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# Map Analysis of Potential Flood Prone Areas in Rajabasa District Bandar Lampung City

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## *Abstract*

Rajabasa District Bandar Lampung City Lampung Province, has a significant history of flooding. Based on BPS data, Rajabasa District, Bandar Lampung City, over the last 5 years, 15 major floods have been recorded from 2019 to 2023, this has resulted in material losses for the community. This research aims to analyze the level of vulnerability to flood disasters in Rajabasa District, Bandar Lampung City by paying attention to various factors that contribute to floods, namely rainfall, slope, land cover, soil type and geology. This research uses the overlay method of each parameter with the geographic information system (GIS) approach of the ArcGIS application and scoring and interval techniques to produce maps that identify areas at high risk of flooding. The research results show that the main factor causing flooding in Rajabasa District, Bandar Lampung City is the slope which tends to be dominated by flat slopes in Rajabasa District of 0-8%. Subdistricts with a very high level of flood vulnerability are Rajabasa, Rajabasa Raya, Rajabasa Jaya, Gedong Meneng and Gedong Meneng Baru subdistricts with a flood prone class classification covering an area of 412.68 ha with a percentage of 33.92% of the total Rajabasa subdistrict. Areas classified as flood prone are in Rajabasa Nunyai, Rajabasa Pramuka, Rajabasa, Rajabasa Raya, Rajabasa Jaya, Gedong Meneng and Gedong Meneng Baru sub-districts with the largest area in Rajabasa District covering an area of 762.18 ha and a percentage of 62.65% of the area of Rajabasa District. The area with the lowest classification, namely the slightly flood-prone class, is spread across Rajabasa Nunyai, Rajabasa Pramuka, Rajabasa , Rajabasa Jaya, and Gedong Meneng sub-districts covering an area of 41.88 ha with only 3.44% of the area of the entire Rajabasa District, Bandar Lampung City.

***Keywords:*** *ArcGis; Flood; Vulnerability; Scoring; Overlay*

## *Introduction*

Indonesia has high rainfall and unpredictable weather and climate changes (Herlina, et al., 2020). This condition makes Indonesia prone to experiencing hydrometeological disasters, one of which is flooding (Fahrudin, et al., 2022). Flood disasters are one of the environmental threats that often occur in various regions in Indonesia (Puspitotanti & Karmilah, 2022), including in Bandar Lampung City, Lampung Province. Rajabasa District, as one of the areas in Bandar Lampung City, is not immune from the risk of flooding. Floods can cause significant economic, social and environmental losses, such as damage to infrastructure, loss of natural resources and negative impacts on community welfare (Risal, et al., 2019). This research will focus on Rajabasa District, Bandar Lampung City, Lampung, which has a significant

history of flooding. Based in BPS data, Rajabasa District, Bandar Lampung City, over the last 5 years, floods have been recorded 15 times from 2019 to 2023, here are the data:

Table 1 Flood History Data in Rajabasa District for 2019-2023

| No | Subdistrict/Sub-district | Year | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2022 | 2023 | |
| 1 | Gedong Meneng | - | - | - | - | - | 0 |
| 2 | Rajabasa | - | 1 | 1 | - | - | 2 |
| 3 | Rajabasa Raya | - | 2 | 1 | - | - | 3 |
| 4 | Rajabasa Jaya | - | 1 | - | - | - | 1 |
| 5 | Rajabasa Nyunyai | - | 1 | 3 | 2 | 1 | 7 |
| 6 | Rajabasa Pramuka | - | 1 | - | 1 | - | 2 |
| 7 | Gedong Meneng Baru | - | - | - | - | - | 0 |
| | **Total** | **-** | **6** | **5** | **3** | **1** | **15** |

Source: BPS Rajabasa District 2019-2023

Table 1 shows that in the last five years, Rajabasa District in Bandar Lampung City recorded 15 major flood events. The intensity of flooding shows variations between sub-districts, with Rajabasa Nunyai Sub-district recorded as the area most frequently affected, namely 7 incidents. Followed by Rajabasa Raya Sub-district with 3 incidents, then Rajabasa and Rajabasa Pramuka each experienced 2 floods. Several other sub-districts such as Gedong Meneng and Gedong Meneng Baru did not record any flooding during this period. 2020 is the year with the highest intensity of flood events (6 events), followed by 2021 (5 events), 2022 (3 events), and 2023 with 1 flood event. This incident shows that the risk of flooding in Rajabasa District is dynamic and influenced by various environmental factors. Another reason for choosing the location for Rajabasa Subdistrict is because its area of 13.53km$^2$ makes this subdistrict the area with the largest flood disaster in Bandar Lampung City. Apart from that, this subdistrict is based on its location close to educational centers such as the University of Lampung, which of course floods will greatly affect the activities of the surrounding community.

Table 2 Area of Districts in Bandar Lampung

| No | Districts | District Capital | Area (Km$^2$) |
|---|---|---|---|
| 1 | Teluk Betung Barat | Bakung | 11.02 |
| 2 | Teluk Betung Timur | Sukamaju | 14.83 |
| 3 | Teluk Betung Selatan | Gedong Pakuon | 3.79 |
| 4 | Bumi Waras | Sukaraja | 3.75 |
| 5 | Panjang | Karang Maritim | 15.75 |
| 6 | Tanjung Karang Timur | Kota Baru | 2.03 |
| 7 | Kedamaian | Kedamaian | 8.21 |
| 8 | Teluk Betung Utara | Kupang Kota | 4.33 |
| 9 | Tanjung Karang Pusat | Palapa | 4.05 |
| 10 | Enggal | Enggal | 3.49 |
| 11 | Tanjung Karang Barat | Gedong Air | 14.99 |
| 12 | Kemiling | Beringin Jaya | 24.24 |
| 13 | Langkapura | Langkapura | 6.12 |
| 14 | Kedaton | Kedaton | 4.79 |
| 15 | Rajabasa | Rajabasa Nunyai | 13.53 |
| 16 | Tanjung Senang | Tanjung Senang | 10.63 |
| 17 | Labuhan Ratu | Kampung Baru Raya | 7.97 |
| 18 | Sukarame | Sukarame | 14.75 |
| 19 | Sukabumi | Sukabumi | 23.6 |
| 20 | Way Halim | Way Halim Permai | 5.35 |
| | **Total** | | **197.22** |

Source: BPS Bandar Lampung City 2023

Table 2 shows that Rajabasa District has an area of 13.53 km², making it one of the sub-districts with a fairly large area in Bandar Lampung City. Compared to other sub-districts, this area is smaller than Kemiling District which covers 24.24 km² but larger than Kedaton with an area of only 4.79 km². Rajabasa's strategic location, close to educational centers such as Lampung University, makes it one of the sub-districts with quite dense community activity. This condition also influences the high risk of vulnerability to flooding due to intense urban activities. Rainfall is an indicator of the cause of flooding, this is because Indonesia is located around the equator which has a tropical climate where rain will fall throughout the year (Malihah, 2022). High rainfall caused flood disasters in Rajabasa District, Bandar Lampung City, to occur when the rainy season entered (Ruliyansyah, 2015). To find out and provide information regarding the distribution of floods in Rajabasa District, Bandar Lampung City, it is necessary to map areas that are prone to flooding. With mapping, the government can take appropriate policies to address and overcome it.

Based on 5 years of data recorded at the Pesawaran climatology station, it was recorded that during 2019-2023 Rajabasa District, Bandar Lampung City had the following annual rainfall:

Table 3 Annual Rainfall Data 2019-2023 Rajabasa District

| Year | Rainfall (mm/ year) |
|---|---|
| 2019 | 1827.4 |
| 2020 | 2834.1 |
| 2021 | 1862.6 |
| 2022 | 2326.8 |
| 2023 | 984.4 |

Source: BMKG Pesawaran -Lampung Data

Table 3 shows that annual rainfall in Rajabasa District shows significant fluctuations over the last five years. In 2019, rainfall was recorded at 1827.4 mm, increasing drastically in 2020 to 2834.1 mm, which was the highest rainfall in that period. However, in 2021, this figure decreased again to 1862.6 mm. 2022 recorded rainfall of 2326.8 mm before finally dropping sharply to 984.4 mm in 2023, which is the lowest figure in the history of rainfall for this region. The drastic decrease in rainfall in 2023 is allegedly influenced by global climate change, which also influences flood risk by changing rain distribution patterns. According to the Head of the Meteorology, Climatology, and Geophysics Agency (BMKG) Dwikorita Karnawati, the hot weather experienced by Indonesia has also hit many places throughout the world. In fact, he said, 2023 will be a year full of temperature records (BMKG: 2023). June to August are the three hottest months in history and July 2023 will be the hottest month. The reality of climate evolution makes 2023 likely to be the hottest year in the history of climate records, beating 2016 (Kompas.com, 2023).

According to Dwikorita (2023), this situation is the impact of climate change which also puts additional pressure on already scarce water resources and produces what is known as a water hotspot. This condition also increases the vulnerability of world food stocks. FAO or the Food and Agriculture Organization, said Dwikorita, even predicts that if this continues to happen, in 2050 a famine will occur due to a food crisis (Kompas.com, 2023).

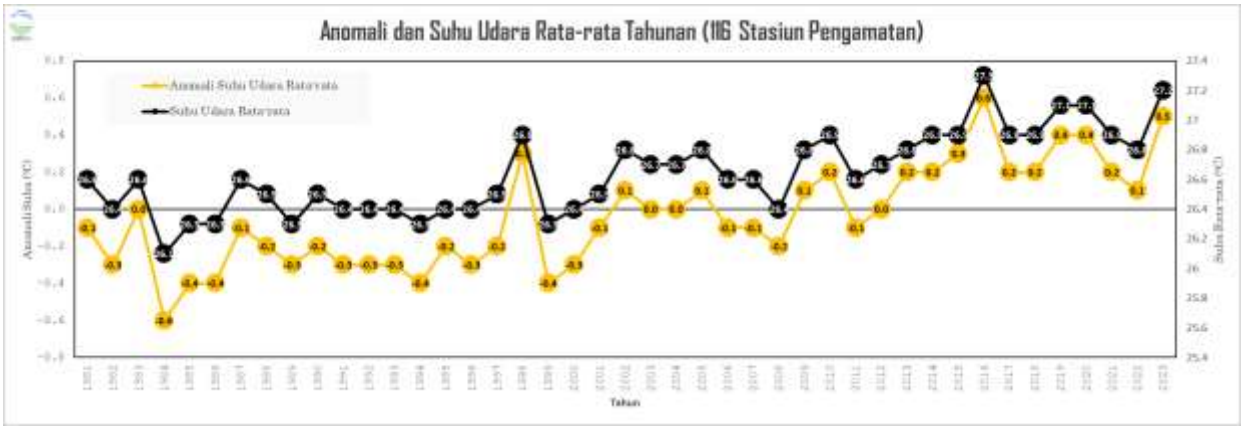


Figure 1 Anomalies and Annual Average Air Temperature
Source: Indonesian BMKG Station

The annual air temperature anomaly is the difference between the air temperature in a particular year and the annual average air temperature for 30 years (normal period 1991-2020) (Faruf, et al., 2023). Based on data from 116 BMKG observation stations, the average air temperature for the 1991-2020 period in Indonesia is 26.7 ºC and the average air temperature in 2023 is 27.2 ºC, so the average air temperature anomaly in 2023 is 0.5 ºC, Throughout the observation period from 1981 to 2023 in Indonesia, 2016 was the hottest year with an anomaly value of 0.6° C. 2023 ranks as the 2nd hottest year with an anomaly value of 0.5° C (BMKG, 2024).

Based on BMKG data regarding annual rainfall data from 2019–2013 in Rajabasa District, it was recorded that 2023 was the year that had the lowest annual average rainfall, even decreasing drastically from the previous year, namely 2022. However, from the Flood History Data table in Rajabasa District for 2019-2023 (table 1), Nunyai Sub-district was recorded as experiencing flooding.

The use of Geographic Information Systems (GIS) is one way in the mapping process, where GIS can be very functional in making flood prone maps which is the focus of this study (Aziza et al., 2021; Saily, et al., 2021). Flood prones can be identified quickly, easily and accurately with Geographic Information Systems (GIS) using the overlay method on flood parameters (Tri, et al., 2021), where in this context, the data layers to be used include slope, rainfall, land use, soil type, and geology. By using the overlay system, this study will produce a flood prone map that identifies areas with flood risk classifications (Dhaniarti, et al., 2021; Pratama, et al., 2020). The overlay system is a geospatial method that allows the combination of various data layers to produce more comprehensive information about the vulnerability of an area to flooding (Erfani, et al., 2023; Manakane, et al., 2023).

The results of this study are expected to be an important contribution to flood disaster mitigation efforts in Rajabasa District. The resulting flood-prone map will be a guide for local governments in planning and developing areas that are safer from flooding, including in spatial planning, water management, and improving flood control infrastructure (Rozita & Setiadi, 2020; Wibowo, et al., 2019). In addition, this study can also provide important information to the community in increasing their preparedness for potential flood prones and also reducing the risks associated with flooding in their area (Afrian, et al., 2019; Qurrotaini, et al., 2022; Yatnikasari, et al., 2020).

Based on the description of the problems above, it is necessary to conduct research to resolve the problem regarding the geographical causes of flooding and the distribution of flood locations that often occur in Rajabasa District, Bandar Lampung City, seen from a regional and environmental perspective in a spatial context. Therefore, research entitled "Flood Prone Mapping Analysis in Rajabasa District, Bandar Lampung City, Lampung" is considered necessary. The map as the output of this research is expected to have high relevance in the context of flood disaster mitigation and a positive contribution as an effort to maintain the security and welfare of the community in Rajabasa District, Bandar Lampung City, and can be a model for other regions facing similar risks in Indonesia.

## *Method and Material*

### 1. Research Method

This study uses a descriptive quantitative research method. Quantitative research is an investigation of social problems based on testing theories consisting of variables, measured by numbers, and analyzed by statistical procedures to determine whether the generalization of predictive theories is true. In this scenario, quantitative researchers test a theory by detailing specific hypotheses, then collecting data to support or refute the hypotheses. Experimental strategies are applied to assess behaviors, both before and after the experimental process. Data are collected with the help of special instruments designed to assess behaviors, while information is analyzed using statistical procedures and hypothesis testing (Jhon, 2009).

### 2. Variables and Variable Operational Definitions

Variables are everything that will be variables in a study. The variables used in this study are Rajabasa District Administration Data, Rainfall Data, Slope Data, Land Cover Data, Soil Type Data, and Geological Data of Rajabasa District, Bandar Lampung City.

### 3. Data collection

### a. SHP Data Collection

SHP for making Land Cover Maps, Soil Type Maps, Geological Maps, Slope Maps, and Rainfall Maps are taken from the same *website, namely the website Indonesian Geospatial.*

### b. Map Making

The creation of Land Cover Maps, Soil Type Maps, Geological Maps, Slope Maps, and Rainfall Maps is done by cutting the SHP data according to the theme that is adjusted to the location of Rajabasa District, Bandar Lampung City.

### 4. Data Analysis Techniques

### a. Attribute Analysis

Two processes in data analysis are scoring and weighting. The two processes are carried out after the value classification process in each parameter. After the two processes are completed, it is continued with the flood vulnerability classification stage.

a. Rainfall Class Scoring

Areas with high rainfall will have more influence on flooding. Based on this, the scoring for the rainfall area is getting higher. The scoring of the rainfall class is based on the type of annual rainfall data. With the scoring as stated in the operational definition table of the variable.

b. Land Cover Class Scoring

Land cover will affect the flood vulnerability of an area. Land cover will play a role in the amount of runoff from rain that has exceeded the infiltration rate. Areas that are heavily overgrown with trees will have difficulty draining runoff. This is due to the large capacity of water absorption by trees and the slow flow of runoff due to being held back by tree roots and trunks, so the possibility of flooding is smaller than areas that are not planted with vegetation. So that the scoring for land cover, the more vegetation there is, the smaller the score level, which means the less likely it is to estimate flooding. The scoring will be as stated in the operational definition table of the variable.

c. Scoring of slope Gradient Class

The steeper the slope, the more water is passed on. Water on the land will be passed on to a lower place faster, compared to land with a low slope (flat). So, the possibility of inundation or flooding in areas with a steep slope is smaller. Therefore, the steeper the area, the smaller the score and the scoring of this slope will be in accordance with that stated in the operational definition table of the variable.

d. Geology Class Scoring

The type and structure of rock affect the ability of the soil to absorb water (infiltration). Permeable rocks, such as sandstone and gravel, tend to allow water to infiltrate more quickly into the soil, reducing the risk of surface puddles and excessive surface flow during heavy rain. On the other hand, impermeable rocks, such as clay or limestone, can cause rainwater to flow quickly over the surface, increasing the risk of flooding. Therefore, rocks with impermeable properties will have a higher score and rocks with permeable properties will have a lower score.

e. Soil Type Scoring

Soils that have low infiltration capacity, such as clay or rocky soils, tend to cause higher surface runoff during heavy rain. This causes water to flow quickly into rivers or drainage channels, increasing the risk of flooding in the area. In contrast, soils that have good infiltration capacity, such as sandy soils or sandy clay soils, are able to absorb water more efficiently, slowing surface runoff and reducing the volume of water that goes directly into water channels. This reduces the potential for flooding because water has more opportunity to be absorbed by the soil before reaching the drainage system. That is why soil types that have high infiltration have small scores and vice versa.

**b. Overlay**

Overlay is the process of combining data from different layers, simply put, overlay is a visual operation that requires more than one layer to be physically combined (Darmawan, 2017). Overlay can be interpreted as the process of overlapping two or more layers (maps) so that an intersection of both appears to form a map that has a combined pattern based on the overlapped layers.

**c. Determining Class Intervals**

Class intervals are used to classify the overlay results into flood vulnerability levels. Class intervals can be calculated using the Sturgess formula (Nur, 2023) , namely:

$$C_i = \frac{X1 - X2}{K}$$

Information:

Ci = class interval K = number of classes

X1 = largest data X2 = smallest data

## *Results and Discussion*

### 1. Result

### a. Location of the Research Area

Rajabasa District is one of the districts in Bandar Lampung City, Lampung Province. Based on (Central Statistics Agency, 2023) the formation of Rajabasa District on February 9, 2002. Rajabasa District is a division of Kedaton District which was determined through Regional Regulation Number. 4 of 2001 dated October 3, 2001 concerning the Development, Elimination and Expansion of Districts and Urban Sub-district s in Bandar Lampung City.

Through the Central Statistics Agency in 2023, Rajabasa District has the following boundaries:

a. North: Tanjung Senang and Labuhan Ratu Districts

b. South side: Langkapura District

c. East side: Labuhan Ratu District

d. West: South Lampung Regency

Geographical location also usually influences local wisdom, which is one form of community culture in the form of knowledge, products, and activities used for survival that are adapted to where they are from generation to generation. This can trigger flooding if people in the area tend to have minimal knowledge and attention to the importance of protecting the environment (Widodo, et al., 2023) .

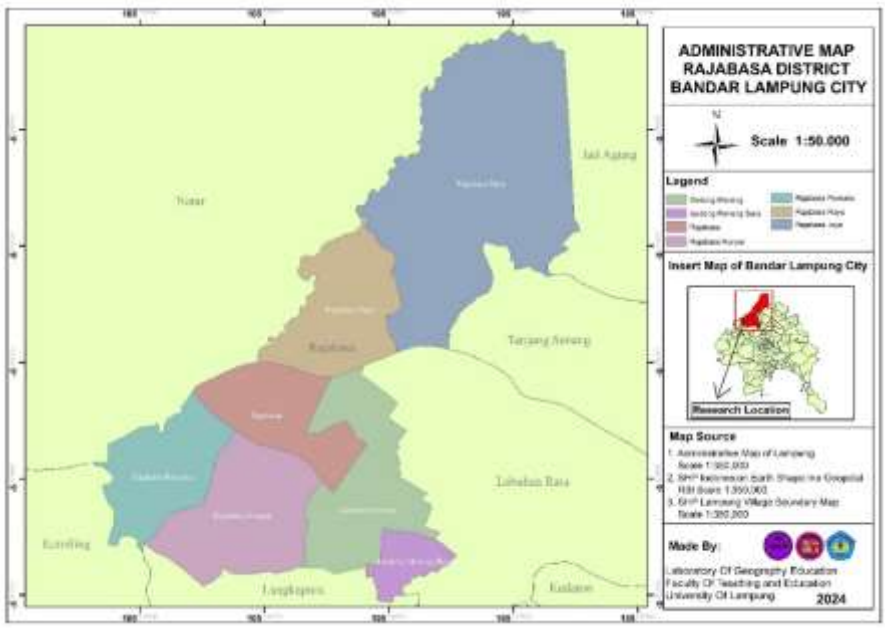


Figure 2 Administrative Map of Rajabasa District, Bandar Lampung City
Source: Results of research data processing, Year 2024

### b. Rainfall

The rainfall map in Rajabasa District illustrates the amount of rain that falls in Rajabasa District in mm/year along with the location of the sub-district. The annual rainfall data used in this map is data from 2019-2023 obtained from the Pesawaran Climatology and Geophysics Agency Station, Lampung.

In the rainfall classification by Aziza, Sitty Nur., et al. (2021) rainfall is divided into 5 classification classes. In Rajabasa District, Bandar Lampung City is dominated by 2 rainfall classification classes, where the dominant class is the rainfall class with a wet classification (2000-2500mm/year). This wet class is almost widespread in all sub-districts in Rajabasa District. Meanwhile, areas with a very wet rainfall classification (2500-3000mm/year) are only in Rajabasa Jaya Sub-district. The area of the wet classification (2000-2500mm/year) is 1144.722729 Ha with a percentage of 11.12%. Meanwhile, the rainfall classification with the smallest area is the very wet classification (2500-3000 mm/year) with an area of 141.78 Ha with a percentage of 88.97% (Table 4).

Table 4 1Rainfall in Rajabasa District

| No | Class | Classification | Score | Area (Ha) | Percentage (%) |
|---|---|---|---|---|---|
| 1 | >2500 mm | Very Wet | | 141.78 | 11.03 |
| 2 | 2001 – 2500 mm | Wet | | 1144.72 | 88.97 |
| **Total** | | | | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

Table 4 shows that rainfall in Rajabasa District is dominated by the wet rainfall class (2000-2500 mm per year) which covers almost the entire sub-district area with an area of around 1144.72 hectares or 88.97% of the total area. Meanwhile, the very wet rainfall class (2500-3000 mm per year) is only found in Rajabasa Jaya Sub-district with an area of around 141.78 hectares or 11.03% of the total area. This distribution of rainfall shows that areas with higher rainfall have a greater potential risk of flooding due to high volumes of rainwater and limited soil absorption capacity.

Table 5 Classification of Rainfall by Subdistrict

| No | Classification | Area (ha) | Ward |
|---|---|---|---|
| 1 | 2500-3000 mm | 141.78 | Rajabasa Jaya |
| | | 350.07 | Rajabasa Jaya |
| | | 151.35 | Rajabasa Raya |
| 2 | | 121.64 | Rajabasa |
| | 2000-2500 mm | 41.15 | Gedong Meneng Baru |
| | | 169.56 | Gedong Meneng |
| | | 130.55 | Rajabasa Pemuka |
| | | 180.42 | Rajabasa Nunyai |

Source: Results of research data processing, Year 2024

Table 5 can be seen that this table classifies rainfall based on five sub-districts in Rajabasa District. Rainfall is divided into two main categories: very wet (2500-3000 mm/year) and wet (2000-2500 mm/year) categories. Rajabasa Jaya sub-district is recorded as the area with the highest rainfall, namely in the very wet category, with an area of around 141.78 hectares. On the other hand, other sub-districts such as Rajabasa Raya and Rajabasa are included in the wet category, with an area of 151.35 hectares and 121.64 hectares, respectively. Other sub-districts such as Gedong Meneng, Rajabasa Nunyai, and Rajabasa Pramuka are also in the wet category, with quite large areas. This different distribution of rainfall shows that areas with higher rainfall, such as Rajabasa Jaya, have a greater potential for flood risk, because the volume of water that must be absorbed by the soil and drainage is higher.

**c. Slope Gradient**

The slope gradient in Rajabasa District is depicted based on the slope gradient map made based on SHP data obtained from the Housing and Settlement Service of Bandar Lampung City. From the map, the area of each slope gradient classification in Rajabasa District can be seen. In the slope classification by Aziza, Sitty Nur., et al. (2021) slope is divided into 5 classification classes. In Rajabasa District, Bandar Lampung City is dominated by 2 slope class classification classes, where the dominant classes are the flat

slope class and the gentle slope class, where the dominant class is the flat slope class (0-8%). This flat slope class is almost widespread in all sub-districts in Rajabasa District. Meanwhile, areas with a gentle slope class classification (8-15%) are only spread in 3 sub-districts, namely Rajabasa Pramuka Sub-district, Rajabasa Nunyai Sub-district, and Rajabasa Jaya Sub-district. Classifications that do not dominate other areas of Rajabasa District are undulating (15-25%) spread throughout Rajabasa District, steep classification (25-40%) and very steep (> 40%) spread only in Nunyai Sub-district with a very narrow area (table 6).

The area of the flat slope class (0-8%) is 1006.65 Ha with a percentage of 11.12%. While the slope classification with the smallest area is the gentle slope classification (8-15%) with an area of 278.42 Ha with a percentage of 88.97% (Table 6). Because the nature of water flows from a higher direction to a lower area, waterlogging occurs and increases the possibility of flooding in flat areas.

Table 6 Slope Gradient of Rajabasa District

| No | Class | Classification | Score | Area (Ha) | Percentage (%) |
|---|---|---|---|---|---|
| 1 | 0-8% | Flat | 5 | 914.25 | 74.78 |
| 2 | 8-15% | Sloping | 4 | 264.84 | 21.67 |
| 3 | 15-25% | Wavy | 3 | 40.29 | 3.30 |
| 4 | 25-40% | Steep | 2 | 3.09 | 0.25 |
| 5 | >40% | Very Steep | 1 | 0.09 | 0.0078 |
| **Total** | | | | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

Table 6 shows that the Rajabasa District area mostly consists of land with a flat slope (0-8%), which covers around 74.78% of the total area or around 914.25 hectares. The gentle slope (8-15%) covers 21.67%, while the wavy slope (15-25%) covers 3.3%. The steep (25-40%) and very steep (>40%) slope classes only cover 0.25% and 0.0078% of the total area, respectively. The flat slope that dominates this area means that rainwater cannot flow quickly, thereby increasing the risk of water pooling which can lead to flooding, especially in residential areas.

d. **Soil Type**

In the classification of soil types by Rakuasa, et,al., (2022) soil types are divided into 5 classification classes. In Rajabasa District, Bandar Lampung City based on the Soil Type Map, it can be seen that Rajabasa District has 2 dominant soil types, the most extensive for soil types is the latosol class classification. Most of the soil types here are found in all sub-districts in Rajabasa District. The second type of soil is the podsol soil type which covers almost the entire Rajabasa Jaya Sub-district area and a small part is spread across Rajabasa Raya Sub-district.

Podsols are formed from the washing process of soluble minerals such as calcium, magnesium, and potassium by acidic rainwater above the soil layer. As a result, podsol soils tend to have eluvial horizons that are relatively poor in organic matter and minerals. However, the high sand and clay content and the lack of organic matter cause podsols to have a looser structure and larger pores. This allows water to easily seep into the soil and reach deeper groundwater layers.

Meanwhile, latosol soil is formed in tropical and subtropical areas with hot and humid climates. Latosol soil tends to have a higher organic matter content compared to podsol. However, the structure of latosol soil tends to be denser and has small pores due to the slower weathering process in the area. Because of its smaller pores and denser structure, latosol soil has a lower water absorption capacity compared to podsol. Water tends to flow on the surface of latosol soil or be trapped in the surface layer of the soil without being able to seep into the soil quickly.

Thus, the difference in water absorption between podsol and latosol soils can be concluded that podsols tend to have better water absorption capacity due to their loose structure and larger pores, while

latosol soils have lower water absorption capacity due to their denser structure and smaller pores. This greatly affects the occurrence of flooding in Rajabasa District.

The type of soil in Rajabasa District is generally latosol soil, where this latosol soil class has an area of 933.86 Ha or 72.73% of the total area of Rajabasa District. The smallest soil class is the podsol soil class with an area of 350.03 Ha with a percentage of 27.27% (Table 7). Because the nature of this latosol soil class holds river overflow water from seeping into the ground, it has an effect on the surrounding area, resulting in waterlogging and increasing the possibility of flooding.

Table 7 Slope Gradient of Rajabasa District

| No | Classification/Class | Score | Area (Ha) | Percentage (%) |
|---|---|---|---|---|
| 1 | Latosol | 4 | 933.86 | 72.73 |
| 2 | Andosol, Laterik, Grumusol, Podsol, Podsolic | 2 | 350.0 3 | 27.27 |
| | **Total** | | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

Table 7 shows that the soil type in Rajabasa District is dominated by latosol soil, which covers 72.73% of the total area or around 933.86 hectares. Meanwhile, podsol soil covers 27.27% or around 350.03 hectares. Latosol soil, which has low infiltration capacity, tends to increase the risk of flooding due to the soil's limited ability to absorb rainwater. The combination of this type of soil with high rainfall increases the potential for waterlogging in this area.

e. **Land Cover**

Rajabasa District, Bandar Lampung City is a district that has good development potential in the economic, social, and educational fields. This is because this district is one of the areas closest to educational environments such as universities. However, Rajabasa District is an area that has a very dense population density based on BPS data in 2023. Therefore, land cover is an important aspect that can be used to determine the function of an area. Land cover is one indicator of flood disaster parameters. Land use in Rajabasa District can be known through land cover data obtained from the Housing and Settlement Service of Bandar Lampung City since 2019-2023 which is then mapped with a classification based on national standardization guidelines Number 8 of 2007 concerning Indonesian National Standards. Land cover map in Rajabasa District with a scale of 1:35,000 is divided into five land cover classes, namely: Settlement/Open Land/River, Rice Fields/Ponds/Mangrove, Fields/Dry, Fields/Gardens/Agricultural Areas, and Shrubs/Non-Agricultural Land. Settlements in Rajabasa District are still widespread, while for river areas there is only Rajabasa Jaya Sub-district (Table 8). Land cover in Rajabasa District has 2 types of land cover, namely dominated by settlements with a percentage reaching 80.93%, while rice fields have a lower percentage, namely 19.07%.

Table 8 Land Cover of Rajabasa District

| No | Classification/Class | Score | Area (Ha) | Percentage (%) |
|---|---|---|---|---|
| 1 | Settlement/Open Land/River | 5 | 1042.69 | 80.93 |
| 2 | Rice Fields/Ponds/Mangroves | 4 | 245.81 | 19.07 |
| | **Total** | | **1286.50** | **100** |

Source: Results of research data processing, Year 2024

Table 8 shows that the Rajabasa District area is dominated by land cover in the form of settlements, which covers around 80.93% of the total area or around 1042.69 hectares. Meanwhile, rice fields or ponds only cover 19.07% of the total area or around 245.81 hectares. The dominance of settlements, especially in flat areas, exacerbates the risk of flooding due to the lack of water catchment areas. In addition, rapid infrastructure development in this region is also reducing green space that can help retain rainwater runoff.

**f. Geology**

Geological rock structures have a major influence on flooding because they affect the soil's ability to absorb and retain water. Alluvial rock formations tend to have low permeability, making it more difficult for water to be absorbed by the soil and easier to flow over the surface. In addition, rock structures also affect the flow patterns of underground water and rivers. For example, the presence of folds or fractures in rocks can cause the formation of underground water sources which then appear as springs or become abundant water sources during heavy rain. When heavy rain occurs, soil in areas with impermeable rocks tends to be unable to absorb water quickly, so water will flow directly into rivers or waterways, increasing the risk of flooding. Meanwhile, for areas with rock formations that are increasingly approaching volcanic formations are areas that tend to have low permeability, so that water is more easily absorbed by the soil and more easily enters the earth. Therefore, understanding the structure of geological rocks is very important in understanding the potential risk of flooding in an area. In the geological classification by Muin & Rakuasa (2023) geology is divided into 5 classification classes. In Rajabasa District, Bandar Lampung City is dominated by 2 geological class classification classes, where the dominant classes are the Lampung Formation and Pesawaran Volcano Formation classifications. The Lampung Formation classification is almost widespread in all sub-districts in Rajabasa District. While the Pesawaran Volcano classification is spread across Rajabasa Pramuka, Rajabasa Nunyai, Rajabasa, and Gedong Meneng Sub-districts.

Geological classification in Rajabasa District is generally dominated by the Lampung Formation, where the Lampung Formation class has an area of 939.83 Ha or 73.10% of the total area of Rajabasa District. The geological class with the smallest area is the Pesawaran Volcano Formation with an area of 345.78 Ha with a percentage of 26.90% (Table 9). The Lampung Formation generally consists of sedimentary rocks such as sand, gravel, and claystone. Meanwhile, the Pesawaran Volcano Formation is formed from volcanic material deposits such as lava, volcanic ash, and lava rocks. One of the main differences lies in the ability of these two formations to absorb water. The Lampung Formation tends to have a lower water absorption rate compared to the Pesawaran Volcano Formation. This is due to the nature of sedimentary rocks which are generally denser and less permeable, so that water tends to have difficulty seeping into these rocks. On the other hand, the Pesawaran Volcano Formation has more porous and permeable rocks, because it is formed from volcanic deposits that contain many cavities and gaps, allowing water to seep into them more easily. This has the effect that many areas in Rajabasa District easily absorb water, causing waterlogging and increasing the possibility of flooding.

Table 9 Geology of Rajabasa District

| No | Classification/Class | Score | Area (Ha) | Percentage (%) |
|---|---|---|---|---|
| 1 | Lampung Formation | 4 | 939.83 | 73.10 |
| 2 | Pesawaran Volcano | 1 | 345.7 8 | 26.90 |
| | **Total** | | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

Table 9 can see that the Rajabasa District area is dominated by the Lampung Formation, which covers around 73.10% of the total area or around 939.83 hectares. The Pesawaran Volcano Formation covers the rest, amounting to 26.90% or around 345.78 hectares. The Lampung Formation, which consists of sedimentary rocks with low permeability, has a lower water absorption capacity than the Pesawaran Volcano Formation. This makes areas dominated by the Lampung Formation more vulnerable to flooding.

**g. Flood Prone Mapping Results**

*Overlay* calculation by combining the existing parameter scores, the class/classification score is determined using the Sturgess formula. (Nur, 2023) so that the level of flood vulnerability in Rajabasa District was found as follows (table 10):

Table 10 Flood Vulnerability Level Classification

| No | Classification | Score | Area (Ha) | Percentage (%) |
|---|---|---|---|---|
| 1 | Somewhat Prone to Flooding | 14-17 | 41.85 | 3.44 |
| 2 | Flood Prone | 18-21 | 762.18 | 62.65 |
| 3 | Very Flood Prone | >22 | 412.68 | 33.92 |
| | **Total** | | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

Table 10 can be seen that Based on the research results, the Rajabasa District area is divided into three levels of flood vulnerability: somewhat vulnerable, vulnerable, and very vulnerable. The slightly vulnerable area covers 41.85 hectares (3.44%), the vulnerable area covers 762.18 hectares (62.65%), and the very vulnerable area covers 412.68 hectares (33.92%). The most vulnerable areas are especially those in areas with dominant land cover in the form of settlements, flat topography and high rainfall. The combination of these factors increases the risk of severe waterlogging when the rainy season arrives. Flood-prone areas are areas that, in terms of their physical and climatological nature, have the potential to experience flooding within a certain period of time (either short or long) and have the potential to cause environmental damage and harm humans. From the flood vulnerability map made based on flood determinant factor maps (parameters), it was found that Rajabasa District consists of three flood vulnerability classes, namely: slightly flood-prone class (41.85 Ha/3.44%), flood-prone class (762.18 Ha / 62.65%), and very flood-prone class (412.68 Ha/33.92%).

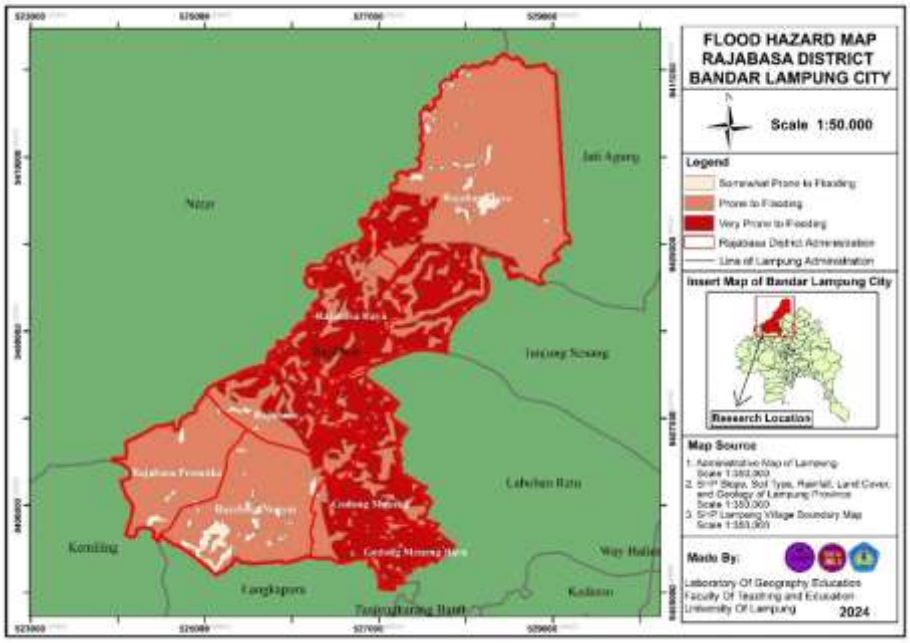


Figure 3 Flood-prone Map of Rajabasa District, Bandar Lampung City
Source: Results of research data processing, Year 2024

From the results of the flood vulnerability map, the classification of sub-district areas with flood vulnerability levels is as follows (Table 11):

Table 11 Classification of Flood Vulnerable Areas in Rajabasa District

| No | Classification | Class | Ward | Area of Subdistrict (Ha) | Classification Area (Ha) | Classification Percentage (%) |
|---|---|---|---|---|---|---|
| 1 | Somewhat Prone t Flooding | 14-17 | Rajabasa Nunyai | 20.85 | 41.88 | 3.44 |
| | | | Rajabasa Pramuka | 4.33 | | |
| | | | Rajabasa | 2.02 | | |
| | | | Rajabasa Jaya | 14.49 | | |
| | | | Gedong Meneng | 0.18 | | |
| 2 | Flood Prone | 18-21 | Gedong Meneng | 42.96 | 762.18 | 62.65 |
| | | | Rajabasa | 53.27 | | |
| | | | Rajabasa Jaya | 350.35 | | |
| | | | Rajabasa Nunyai | 152.19 | | |
| | | | Rajabasa Pramuka | 117.48 | | |
| | | | Rajabasa Raya | 42.19 | | |
| | | | Gedong Meneng Baru | 3.74 | | |
| 3 | Very Flood Prone | >22 | Gedong Meneng | 117.35 | 412.68 | 33.92 |
| | | | Gedong Meneng Baru | 32.16 | | |
| | | | Rajabasa Nunyai | 1.42 | | |
| | | | Rajabasa | 63.58 | | |
| | | | Rajabasa Jaya | 97.97 | | |
| | | | Rajabasa Raya | 100.22 | | |
| | **Total** | | | **1286.51** | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

Table 11 shows that the classification of flood-prone areas is based on an overlay analysis of various factors, such as rainfall, slope, soil type, land cover and geology. Rajabasa District is divided into three categories of flood vulnerability: somewhat prone to flooding, prone to flooding, and very prone to flooding. Areas categorized as slightly prone to flooding cover 41.88 hectares or around 3.44% of the total area of the sub-district, with sub-districts such as Rajabasa Nunyai, Rajabasa Pramuka, and Rajabasa included in this category. Although this area has the potential to experience waterlogging, the impact is relatively small. The flood-prone category covers 762.18 hectares or 62.65% of Rajabasa District, which indicates areas that are at higher risk of flooding which can impact people's lives. Highly flood-prone areas, which cover 412.68 hectares or 33.92% of the area, are areas with a very high potential for flooding, especially during the rainy season, which can cause damage to property and disruption of socio-economic life.

## 2. Discussion

### a. Analysis of Flood-Prone Areas

Flood vulnerability according to Cannon (1984) is defined as the condition of geographical, social, economic, political, cultural, biological, and technological characteristics of a community in an area for a certain period of time that can reduce the community's ability to prevent, mitigate, and achieve readiness or to respond to the impacts of certain prones (Wismarini & Sukur Muji, 2015). Floods in technical terms are river water flows that exceed the river's capacity so that the water flow passes through the riverbank and inundates the surrounding area (Frizani et al., 2021). There is a frequency of analysis units for each vulnerability instrument variable with the same purpose for all *stakeholders*, including rainfall, slope

gradient, soil type, land cover, and geology are one of the vulnerability variables that have indications of influencing flood disasters (Akhirianto, 2019) .

Determining the level of flood vulnerability is by determining the interval class from the value obtained from the total flood parameters. Determination of the interval class in Padang Cermin District is based on the formulas *Sturgess* (Nur, 2023), with the aim of distinguishing flood vulnerability classes between one and another. The following is the determination of the flood vulnerability level interval class in Rajabasa District, namely:

$$C_i = \frac{X1 - X2}{K}$$

$$C_i = \frac{25 - 5}{5}$$

$$C_i = 4$$

The creation of flood vulnerability class intervals using the Sturgess formula produces a class interval *value* of 4. This shows that the flood vulnerability level has interval members with a range of 4. The interval value of 4 is obtained from the total score that has been obtained from adding up the highest scores from each of the same parameter scores, while the lowest score is obtained from adding up each of the lowest scores for each parameter, so that it is obtained The highest score, namely (X1) : 25 minus the lowest score (X2): 5 then divided by the desired number of classifications, namely 5 classifications, then the class interval value (Ci) is obtained, namely 4. The level of vulnerability in Rajabasa District can be seen in the flood vulnerability map (Figure 3).

Based on the flood vulnerability level map, it can be seen that the flood-prone areas in Rajabasa District, Bandar Lampung City, flood-prone areas in Septian's research are areas that from a physical and climatological perspective have the possibility of flooding within a certain time and have the potential for environmental damage (Septian., 2020). Based on this map, the area of each flood vulnerability class in Rajabasa District can be seen in the Flood Vulnerability Area Classification table for Rajabasa District (Table 12). With the following information:

Table 12 Area of Flood Vulnerability Level in Rajabasa District

| No | Classification | Score | Area (Ha) | Information |
|---|---|---|---|---|
| 1 | Somewhat Prone Flooding | 13-17 | 41.88 | The area may experience flooding but this does not hav an impact on community life. |
| 2 | Flood Prone | 18-21 | 762.18 | The area may experience flooding and this may impac people's lives. |
| 3 | Very Flood Pron | >22 | 412.68 | The area is prone to flooding and can have a major impact on people's lives. |
| **Total** | | | **1286.51** | **100** |

Source: Results of research data processing, Year 2024

It can be seen from table 12 that this table provides further details regarding the area that is included in various categories of flood vulnerability in Rajabasa District. The slightly flood-prone category has an area of 41.88 hectares (3.44%), which is an area with minimal potential for waterlogging and does not have a major impact on people's lives. Flood-prone covers an area of 762.18 hectares (62.65%), this area is at risk of experiencing flooding which can affect people's lives, such as damage to infrastructure and disruption of activities. The highly flood-prone category covers 412.68 hectares (33.92%), which includes areas with very high potential for flooding, with major impacts on daily life, infrastructure and the economy. This classification is important in disaster mitigation planning, because it provides a clear picture of areas that require more attention in terms of drainage management and community protection.

Flood according to Yulianto (2022) is a river water flow that is higher than the normal water level so that it overflows from the riverbed, causing puddles on low-lying land on the side of the river (Yulianto., 2022). The overflow flow increases, flows and overflows the land surface that is usually not passed by water flow. Classification in Rajabasa District has 3 flood vulnerability classification areas, namely areas with a classification of somewhat flood-prone, flood-prone, and very flood-prone, while the other two classifications do not exist at all, illustrating that this district has a significant level of flood vulnerability. This shows that the majority of areas in the district have varying risks from somewhat vulnerable to very vulnerable to flooding. This condition indicates that there are a large number of areas in the district that have characteristics that increase the risk of flooding, ranging from lower risk levels to very high risks.

Based on the table of flood vulnerability level area in Rajabasa District, it can be concluded that for the flood vulnerability classification class, the slightly flood prone class has a very small/narrow area compared to the other two classifications where the slightly flood prone classification is only 3.44% of the total area of Rajabasa District, while the most dominant classification is the flood prone classification with a percentage of 62.64% of the total area of Rajabasa District, then followed by the very flood prone classification which dominates in second place with a percentage of 33.92% of the total area of Rajabasa District. The following is a more detailed explanation of each existing classification.

**b. Classification Slightly Prone to Flooding**

Flood classification at the level of being somewhat prone to flooding means that in areas in this class there may be inundation, or water runoff that exceeds the normal water level is an area that can experience flooding but does not have an impact on community life, this means that the flood that occurs is overflow from the riverbed which causes inundation but gradually returns to normal.

This is generally found in areas with good irrigation channels and less blockage in the irrigation channels, there are infiltration wells or there are several areas planted with trees that absorb a lot of water. Areas classified as somewhat prone to flooding in Rajabasa District are in Rajabasa Nunyai Sub-district with an area of 20.85 ha, Rajabasa Pramuka with an area of 4.33 ha, Rajabasa with an area of 2.02 ha, Rajabasa Jaya with an area of 14.49 ha, and Gedong Meneng Sub-district 0.18 ha. Areas classified as somewhat prone to flooding are located in areas with wet rainfall, namely 2001-2500 mm/year for Rajabasa Nunyai , Rajabasa Pramuka, Rajabasa, and Gedong Meneng Sub-district s with an area of 27.36 ha, while for the very wet class classification, namely >2501 mm/year, only in Rajabasa Jaya Sub-district with an area of 0.35 ha.

podsol soil types, it is only found in Rajabasa Jaya with an area of 14.49 ha, while for the geological classification of volcanic formations The availability and classification of Latosol soil types are spread across Rajabasa Nunyai Sub-district with an area of 20.85 ha, Rajabasa Pramuka Sub-district with an area of 4.33 ha, Rajabasa Sub-district with an area of 2.02 ha, and Gedong Meneng Sub-district 0.18 ha.

Judging from the classification of very steep slopes (>40%) only in Nunyai Subdistrict, namely with an area of 0.09 ha, which means only 0.054% of the total area of Nunyai Sub-district and only 0.008% of the total area of Rajabasa District. Furthermore, for the steep slope classification (24-40%) it is found in Nunyai Sub-district covering an area of 3.04 ha and Rajabasa Pramuka Sub-district covering an area of 0.07 ha. For the Wavy classification (15-25%) it is found in Rajabasa Sub-district covering an area of 2.02 ha, Rajabasa Jaya Sub-district covering an area of 1.42 ha, Rajabasa Nunyai Sub-district covering an area of 17.77 ha, Rajabasa Pramuka Sub-district covering an area of 4.26 ha, and Gedong Meneng Sub-district covering an area of 0.18 ha. And the last slope classification for the slightly flood-prone class is the gentle slope classification (8-15%) which is only found in Rajabasa Jaya Sub-district covering an area of 13.07ha.

Judging from the flood-prone map of Rajabasa District, the area classified as slightly flood-prone is also passed by a river or an area close to a river, so this is the first area to be hit by water runoff when it rains. However, based on the 5 parameters, the reason this area is classified as slightly flood-prone is because it is located in an area with a very steep to wavy slope, unlike other classifications that have a wavy

to flat slope, so this is quite helpful in overcoming flooding because this area is slightly higher than other areas. However, the area classified as slightly flood-prone is only a small part of the entire area in Rajabasa District.

**c. Flood Prone Classification**

After the classification of slightly flood-prone becomes the lowest classification and has the smallest area in Rajabasa District, the classification above it is the classification of areas with a flood-prone level, which means in areas that can experience flooding and can have an impact on people's lives, for example, a flood can occur which causes puddles near waters or irrigation channels which if left too long can damage facilities in the community. Areas with flood-prone classification in Rajabasa District are in areas with rainfall consisting of two classes, namely very wet rainfall (2500-3000 mm) covering an area of 15.93 ha and wet rainfall class (2000-2500 mm) covering an area of 746.26 ha, in the flood-prone class, the classification of soil type parameters is that there are 2 classes of soil types, namely podsol soil types covering an area of 317.58 ha and latosol soil types covering an area of 444.61 ha. For the classification of geological formations, it also consists of 2 types of classifications, namely the Pesawaran volcanic formation with an area of 302.54 ha and the Lampung formation with an area of 459.65 ha, while for the land cover parameters of the vulnerability class for the flood prone level of 545.56 ha dominated by residential areas and with an area of 216.67 ha filled with the rice field land cover class.

The classification of vulnerability classes with flood risk levels is also at 3 levels of slope, namely the undulating slope level (15-25%) with an area of 14.48 ha, the gentle slope level (8-15%) with an area of 250.07 ha, and the flat slope level (0-8%) with an area of 497.65 ha. The flood vulnerability class with this flood prone level is the most dominant class with the largest and widest area, namely 762.18 ha in Rajabasa District, with details of the area of the sub-district as stated in the flood prone area classification table in Rajabasa District (Table 12), seen from the flood prone map of Rajabasa District, it can be seen that the dominant formation for the flood prone class is the slope, geology, and soil type parameters where for slopes consisting of 3 types of slopes where the flat slope type dominates with the largest area compared to other slope classifications , this can be one of the factors causing this area to be included in the flood-prone classification. However, in addition to that, the reason why this area is a flood-prone area and is not included in the very flood-prone area is two other influential classifications, namely soil type and geology. The type of soil that dominates in areas with a flood-prone class level is podsol soil, this type of soil has a slightly better water absorption rate than latosol in the surface layer of the soil due to its high organic matter content. Meanwhile, for other parameters that greatly influence, namely geology in this flood-prone class, the area that includes the Pesawaran volcanic formation which again has a better water absorption rate than the Lampung formation geological formation because the Pesawaran volcanic formation has more porous and permeable rocks, because it is formed from volcanic deposits that contain many cavities and gaps, allowing water to seep into it more easily.

**d. Very Flood Prone Classification**

After the two vulnerability class classifications above, the highest vulnerability class with the category of very flood prone actually has an area that is not as wide and as wide as the flood prone class, which is only 412.68 ha, meaning that areas with a very flood prone vulnerability class are areas that often experience floodwater overflow, causing puddles that continue to rise, disrupting human activities, damaging facilities in the community and even causing loss of life. Vulnerability in this class is generally located in areas near rivers, densely populated, minimal irrigation, minimal infiltration areas and lots of garbage that can clog irrigation channels and shallow rivers. Areas classified as very prone to flooding in Rajabasa District are located in areas with wet rainfall of 2000-2500 mm, in the geology of the Lampung formation, with latosol soil types, located in residential land cover areas, and have a flat slope of 0-8% which are located in the Sub-district s of Rajabasa, Rajabasa Jaya, Rajabasa Jaya, Rajabasa Nunyai, Rajabasa Raya, Gedong Meneng, and Gedong Meneng Baru with an area that can be seen in the flood-prone area classification table in Rajabasa District (Table 12) which has the 2nd largest area after the flood-prone area classification with an area of 412.68 ha.

However, if we analyze more deeply based on field research, the results of the questionnaire, seen from *Google earth*, and also seen from the Flood Prone Result Map of Rajabasa District based on the approach of areas with flood-prone classification, this actually has a higher potential for flood prone compared to areas with a very flood-prone classification. This is because areas with flood-prone classes have many roads and are crossed by several rivers with a distance that is not too far (figure 9 page 109) this causes the area around the river to be hit first by river runoff when it rains and due to the many roads and being in a residential area, the water absorption rate is very slow, in addition, the accumulation of garbage in the river area also greatly affects the level of flooding due to river runoff. The sub-districts crossed by the river based on the results of field research using the following questionnaire:

1. Rajabasa Pramuka sub-district has one river that does not branch
2. Rajabasa Nunyai sub-district has one river with one branch so that the river flows into 2 with a fairly close distance.
3. Rajabasa sub-district has one river with one branch so that the river flows into 2 with a distance that is not too far.
4. Rajabasa Raya sub-district has one river flow
5. Rajabasa Jaya sub-district has 3 rivers that are quite far apart

Figure 4 Rajabasa Nunyai Sub-district, Rajabasa District in 2023
Source: BPBD of Bandar Lampung City

## *Conclusion*

Thus, the conclusion of the analysis is that Rajabasa District has a fairly high level of flood vulnerability. Factors such as high rainfall, slope gradient, soil type with low water absorption capacity, dominance of settlements, and geological characteristics make this area vulnerable to flooding. Sustainable mitigation efforts and more detailed flood risk mapping are needed to reduce the impact of flooding in the area. The main factors that influence flood vulnerability in Rajabasa District are rainfall, slope slope, soil type, land cover and geology. High rainfall, especially in areas with very wet rainfall such as in Rajabasa Jaya Sub-district, increases the potential for flooding even though the area is smaller. Slopes that are dominated by flat areas also worsen the risk of flooding, because water flows more slowly. Latosol soil types with low water absorption capacity increase the potential for inundation, although podsol soil in some areas is better at absorbing water. Land cover dominated by settlements exacerbates the risk of flooding, while the presence of rivers and rice fields also influences water flow. Finally, the geology of areas dominated by the Lampung Formation with low water penetration shows that areas with the more permeable Pesawaran Volcano Formation are better able to absorb water, reducing the potential for flooding. The combination of these factors makes Rajabasa District very vulnerable to flooding.

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