MAPPING THE POTENTIAL DISTRIBUTION OF FLOOD DISASTERS IN THE CITY OF SUNGAI PENUH USING ARCGIS

D. M. Magdalena Ritonga[1], Anggi Deliana Siregar[1*], Ira Kusuma Dewi[2], Raja P Simbolon[1], Dhinda Ayu Nawangsari[1], Bima Kurnia Sandy[1]

[1] *Teknik Geologi, Sains dan Teknologi, Universitas Jambi, Jl. Jambi-Muara Bulian No. KM. 15 Mendalo Darat, Muaro Jambi, 36361, Indonesia*

[2] *Teknik Geofisika, Sains dan Teknologi, Universitas Jambi, Jl. Jambi-Muara Bulian No. KM. 15 Mendalo Darat, Muaro Jambi, 36361, Indonesia*

*email: anggidelianas@unja.ac.id

ABSTRACT

This study aims to map the potential distribution of flooding in Sungai Penuh City by utilizing Geographic Information System (GIS) technology using ArcGIS software. The analysis was conducted by integrating several key parameters that influence flooding, namely rainfall, slope, soil type, land use, and proximity to rivers. Each parameter was reclassified and weighted based on its level of influence on flood potential, then a Weighted Overlay analysis was performed to produce a flood vulnerability zoning map. The results showed that the area with the highest flood vulnerability was in the central part of Sungai Penuh City, which has relatively flat topography, high rainfall intensity, and is a densely populated residential area crossed by several rivers. Meanwhile, the northeastern part and areas with steep slopes showed lower vulnerability levels. The resulting flood vulnerability map can be used as a reference in spatial planning, disaster mitigation, and sustainable land resource management in Sungai Penuh City.

Keywords: *Disaster, Flood, ArcGIS, Mapping, Vulnerability*

INTRODUCTION

Flooding is an event or condition in which an area or land is submerged due to increased water volume (Rakuasa et al., 2022; Rakuasa and Latue 2023). Flooding is a situation in which water overflows and covers areas that are not normally submerged by water (Muin et al., 2023). According to Latue et al. (2023), flooding can be caused by high rainfall that is not balanced by sufficient soil absorption. This can occur for various reasons, including heavy rain and overflowing rivers or lakes. Maryono (2020) adds that there are several factors that cause flooding, including the decreasing capacity of rivers due to siltation, high-intensity and prolonged rainfall, and the conversion of land into residential and office areas, which results in a decrease in water retention capacity.

Natural disasters are disasters caused by events or a series of events caused by nature, including earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes, and landslides. Climate change is one of the environmental phenomena that is worrying internationally today. Because climate change not only affects the temperature of the earth, the temperature that not only affects the biological system, but also affects the social conditions of the community. The impact on the social conditions of this community is because climate change, which also reduces the intensity of rainfall in some areas affects access to clean water, health and nutrition. Affecting this is of course a threat, especially for countries dependent on the agricultural economy (Rafly, 2023). Climate change is expected to be recognized earlier to find out how to mitigate it.

In the current era of globalization, regional development has experienced significant development. The development of residential areas and infrastructure that initially only occurred in large areas, but is now starting to spread to small areas. In the process of implementing development and regional planning, the relevant parties seem to forget or deliberately ignore vulnerable areas, in this case especially regarding flood-prone areas.

Floods as natural disasters that can potentially damage and harm life. Floods are the inundation of a place due to overflowing water that exceeds the water disposal capacity in an area and causes physical, social, and economic losses (Rahayu, 2009). Floods occur due to low soil infiltration, so that the soil is no longer able to absorb water. In addition, floods can be caused by overflowing surface water and the volume exceeds the irrigation capacity of the drainage system or river flow system (Nuryanti, 2018).

In developing development requires a lot of land and of course clear and detailed information is also needed regarding areas that are obediently selected and avoided. The criteria for selecting land for regional development must be in a safe area and far from natural disasters, such as floods which are very closely related to people's lives. The availability of information and data access that can be easily assisted by the community and policy makers in determining. The acquisition and provision of data (data acquisition) has complete, accurate, and up-to-date information. With the support and development of information

technology, the process is renewable. Geographic Information Systems (GIS) which act as a tool for processing, combining, and storing various spatial and non-spatial data are expected to be able to present information with geographical appearance according to what is needed. The expected results can act as information in the form of flood vulnerability zoning maps based on dominant values and parameters.

The existence of geographic information system-based technology greatly supports the needs of regional analysis. Geographic Information System (GIS) is a system supported by computer devices (hardware and software) to process, combine, overlay processes and store various types of georeferenced data so that geographic appearance is obtained. A simpler definition of GIS is a computer system that is able to handle and use data to explain places/positions on the earth's surface (Aronoff, 1989).

The problem focuses on the research of flood disaster distribution mapping in Sungai Penuh City, Jambi. The research covers administrative aspects, slope, elevation, rainfall, and land use for flood distribution at the research location. The potential for flood disasters in Indonesia occurs very often, especially in Sungai Penuh City which is prone to flooding, therefore flood distribution mapping activities are carried out using ArcGis which will then be known which locations have the highest potential for flooding.

METHOD

In general, the stages of this research consist of research preparation, preparation of supporting facilities and literature studies; processing, data analysis, and drawing conclusions from research results; and compiling final reports and scientific articles. In the preparation stage, a preliminary study is carried out related to the research topic, both from books and journal articles from previous research results. From this study, the method is determined and then research preparation is carried out. This preparation is the initial step in the systematics of research, in order to achieve the research objectives.

Preliminary Study

The research begins with a supporting preparation stage in the research such as the preparation of topographic map materials using Indonesian Rupa Bumi (RBI) data and Digital Elevation Model (DEM) images. This approach is carried out to obtain detailed information related to river flow direction data and estimates of rain catchment areas, the highest and lowest elevations, elevation slopes, rainfall, and land use. Output from the preliminary study carried out.

Implementation and Data Processing

Implementation and data processing such as editing digital maps and required data, merging spatial and non-spatial data. The data required in this study are only secondary data containing several parameters for determining the level of flood potential in Sungai Penuh City, such as population distribution data for the last 5 years, slope data, elevation data, rainfall data, and land use data. Each data has a value based on its level, which correlates with the vulnerability to potential flooding. Each data is combined using the ovrelay method with the composition of merging population distribution data with slope data to produce land unit 1, elevation data combined with rainfall data will produce land unit 2.

In research on mapping the potential distribution of flooding in Sungai Penuh City using ArcGIS, the data used came from various official sources. Elevation data was obtained from the Digital Elevation Model (DEM) sourced from DEMNAS (BIG) or SRTM (USGS), while rainfall data was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG). Land use or land cover data was taken from the Ministry of Environment and Forestry (KLHK), while soil type data was obtained from the Geospatial Information Agency (BIG) or the Center for Agricultural Land Resources (BBSDLP). In addition, river network and administrative boundary data was obtained from Bappeda or other official geospatial data sources.

The maps used in this study have a scale ranging from 1:25.000 to 1:50.000, depending on the size and level of detail of the study area. The spatial resolution of the data varies according to type, including DEMNAS with a resolution of approximately 8.25 meters, SRTM with a resolution of 30 meters, and land cover imagery with a resolution of 10–30 meters depending on the source of the imagery (e.g., Sentinel-2 or Landsat 8). The year of data collection is adjusted to the availability of the latest data, such as DEM data from 2022–2024, land cover imagery from 2023, and rainfall data taken from the average period of 2013–2023 to obtain more representative values.

Data processing is carried out in several main steps using ArcGIS software. The first step is to collect and correct data so that all datasets have the same coordinate system, for example UTM Zone 47S. Next, each parameter is reclassified, such as slope, rainfall, soil type, land

use, and distance to rivers. Reclassification is done by converting continuous values into specific classes based on flood vulnerability levels. For example, flat slopes (0–2%) are categorized as highly vulnerable with a high value, while steep slopes (>40%) are categorized as not vulnerable with a low value.

Each parameter is then weighted based on its level of influence on flood potential. This weighting process can be done using the Weighted Overlay or Analytical Hierarchy Process (AHP) methods, with examples of weighting being rainfall 30%, slope 25%, soil type 20%, land use 15%, and distance to rivers 10%. After that, all reclassified layers are combined through a raster overlay process using the Weighted Overlay feature in ArcGIS. The result of this stage is a flood potential zoning map that shows the classification of areas based on their level of vulnerability, such as very vulnerable, vulnerable, moderate, and safe.

The final stage involved validating the results by comparing the flood potential map with actual flood data or field reports to ensure spatial accuracy. Based on the results of this analysis, the distribution patterns of flood-prone areas in Sungai Penuh City were interpreted. The final map produced illustrates the zoning of flood-prone areas and safe areas, which are then discussed descriptively to support the research conclusions.

Data Processing and Analysis

After the data processing was completed, the data analysis stage was carried out. At this stage, a final overlay was performed by combining the results from land unit 1 and land unit 2 to produce a new map. The map was then used to compile the values of each parameter with their respective weights, resulting in the distribution of flood-prone areas. Based on these results, the areas classified as flood-prone and those classified as safe in the study area were determined. The final stage included a discussion of the analysis results and conclusions drawn from the entire process.

RESULTS AND DISCUSSION

This study is to determine the level of potential flood disasters using secondary data to map areas in Sungai Penuh City. The data used include: rainfall data, slope gradient, altitude, land use, and soil type. Each type of data has a value that indicates the level of flood risk. The data is then combined using the overlay method in the Geographic Information System (GIS).

Rainfall

Rainfall is the first parameter used to determine the potential for flood disasters in Sungai Penuh City using rainfall data and processed using Arc Gis software. High rainfall in this area also affects flooding that may arise from rainfall intensity and duration. When the intensity and duration of rain are not comparable to supporting facilities such as drainage, rivers, or infiltration areas, it can cause flooding. The rainfall map of Sungai Penuh City was obtained from the BMKG Sungai Penuh City station. The map has light to heavy annual rainfall intensity. Based on the rainfall map, the research area with the lowest annual rainfall intensity, which is around 1000–2000 mm/year, is located in the northeast and is shown in gray. Meanwhile, the highest annual rainfall intensity, around 4000–4500 mm/year, is found in the central region, which is marked in purple. The high rainfall in the central part of this region is closely related to the relatively flat local topography and is the main catchment area for the surrounding hills.

Hydrologically, the central part of the city is traversed by several rivers and tributaries that flow into the main river system, thus potentially experiencing greater surface water runoff accumulation. In addition to natural factors, human activities also contribute to the high level of vulnerability in this region. Intensive land use changes, such as the conversion of open land into residential and built-up areas, have reduced soil infiltration capacity and increased surface runoff. The combination of high rainfall, relatively flat topography, and the dominance of built-up land has

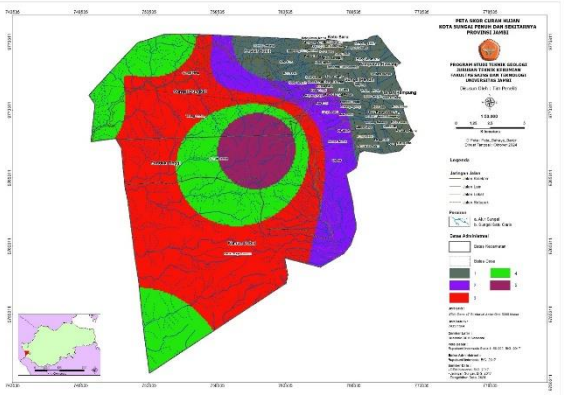

Figure 1. Rainfall Map of Sungai Penuh City

Rainfall data for Sungai Penuh City in January - July 2024 with the lowest intensity of 4.91 mm/month and the highest of 11.88 mm/month, can be seen in (Table 1). High rainfall in this area will affect flooding that occurs due to high rainfall and long duration, if the rain is not comparable to infiltration and drainage, flooding will occur. Areas with high rainfall intensity are not necessarily areas with high

flood potential, there are several other parameters that must also be considered, and vice versa, areas with low intensity are not necessarily free from flood potential.

Table 1. Rainfall Data for Sungai Penuh City (BMKG of Sungai Penuh City)

X	Y	Month	Rainfall (mm/month)
101.45000	-2.08300	January	11.88
101.45000	-2.08300	February	6.54
101.45000	-2.08300	March	4.91
101.45000	-2.08300	April	10.83
101.45000	-2.08300	May	6.43
101.45000	-2.08300	June	6.87
101.45000	-2.08300	July	11.53

Slope Gradient

Slope gradient is the second parameter used to determine the potential for flood disasters, using a Digital Elevation Model (DEM) then processed using Arc Gis, so that a slope gradient map is obtained. Slope gradient affects the amount and speed of surface runoff, surface drainage, land use and erosion. It is assumed that the gentler the slope, the slower the surface runoff flow will be and the greater the possibility of puddles or floods, while the steeper the slope, the faster the surface runoff flow will be so that the rainwater that falls will be drained directly and not inundate the area, so that the risk of flooding becomes small (Wijaya, 2023).

Slope gradient is divided based on the slope gradient classification according to Van Zuidam. The research area is dominated by steep to slightly steep slopes, namely areas with dark blue and pink colors covering around 75% of the research area and areas with gentle to flat slopes with light blue and green colors covering 25% of the research area. Steep to slightly steep slopes will cause rainwater to run off immediately and not have time to infiltrate so that areas with slopes like this are quite safe from potential flooding. Gentle to flat slopes make water not run off quickly so that areas that are gentle to flat have more potential to be flooded as seen in (Figure 2).

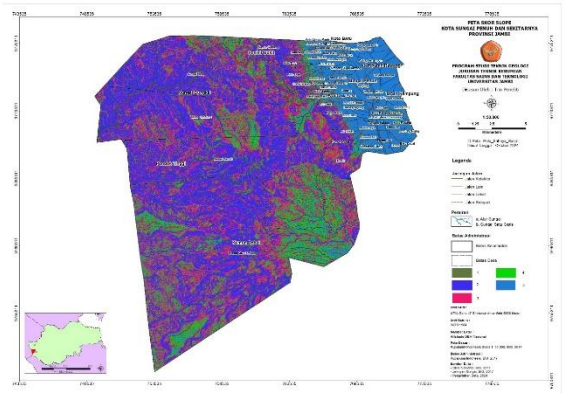

Figure 2. Slope Map of Sungai Penuh City

Altitude

Altitude is the third parameter used to determine the potential for flooding, using DEMNAS data, a map of the height of the place will be obtained which is processed using Arc Gis. The elevation factor affects the level of flood vulnerability because basically the nature of water flows from high areas to low areas. Areas that have a higher elevation have a small potential for flooding, while areas with low elevations are more likely to experience flooding, areas that are prone to flooding because basically water flows from high areas to low areas (Karasius, 2024). Altitude is correlated with the potential for flooding, in general areas with low elevations are more prone to flooding than areas with high elevations. Low areas tend to be places where water accumulates from high places. When rainfall is high upstream, low areas will feel the impact of rising water or faster river flow. High areas act as water catchment areas, water will run off and go to lower areas or water will seep into the ground and flow to lower places too. Based on the processed map, the areas with green, red, and dark blue colors are the highest areas, then the areas with light blue and yellow colors are the areas with the lowest elevation, so that areas with low elevations have the potential for flooding. In general, it can be concluded that altitude is one of the important factors that affect the potential for flooding. Areas with lower altitudes tend to be more vulnerable to flooding compared to higher areas as seen in (Figure 3).

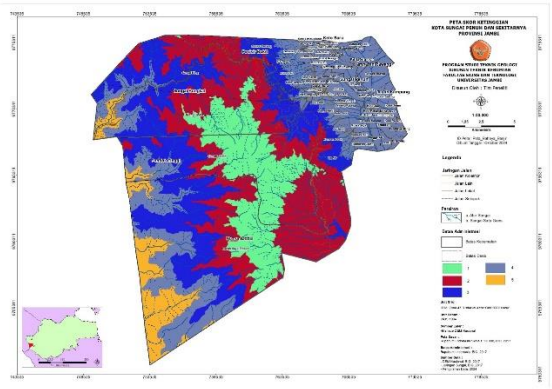

Figure 3. Map of Height of Sungai Penuh City

Land Use

Land use is the fourth parameter used to determine the potential for flood disasters. Changes in land use are changes in land use from one land to another, as well as changes in the function of an area over different periods of time. Changes in land cover functions from forest areas or green areas to built-up land areas will affect the rate of erosion and sedimentation in the area and can cause puddles in the surrounding area, which can also be called flood disasters (Rizani, 2024). Land use is the scope of an area with certain functions, the process of water infiltration into the soil can be faster or slower depending on the land use used. For example, forest

areas filled with water trees will absorb water faster than residential areas. Land use maps provide a visual view of areas that are likely to flood, by combining this map with other parameters, we will get areas that will have the potential for flooding. Based on the land use map, the brown area is a forest area, so the forest area has a small potential for flooding because there are trees that help to hold water. The light blue area is a bush, the bush area is less good at accommodating and storing water so the bush land use has a high potential for flooding. The red land use is a field and garden area. Field areas are also not as effective as forests for storing water. The dark blue land use is a rice field, irrigation, and pond area, the area is very potential for flooding because the location of the rice fields that need water and are close to the river and are located in a flat area and are one of the places where water accumulates, and the last green land use is a settlement where this area has been occupied by humans, so it has a high potential for flooding, in addition to the reduced absorption area due to the development of facilities and infrastructure, the human attitude of carelessness, namely throwing garbage carelessly into the river, makes the potential for flooding even greater, as can be seen in (Figure 4).

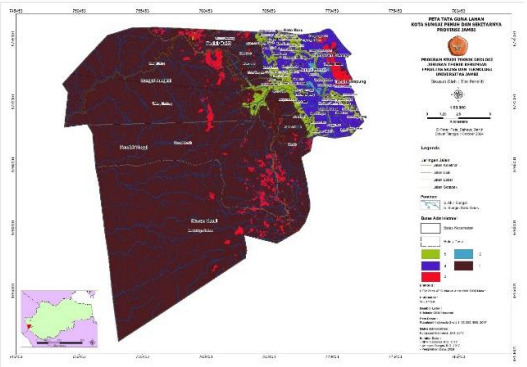

Figure 4. Land Use Map of Sungai Penuh City

Soil Type

Soil type is the fifth parameter used to determine the potential for flooding. The type of soil in an area greatly influences the water absorption process or what we usually call the infiltration process. The type of soil that is not sensitive to water causes water that falls and flows to the surface of the soil from rainfall or river overflows to not be able to seep into the soil, resulting in waterlogging. The type of oxisols soil is a type of insensitive infiltration soil, this type of soil has a very high flood risk. The type of ultisols soil with slightly sensitive infiltration, this type of soil has a high flood risk. The type of inceptisols soil with moderate sensitivity infiltration, the type of entisols soil with sensitive infiltration (Karasius, 2024). The type of soil can be sensitive to water infiltration depending on the porosity and permeability of the soil, the better the porosity and permeability, the more sensitive it will be to water infiltration, and vice versa, the worse the porosity and permeability, the less sensitive it will be to water infiltration. Based on the soil type map, Sungai Penuh City is divided into two types of soil, the first type is regosol, litosol with green color covering 40% of the research area, this type of soil has a very sensitive level of sensitivity, so this area should not have the potential for major flooding, but the potential will be large if other parameters are large enough. The second type of soil is inceptisols with a moderate level of sensitivity with a purple color covering 60% of the research area. This type of soil has a moderate level of sensitivity so that the potential for flooding is not too large and other parameters need to be considered as seen in (Figure 5).

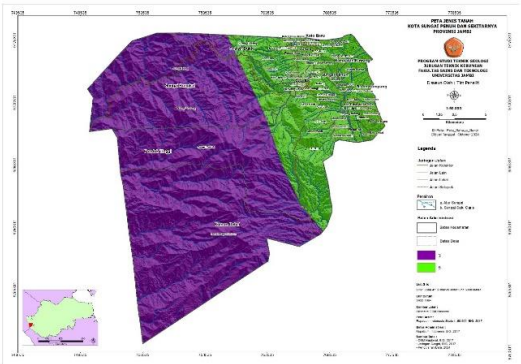

Figure 5. Map of Soil Types of Sungai Banyak City

Flood Prone Areas

Flood-prone areas are obtained by combining flood-causing parameters, namely rainfall maps, slope maps, elevation maps, land use maps, and soil type maps. These parameters are overlaid and calculated to produce a new map. The combined map is then classified to obtain a flood vulnerability map. In general, flooding is an event where land that is usually dry becomes inundated by water. This is caused by high rainfall and low to depression topographic conditions of the area. The occurrence of flooding is also caused by low soil infiltration capacity (the process of rainwater entering through the pores of the soil surface) so that the soil is no longer able to absorb water. In addition, flooding can be caused by surface water runoff that overflows and its volume exceeds the irrigation capacity of the drainage system or river flow system (Wijaya, 2023). The potential for flooding can be obtained using existing parameters. Flood potential can occur if several parameters are met and the potential for flooding will be greater if the five parameters are correlated with each other. A map showing areas prone to flooding is created by combining five different maps: a land use map, a rainfall map, a slope map, an elevation map, and a soil type map. These five maps are then combined (overlay) and calculated mathematically to produce a new map (Figure 6). The combined map is then grouped into several classes to show the level of flood

vulnerability in each area. Based on the disaster-prone area map made based on the five parameters, the red location is an area with a high potential for flooding, based on the 5 parameters, the rainfall at this location is relatively light each year, but because the area is flat, high rainfall in high areas flows to areas with lower altitudes, so that high rainfall in high areas with steep to slightly steep slopes will accumulate in the low areas, so that the red area becomes the area with the highest level of flood potential in Sungai Penuh City. Meanwhile, the yellow area is an area with a moderate level of flood potential, and the green area is an area that is safe from flooding because it is high, dominated by steep to slightly steep slopes.

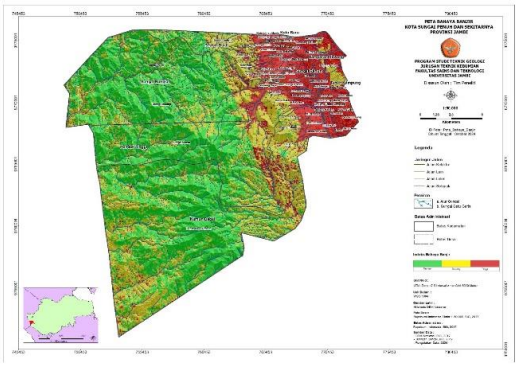

Figure 6. Full River City Flood Hazard Map

CONCLUSION AND SUGGESTIONS

Based on the results of spatial analysis using ArcGIS software, mapping of the potential distribution of flooding in Sungai Penuh City shows that the level of flood vulnerability in this area is influenced by a combination of various factors, including rainfall, slope, soil type, land use, and proximity to river networks. The overlay of all these parameters produced a flood vulnerability zoning map divided into several classes, namely very vulnerable, vulnerable, moderate, low, and safe. Areas with the highest vulnerability levels are generally located in the central part of the city, which has relatively flat topography, high rainfall intensity, and is traversed by several major rivers. In addition to natural factors, high human activity, such as land conversion for residential areas and infrastructure development, also increases the potential for flooding in this area. Conversely, the northeast and areas with steeper slopes have lower vulnerability due to better natural drainage.

Overall, the results of this mapping can be used as a basis for flood mitigation efforts in Sungai Penuh City. The flood vulnerability zoning information produced is expected to assist local governments in spatial planning, drainage management, and determining priority areas that require flood control measures and sustainable land use control.

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