. The non-prone class is 7,580.157 ha or 3.29% in the sub-districts including: Margomulyo, Ngraho, Tambakrejo, Kedewan, Malo, Trucuk, Sekar, Ngambon, Gondang, Temayang, Sugihwaras and Kedungadem. Areas that have a high level of vulnerability are around the Bengawan Solo River which crosses Bojonegoro Regency. This can be caused because the area around the Bengawan Solo River has a height of <25 m and frequent flooding from the upstream and tributaries of the Bengawan Solo River

Keyword: Flood, Geographic Information System (GIS), flood-prone areas.

1. INTRODUCTION

Floods are part of natural disasters that often occur throughout the world, especially in flood-prone areas such as lowlands, river valleys, and coastal areas. Floods occur when water from rivers[1], lakes, or seas overflows beyond its holding capacity, which can be caused by heavy rain, melting snow, or high tides. Floods can cause great damage to infrastructure, plants, animals and people. Therefore, flood risk mitigation is very important to reduce losses caused by floods. Flood risk mitigation efforts can include proper spatial planning, development of early warning systems, construction of flood-resistant buildings [2], [3] and infrastructure, land use regulation, and public education on how to deal with floods and how to reduce their impact.

Floods often occur in Bojonegoro Regency every year [4]. The impact of the floods that occurred in Bojonegoro Regency included damage to infrastructure and casualties, so that it became a serious

problem that required speed in handling. Subur Tjahyono, 2009 in his research stated that Bojonegoro Regency is the area that has been traversed by the Bengawan Solo for about 100 kilometers and 24,753 hectares of area is watershed [5]. Floods that have occurred in Bojonegoro Regency almost every year. Floods in Bojonegoro Regency can be seen in 1968 which flooded an area of 12,000 hectares and 152,000 with losses of up to Rp. 8 billion (Excavator and Originator of District Anniversary Bojonegoro Region II, 1988: 618). On February 20, 1984, there was a flood that flooded 21,115 families or 74,404 people in Bojonegoro Regency, causing a loss of IDR 1,840,800,300, 5,630 hectares of disabled gardens, 1,881.30 hectares of moor, 4,576.36 hectares of yard, 3 broken bridges and a path during 116. 119 kilometers disabled. The next flood occurred again in 2005 flooding 15 sub-districts 71 hamlets, inundating 443 hectares of rice fields, 1,149 houses and causing a loss of IDR 876 million [6]. In order to deal with floods that occur frequently every year, it is necessary to map areas that are prone to flood disasters so that the community and the government can easily carry out disaster mitigation appropriately and quickly using GIS which can be used to monitor the location and area of the area that floods occur precisely. This study aims to analyze flood-prone areas and compile maps of flood-prone areas and describe the conditions of flood-prone areas in Bojonegoro Regency based on GIS. Floods occur when heavy rainfall [7] or extreme weather such as storms, typhoons, or blizzards cause excess water that cannot be absorbed by soil or waterways [8]. Floods can occur in urban or rural areas and can cause damage to buildings, roads and other infrastructure [9]. Floods can also cause loss of life [10] and cause negative impacts on public health. Therefore, flood mitigation and good infrastructure development are very important to minimize the impact of floods.

2. METHODOLOGY

These data can then be analyzed and manipulated in GIS to obtain more detailed and easy-to-understand information. There are two very important methods of data analysis, namely scoring and weighting. After carrying out these two processes, the next step is to analyze the level of flood vulnerability.
1. Scoring
2. Weighting
3. Analysis of Flood Vulnerability and Risk Levels [11], Analysis of the level of vulnerability and risk of flooding aims to determine which areas are more vulnerable to flooding and identify the factors that cause flooding. The value of the vulnerability can be calculated by the following formula:

$$X = \sum (W_i \times X_i)\ n\ i=1 \qquad\qquad (1)$$

Information:
K   = Vulnerability Value
Wi   = Weight for the i-th parameter
Xi   = Score of the i-parameter class

The formula for creating an interval class uses the theory according to Pratomo (2008), namely:

$$K_i = X_t - X_r\ k \qquad\qquad (2)$$

Information :
Ki   = Interval class
Xt   = Highest value
Xr   = The lowest value
K   = Number of classes desired

The potential value of an area for Threat is determined from the overall score of each parameter [12]. Areas that are very potentially dangerous have a very large total number and conversely areas that are not potentially dangerous have a small total number. Processing [10] Geographic Information System (GIS) is a process of collecting, storing, analyzing, visualizing, and processing geographic or spatial data using information technology. GIS enables users to integrate geographic data from a variety of sources, including maps, satellite imagery, and other numerical data. GIS processing involves several

stages, including: data collection, data processing, data visualization, data analysis, dissemination. GIS processing can be used in various fields, including natural resource management, urban planning, transportation, disaster mapping [9], and others.
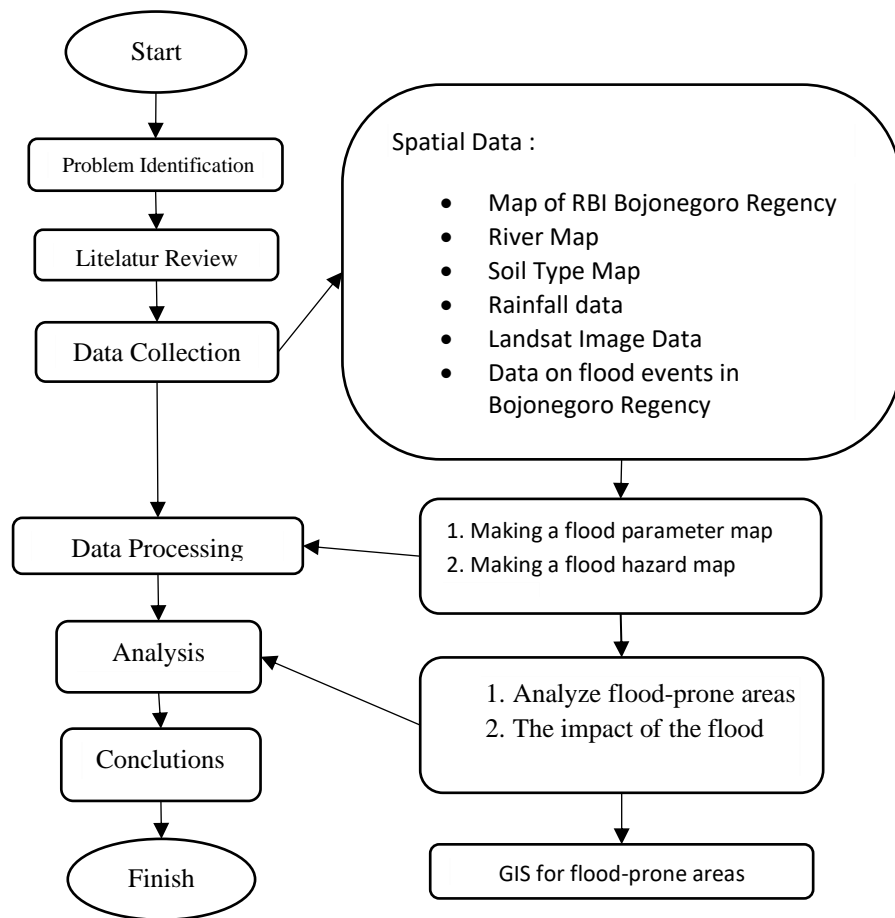

Figure 1. Research Flow

The data used in this study include:
a. Map of different types of earth of Bojonegoro Regency
b. Data on flood events in Bojonegoro Regency
c. River pattern map
d. Rainfall data
e. Map of soil types
f. Satellite image data

3. RESULTS AND DISCUSSION

3.1. Topographic Maps

Topographic data is used in analyzing flood-prone areas because it can determine the height of the land from the highest to the lowest according to the contour lines. The topographic map can be seen in Figure 2 below:
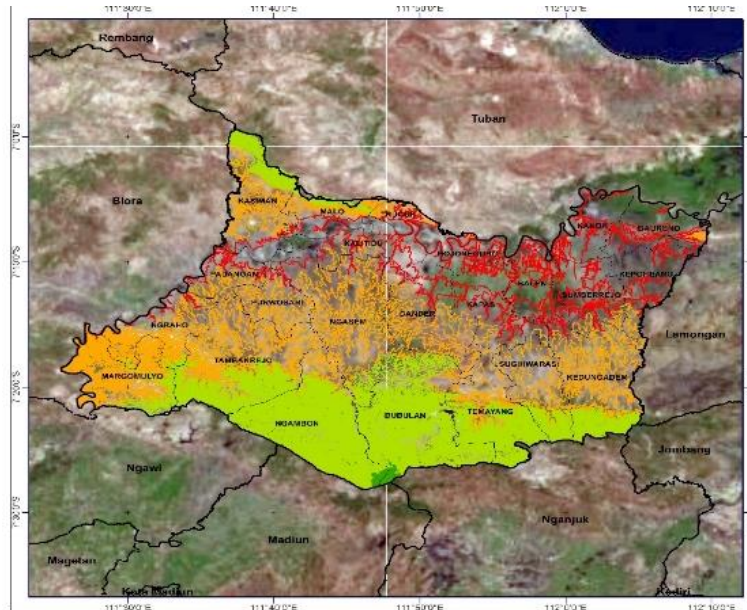
Figure 2. Topographic Maps

From the contour map above, it can be seen that there are variations in elevation in Bojonegoro Regency. The southern area is dominated by southern [13] limestone hills with altitudes ranging from 100 -> 900 m and in the northern area with low elevations and sloping around 25-> 100 m. Based on the map above, the altitude data in Bojonegoro Regency can be classified into 4 classes with details as in the following table:

From the contour map above, it can be seen that there are variations in elevation in Bojonegoro Regency. The southern area is dominated by southern limestone hills with altitudes ranging from 100 -> 900 m and in the northern area with low elevations and sloping around 25-> 100 m. Based on the map above, the altitude data in Bojonegoro Regency can be classified into 4 classes with details as in the following table:

Table 1. Area Altitude

Score	Place Altitude (Mdpl)	Area (Ha)	(%)
1	< 25 m	43.155	18,71
2	25 m – 100 m	104.629	45,35
3	100 m – 500 m	82.629	35,69
4	>500 m	574	0,25
	Amount	230.706	100

Table 1 shows that the area at score 1 with a height of <25 m covers an area of 43,155 Ha or 18.71% of the total area of Bojonegoro Regency, this area is included in a flood-prone area due to lowland. The area on score 2 with a height of 25 m – 100 m covering an area of 104,629 Ha or 45.35% of the total area of Bojonegoro Regency, this area is included in the widest area spread over the central and northern parts of Bojonegoro Regency. Areas that have a score of 3 with a height of 100 m – 500 m have an area of 82,629 Ha or equivalent to 35.69% of the total area of Bojonegoro Regency. The area on score 4 with a height of >500 m covers 574 Ha or 0.25% of the total area of Bojonegoro Regency.

3.2. Soil Type Map

The Ministry of Agriculture's WEBGis provides a map of soil types which is the result of direct measurements in the field and then processed using processing methods or by digitizing to obtain the results. Figure 3 shows that there are 4 types of soil in Bojonegoro Regency, namely alluvial, gromusol, litosol, and Mediterranean soil types.
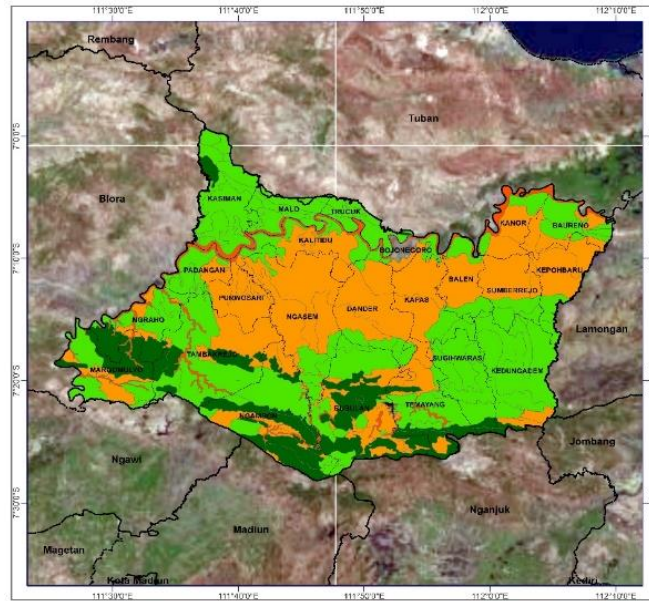
Figure 3. Soil Type Maps of Bojonegoro District

Table 2 . Soil Type Area

Score	Soil Type	Area (Ha)	(%)
1	Alluvial	46.349	20,09
2	Gromusol	88.937	38,55
3	Litosol	50.871	22,05
4	Medeteran	44.549	19,31
	Amount	230.706	100

3.3.   River Buffer Map

The river buffer map in Figure 4 and Figure 5 shows the distribution of rivers in Bojonegoro Regency which consists of 2 rivers and tributaries. Many tributaries are found in sub-districts in Bojonegoro including: Kanor, Purwosari, Gayam, Kalitidu, Sukosewu, Balen, Sumberrejo, Gondang and Kepohbaru.

Figure 4. River Map of Bojonegoro District
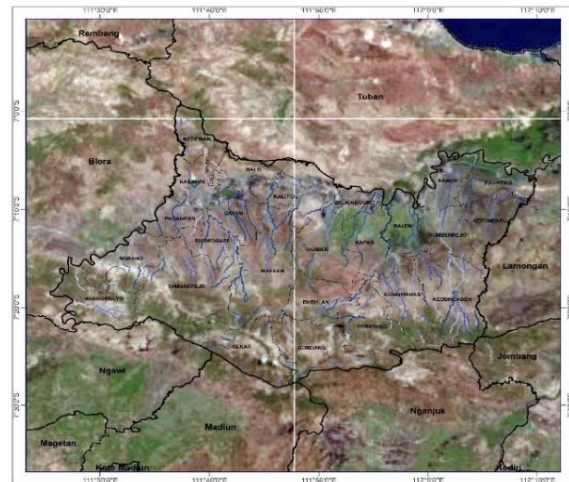
Figure 5. River Buffer Map of Bojonegoro District

This can cause several areas that are crossed by these tributaries to be prone to flooding, if there is a high intensity of rain and the delivery of water from the upstream of the tributary cannot be accommodated and can become a flood of shipments to Bojonegoro City which is close to the downstream of the Bengawan Solo river. On the river buffer map this is the result of dividing into several classes, including a radius of 0-50 m which is the area closest to the river and tributaries so it is classified as prone to flooding, while the radius of 50-150m is an area that is quite vulnerable because it is still close to rivers and streams, and at a radius of 150-300m is an area that is safe from flooding. Buffers are focused on rivers and streams that frequently flood.

3.4. Landuse Map

The land cover map for Bojonegoro Regency was made based on Landsat 8 imagery data on December 30 2019. To get a land cover map, the latest image data is needed, then it is cut using polygons for Bojonegoro Regency. Areas with land use that is overgrown with vegetation will be able to absorb runoff water, so that the area can hold runoff water flowing and the possibility of flooding is less likely compared to land that is not planted with vegetation. Classification of satellite imagery can be divided into several classes as shown in table 5, namely:
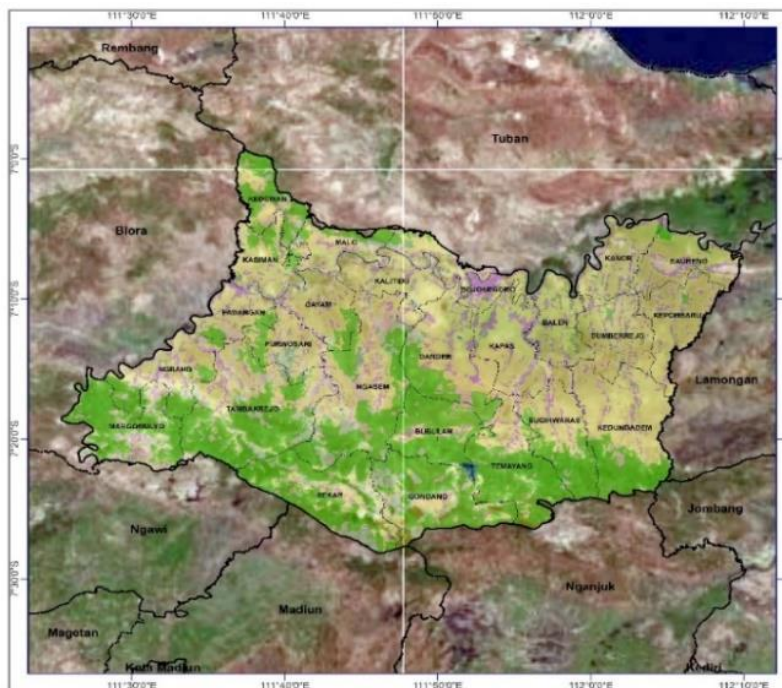
Figure 6. Landuse map of Bojonegoro District

Table 3. Landuse area map of Bojonegoro district in 2020

Score	Class	Area (Ha)	(%)
1	Hutan	95.935,81	41
2	Ladang	23.439,73	10,15
3	Sempadan Sungai	1.242,04	0.53
4	Pemukiman	23.970,35	10,38
5	Waduk	967,27	0,01
6	Kebun	1.522,66	0,66
7	Sawah	83.628,14	36,24
	Amount	230.706	100

The data used is multi-temporal data for land use parameters to support knowledge about the changes that have occurred so that they can find out the causes of their occurrence in Bojonegoro Regency.

3.5. Rainfall Data

Rainfall data obtained from the CHRS Data Portal. PERSIANN-Cloud Classification System (PERSIANN-CCS) (Figure 7) is a universal product with high resolution (0.04 ° x 0.04 ° or 4 km x 4 km) developed by the Center for Hydrometeorology and Remote Sensing (CHRS) in University of California, Irvine (UCI).
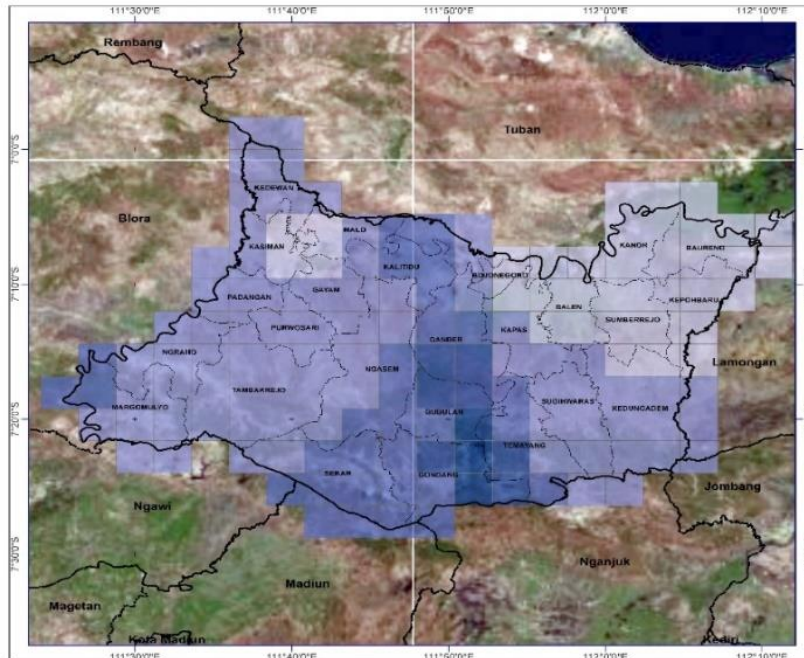
Figure 7. Bojonegoro District Rainfall Map

Table 4 shows the area at score 1 with a very low rainfall value with an area of 50,940.882 Ha or 22.08% of the total area of Bojonegoro Regency in several sub-districts including Kanor, Baureno, Kepohbaru, Sumberrejo, Balen, Kapas, Kedungadem, Bojonegoro , Kedewan, Kasiman, Malo and Gayam. The area on score 2 has a low rainfall value with an area of 99,803.617 Ha or 43.26% of the total area of Bojonegoro Regency, with the largest area spread over the western and eastern regions covering several sub-districts including: Margomulyo, Ngraho, Tambakrejo, Padangan, Purwosari, Ngasem, and Sugihwaras and these areas are categorized as flood-prone areas. Areas with a score of 3 average rainfall values have an area of 59,970.246 Ha or 25.99% located in the middle to lower part of Bojonegoro Regency covering parts of Margomulyo, Sekar, Bubulan, Ngasem, Gondang, Temayang, Dander and Kalitidu Districts. The area on score 4 with high rainfall has an area of 13,993.394 Ha or 6.08% of the total area of Bojonegoro Regency which is spread over several sub-districts: Gondang, Temayang, Bubulan and Dander. Areas with a score of 5 with very high rainfall have an area of 5,997,861 Ha or equivalent to 2.59% of the total area of Bojonegoro Regency which is located in parts of the Districts: Gondang, Temayang and Bubulan which causes high water discharge in the Bengawan Solo tributary so that it can flooding occurred in the area passed by the Bengawan Solo tributary.

Table 4. Rainfall area of Bojonegoro Regency

Score	Class	Area (Ha)	(%)
1	Very low	50.940,882	22,08
2	low	99.803,617	43,26
3	Currently	59.970,246	25,99
4	Tall	13.993,394	6,08
5	Very High	5.997.861	2,59
	Amount	230.706	100

3.6. Flood Intensity Map

This flood intensity map was obtained from data previously obtained from the relevant agencies in jpeg, excel format, then processed using Arcgis 10.8 to obtain a file in shp form to facilitate analysis using a Geographic Information System (GIS) so that it can be processed into a flood intensity map. Bojonegoro Regency.

Table 5. Flood Vulnerability Levels in Bojonegoro Regency

Class	Vulnerability Level	Area (Ha)	(%)
1	Very Prone	49.963,671	21,66
2	Prone	173.162,171	75,05
3	Not Prone	7.580,157	3,29
	Amount	230.706	100

The results of the analysis of the flood intensity map in Bojonegoro Regency obtained data on flood-prone areas and the following is the distribution condition of each class of flood parameters in Bojonegoro Regency:

a) Very Prone
The condition of the flood-prone area with a very vulnerable class of 49,963.671 Ha is in the northern part of Bojonegoro Regency which is located near the Bengawan Solo river and tributaries. The topography in this area is relatively low between 0 - 25m. The distribution of flood-prone areas is in sub-districts including: Margomulyo, Ngraho, Padangan, Kasiman, Malo, Purwosari, Trucuk, Kalitidu, Ngasem, Bojonegoro, Kapas, Dander, Balen, Kanor, Baureno, Sumberrejo, Kepohbaru and Gondang

b) Prone
The condition of flood-prone areas with vulnerable classes has an area of 173,162.171 Ha with relatively sloping topography between 25-500m. Administratively the level of vulnerability of the flood area to Bojonegoro Regency is in the central and southern regions of Bojonegoro Regency covering the following sub-districts: Margomulyo, Ngraho, Tambakrejo, Kedewan, Malo, Trucuk, Sekar, Ngambon, Ngasem, Gondang, Bubulan, Dander, Temayang, Sugihwaras and Kedungadem .

c) Not Prone
The condition of the non-prone class area has an area of 7,580.157 ha with relatively high topography > 500m. This area is located in the northern and southern parts of Bojonegoro Regency and includes sub-districts including: Margomulyo, Ngraho, Tambakrejo, Kedewan, Malo, Trucuk, Sekar, Ngambon, Gondang, Temayang, Sugihwaras and Kedungadem.

Table 6. Flood Prone Areas in Bojonegoro Regency for each District

No	Subdistrict	Flood Prone Class	Area (Ha)	%
1	Balen	Very Prone	4.564,772	2,117
		Prone	930,549	0,432
2	Baureno	Very Prone	6.238,185	2,893
3	Bubulan	Very Prone	867,766	0,402
		Prone	4.428,063	2,054
4	Bojonegoro	Very Prone	2.756,193	1,278
5	Dander	Very Prone	5.482,114	2,543
		Prone	3.923,041	1,820
		Not Prone	1.818,492	0,843
6	Gayam	Very Prone	3.922,127	1,834
		Prone	1.742,097	0,687
7	Gondang	Very Prone	314,150	0,146
		Prone	10.389,285	4,819
		Tidak Rawan	402,115	0,187
8	Kalitidu	Very Prone	6.537,278	3,032

No	Subdistrict	Flood Prone Class	Area (Ha)	%
		Prone	1.972,047	0,915
9	Kasiman	Very Prone	2.631,048	1,220
		Prone	2.469,637	1,145
10	Kedewan	Very Prone	2.434,517	1,129
		Prone	3.089,936	1,433
		Tidak Rawan	1.157,517	0,537
11	Kapas	Very Prone	3.235,307	1,501
		Prone	636,634	0,295
12	Kepohbaru	Very Prone	4.872,244	2,260
		Prone	1.923,833	0,892
13	Kedungadem	Very Prone	10.641,977	4,936
		Prone	2.331,898	1,082
		Not Prone	1.103,997	0,512
14	Kanor	Very Prone	5.367,079	2,489
15	Margomulyo	Very Prone	55.276	0,026
		Prone	9.830,344	4,559
		Not Prone	197,852	0,092
16	Malo	Very Prone	2.647,599	1,228
		Prone	3.082,147	1,329
		Not Prone	219,851	0,102
17	Ngasem	Very Prone	14.412,792	6,685
		Prone	2.180,485	1,011
		Not Prone	579,272	0,269
18	Ngambon	Very Prone	915,204	0,424
		Prone	5.215,340	2,419
		Not Prone	570,914	0,265
19	Ngraho	Very Prone	1.492,711	0,692
		Prone	5.101,327	2,366
		Not Prone	253,023	0,117
20	Padangan	Very Prone	4.103,986	1,903
21	Purwosari	Very Prone	5.540,021	2,569
22	Sumberrejo	Very Prone	6.559,712	3,042
23	Sekar	Very Prone	1.773,409	0,823
		Prone	7.528,254	3,492
		Not Prone	823,306	0,382
24	Sugihwaras	Very Prone	5.674,869	2,632
		Prone	2.050,775	0,951
		Not Prone	1.650,441	0,765
25	Sukosewu	Very Prone	4.659,763	2,161
26	Tambakrejo	Very Prone	5.348,336	2,481
		Prone	14.478,188	6,715
		Not Prone	1.185,117	0,550
27	Trucuk	Very Prone	2.756,454	1,278
		Prone	1.112,434	0,138
		Not Prone	302,808	0,140
28	Temayang	Very Prone	1.223,626	0,568
		Prone	9.549,938	4,429
		Not Prone	11,754	0,005

The level of flood vulnerability will continue to increase if a certain area of land is used for residential areas for a wider population of certain vulnerability classes. This means that if the use of land that has never been inhabited by humans is associated with a particular flood-prone vulnerability class, then the flood hazard level will be low.

4. CONCLUSION

Based on the results of the analysis that has been done, it can be concluded as follows:
1. The level of flood-prone areas in Bojonegoro Regency is divided into 3 classes, namely: very vulnerable class of 49,963.671 Ha or around 21.66%, vulnerable class of 173,162.171 Ha or around 75.05%, and non-prone class of 7,580 .157 ha or 3.29% of the total area of Bojonegoro Regency.
2. Flood-prone areas in Bojonegoro Regency with the following hazard classes:
   a. The very vulnerable classes include Margomulyo District, Ngraho District, Padangan District, Kasiman District, Malo District, Purwosari District, Trucuk District, Kalitidu District, Ngasem

District, Bojonegoro District, Kapas District, Dander District, Balen District, Kanor District, Baureno District, District Sumberrejo, Kepohbaru District and Gondang District.

b. Vulnerable classes include: Margomulyo District, Ngraho District, Tambakrejo District, Kedewan District, Malo District, Trucuk District, Sekar District, Ngambon District, Ngasem District, Gondang District, Bubulan District, Dander District, Temayang District, Sugihwaras District, and Kedungadem District.

c. Non-prone classes include: Margomulyo District, Ngraho District, Tambakrejo District, Kedewan District, Malo District, Trucuk District, Sekar District, Ngambon District, Gondang District, Temayang District, Sugihwaras District, and Kedungadem District.

3. Areas that have a high level of vulnerability are around the Bengawan Solo River which crosses Bojonegoro Regency. This can be caused because the area around the Bengawan Solo River has a height of <25 m and frequent flooding from the upstream and tributaries of the Bengawan Solo River.

REFERENCES

[1] M. Qomaruddin, A. Ariyanto, K. Umam, and Y. A. Saputro, "Studi Komparasi Karakteristik Pasir Sungai Di Kabupaten Jepara," *J. Ilm. Teknosains Univ. PGRI Semarang*, vol. 4, no. 1, 2018.

[2] R. A. Nugroho *et al.*, "Perencanaan Struktur Gedung 9 Lantai Hotel Sky Sea View Jepara," *J. Civ. Eng. Study*, vol. 01, no. Dl, pp. 34–46, 2021.

[3] H. Manik, V. H. Puspasari, W. Nuswantoro, and A. Purwantoro, "Kunci Utama Pelaksanaan K3 Pada Proyek Pembangunan Gedung Muhammadiyah Palangka Raya Kampus II Di Saat Pandemi," *J. Civ. Eng. Study*, vol. 1, pp. 1–5, 2021.

[4] A. V. Vitianingsih and Y. Kristyawan, "Web Map untuk Mengetahui Daerah Rawan Banjir di Kabupaten Bojonegoro," no. 031, pp. 1–12.

[5] M. K. Mahfidh *et al.*, "Analisa Kapasitas Saluran Drainase Pada Jalan Raya Kelet - Bangsri," *J. Civ. Eng. Study*, vol. 02, pp. 0–7, 2022.

[6] D. E. Arianto and Nawiyanto, "Banjir Bengawan Solo dan Pengaruhnya Bagi Kehidupan Masyarakat di Kabupaten Bojonegoro Tahun 2007 – 2008," vol. 4, no. 2, pp. 180–194, 2022.

[7] M. A. T. Putra, Y. S. Putra, and R. Adriat, "Analisis Tingkat Kerawanan Banjir Kabupaten Mempawah Provinsi Kalimantan Barat Menggunakan Metode Overlay Dengan Scoring Berbasis Sistem Informasi Geografis," *Prism. Fis.*, vol. 9, no. 3, pp. 234–243, 2021.

[8] M. Qomaruddin, A. I. A. Saputra, T. H. Munawaroh, Z. Isnaini, and S. I. Ariyani, "Pemanfaatan Air Bersih Masyarakat Pada Program Pamsimas di Desa Raguklampitan Kabupaten Jepara," *Pros. Semin. Nas. Publ. Hasil-Hasil Penelit. dan Pengabdi. Masy.*, no. September, pp. 571–578, 2017.

[9] S. N. Qodriyatun, "Bencana Banjir: Pengawasan dan Pengendalian Pemanfaatan Ruang Berdasarkan UU Penataan Ruang dan RUU Cipta Kerja," *Aspir. J. Masal. Sos.*, vol. 11, no. 1, pp. 29–42, 2020, doi: 10.46807/aspirasi.v11i1.1590.

[10] A. Findayani, "Kesiap Siagaan Masyarakat Dalam Penanggulangan Banjir Di Kota Semarang," *J. Geogr. Media Inf. Pengemb. dan Profesi Kegeografian*, vol. 12, no. 1, pp. 102–114, 2015.

[11] E. Efrizal, Y. A. Saputro, and N. Hidayati, "Implementasi Software Hec-Ras 4.1. 0 Dan Epa Storm Water Management Model (Swmm) 5.1. 0 Pada Efektivitas Analisis Saluran Drainase (Studi Kasus Desa Kelet …," *J. Civ. Eng. …*, vol. 02, 2022, [Online]. Available: https://journal.unisnu.ac.id/CES/article/view/222%0Ahttps://journal.unisnu.ac.id/CES/article/download/222/134.

[12] R. A. Ayuningtyas, "Tingkat Kenyamanan Hunian Berdasarkan Kondisi Fisik Rusunawa Blok A dan Blok B Jalan Kom Yos Sudarso Pontianak," *UNIPLAN J. Urban Reg. Plan.*, vol. 2, no. 1, p. 41, 2021, doi: 10.26418/uniplan.v2i1.45887.

[13] M. Qomaruddin and S. Sudarno, "Pemanfaatan Limbah Bottom Ash Pengganti Agregat Halus Dengan Tambahan Kapur Pada Pembuatan Paving," *Rev. Civ. Eng.*, vol. 1, no. 1, pp. 13–18, 2017.