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The Relationship Between Morphology, Morphogenesis and Morphotectonics Potential for Flood Disasters in the Karanggayam Area, Kebumen Regency, Indonesia

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Abstract

The Regional Disaster Management Agency (BPBD) of Kebumen Regency recorded that from 2011 to 2020 there were 1,335 disaster events, 154 (11.5%) of which were flood disasters. There were eight flood disasters in Karanggayam District were 8 incidents. This research method consists of four stages: literature study, field observation and mapping, analysis of morphology, morphogenesis, and morphotectonics, and analysis of the relationship between morphology, morphogenesis, morphotectonics, and flood potential. The potential for flood disasters is related to the morphological aspects, morphogenesis, and morphotectonics as controlling factors for flood disasters in the research area. Based on the potential for flood disasters in the research area, it is necessary to carry out non-structural mitigation in the research area. Appropriate nonstructural mitigation of flood disasters based on field facts, such as installing an early warning system for flood disasters, having evacuation routes and signs pointing to evacuation routes, socializing flood disasters, and installing warning boards in areas prone to flood disasters to minimize the risk of flood disasters in the Karanggayam area.

Keywords: Relationship, Morphology, Morphogenesis, Morphotectonics Flood, Disasters, Karanggayam, Kebumen

1. Introduction

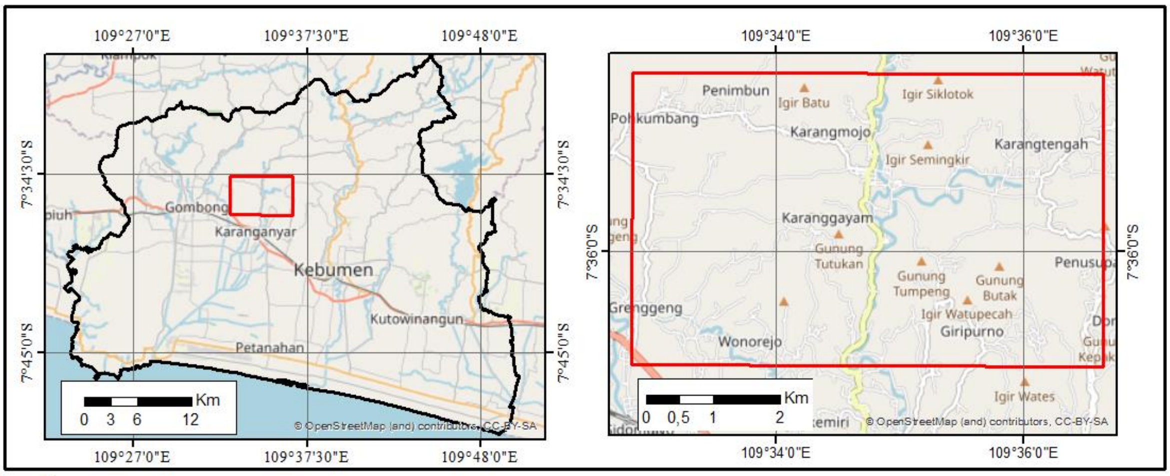
The Regional Disaster Management Agency (BPBD) of Kebumen Regency has recorded that from 2011 - 2020 there were 1,335 disaster events, 154 (11.5%) of which were flood disasters. Overall flood disasters in Karanggayam District were 8 incidents. The risk of moderate to high flood disasters is located in Karanggayam Village, which is an area with a confluence of tributary branches that can increase the flow rate when it rains (Retongga, 2023). Geomorphological conditions, such as landforms and slopes, influence the occurrence of flood disasters (Dahlia et al., 2018), areas with high resistance rock lithology or material sub-soil highly permeable ones have low density drainage levels that affect vulnerability to flood disasters (Srivastava et al., 2014), (Rahmati et al., 2016), and land use in sparsely vegetated areas is susceptible to flooding due to the positive relationship between infiltration capacity and vegetation density (Rahmati et al., 2016). Several aspects related to the possibility of flooding in an area include lithology, which is related to the type of rock texture; land use; rain intensity; slope; flow characteristics related to flow order; and land deformation due to tectonics, which are related to morphotectonics (Sukiyah et al., 2004). Kebumen Regency is one of the southwest coastal areas of Central Java, which is characterized by high rainfall, and the average rainfall in Kebumen Regency was 3,250 mm/year in 2010, reaching 4,100 mm/year (BPS, 2011; Indratmoko et al., 2017)). The morphology is controlled by high-medium levels of tectonic activity and surface processes, such as denudation and erosion, which can result in the risk of flood disasters (Raid and Setiawan, 2021). Structural and nonstructural disaster mitigation must be carried out to increase resilience and reduce the impact of flood disasters (Retongga et al., 2024). As the occurrence of flood disasters is closely related to geomorphological conditions such as morphology, morphogenesis, and morphotectonics, this study aims to determine the influence of morphology, morphogenesis, and morphotectonics on flood potential in the Karanggayam area as a basis for non-structural flood disaster mitigation.

2. Methodology

This research method consisted of four stages: literature study, field observation and mapping, morphological analysis, morphogenesis, morphotectonic analysis, and analysis of the relationship between morphology, morphogenesis, morphotectonics, and flood potential.

1. A literature review was conducted by previous researchers to obtain an overview of the research to be carried out and as a basis for reference for supporting data in this research.
2. Direct observation and mapping in the field were used to collect geomorphological data, such as morphology, including landform types, slopes, height differences, and drainage patterns. Morphogenesis includes lithology, vegetation, geological structure, and erosion rate. Photographs of potential points for overflowing water or flood routes.
3. Morphotectonic analysis includes: Bifurcation Ratio (Rb) to determine the level of river branching is a number or index obtained based on the results of the number of river channels for an order, Drainage Density (Dd) to determine the relief, valley density, rocks, soil, climate and vegetation, Hypsometric Integral (HI) to determine the level of erosion of the River Watershed (DAS), and Asymmetry Factor (AF) to determine the level of tectonic activity according to the slope of a watershed (DAS).
4. Analyses of morphology, morphogenesis, and morphotectonics with flood potential were performed to determine the relationship between geomorphology and flood potential in the study area. Thus, conclusions can be drawn about the potential for flooding in the research area and appropriate non-structural mitigation in the research area.

The research site is located in the Karanggayam Region, Kebumen Regency, Central Java Province. Astronomically, it was located between 339750 and 346750 and 9155200–9162200 (Figure 1).



Location of research area

Fig 1. Location of research area

3. Result and Discusstion

The results of observations in the field in the area of structural valley landforms and river bodies show that there are several points on short river slopes that can become flood routes if the river water overflows, which is proven by rubbish stuck in bamboo trees and other trees around the river flow. and has potential for flooding (Figure 2).

There are four points (Figure 2), which are indicated as water paths overflowing to the surface, namely in river bodies with gentle slopes and close to residential areas, flowing on bedrock and alluvial, namely andesite breccia, sandstone-limestone, calcarenite, tuffaceous sandstone, and alluvial deposits with weak-strong resistance or subsoil, which affects the absorption of water by bedrock, in tributaries and wild channels; if there is high-intensity rain with the river flow leading to the main river, it will increase the flow discharge at the confluence of the main river with the main river, which can make it prone to flooding, as evidenced by rubbish-garbage stuck in bamboo trees with a height of ± 3 m (Figure 2).

The potential for flood disasters was studied based on morphological, morphogenetic, and morphotectonic aspects. Flood disasters are studied based on morphological aspects, namely, the morphography of the river body's landform with morphometric slope values of 5–64° on the slope walls of the river body. It can control the infiltration of surface runoff and the speed of water flow in areas with gentle slopes, allowing more time for absorption. In areas with large slopes, it speeds up the flow of water and slows down absorption, making it prone to flood disasters. Slopes control surface runoff infiltration and water flow velocity. In areas with gentle slopes, slow runoff allows more time to absorb, and in areas with large slopes, it will speed up the flow of water, slowing absorption and making it vulnerable to flooding (Adiat et al., 2012), (Rahmati et al., 2016). Based on the morphogenesis aspect, namely passive morphostructure with the lithology of andesite breccia, calcareous sandstone, calcarenite and tuff sandstone which are rocks that lack high - medium resistance, it will affect the density of river flow, and erodibility and permeability and according to Rahmati et al., (2016), areas with high resistance rock lithology or materials sub-soil highly permeable ones have density drainage low levels, soil layers and especially resistant rock lithology, both in terms of erodibility and permeability are important natural factors for determining flood vulnerability. In active morpho structures, there are areas of discontinuity that affect rock permeability, and good permeability accelerates water absorption and minimizes river overflows. The Karanggayam River is composed of fine-grained sedimentary rock lithology and it is difficult to absorb water (Retongga, 2023); therefore, it has the potential for flooding. In dynamic morphostructures, if erosion and deposition occur in the landform area of the river body, it will cause the river to become shallow. If a river shallows, it is prone to flooding. Erosion, such as landslides, often occurs in the Karanggayam River basin and can hamper river flow (Retongga et al., 2024b), resulting in potential flooding.

Supported by data from morphotectonic analysis and calculations in the research area, namely,

1. Bifurcation Ratio (Rb)
   Analysis and calculation results of Bifurcation Ratio (Rb) in the study area (Table 1).

Table 1. The calculation results *Bifurcation Ratio* (Rb)

Nu = Number of River Flows for Order U	Nu + 1 = Number of River Flows for Order U + 1	Rb = River Branching Level Index
67	68	0.985

2. Drainage Density (Dd)
   Analysis and calculation results Drainage Density (Dd) in the study area (Table 2) and the relationship between Drainage Density (Dd) and rock lithology type in the study area (Table 3).

Table 2. The calculation results *Drainage Density* (Dd)

Total Length of River Flow (L)	Total Area of Watershed (A)	River Flow Density (Dd)	Texture (Sukiyah, 2009)
66.959722 km	29.75 km^2	2.250746958 km/km^2	Country

Table 3. River flow density classes and their relationship with lithology (Soewarno, 1991)

Drainage Density (Dd)	Density	Information
0.25- 10	Currently	Streams that flow over rocks that have strength are brittle.

3. Hypsometric Integral (HI)
   The results of the analysis and calculations obtained the maximum, minimum, average, and final values of the Hypsometric Integral (HI) watershed (DAS) in the study area (Table 4).

Table 4. Calculation results Hypsometric Integral (HI)

Maximum Height / Elevation of Watershed (Hmax)	Watershed Minimum Height / Elevation (Hmin)	Height / Average Elevation of Watershed (Hmean)	*Hypsometric Integral* (HI)
387.5	12.5	200	0.5

4. Asymmetry Factor (OF)
   The results of the analysis and calculations obtained the right area of the watershed from the downstream part of the main river (Ar), total area of the watershed (At), asymmetry factor (AF), and final value of Class 1 (High Tectonic Activity) (El Hamdouni et al., 2008) in the research area (Table 5).

Table 5. Calculation results Asymmetry Factor (OF)

Width of the Right Watershed Area from the Lower Part of the Main River (Ar)	Total Watershed Area (At)	Factor Asymmetry (AF)	Class 1 (High Tectonic Activity) (El Hamdouni et al., 2008)
15.27 km^2	29.75km^2	51.32773109 km^2	OF > 50

The results of morphotectonic analysis and calculations of the grade Bifurcation Ratio (Rb) < 3 will experience a rise in the water level, which can cause flooding and a slow decline. Density Drainage (Dd) produces a rough texture and a moderate friability value of 2,250, which is controlled by rock lithology. Therefore, it can be interpreted that the study area has a rather rough surface texture or landform. The low - medium density value is due to the permeable subsurface layer. Hypsometric Integral (HI), with a result of 0.5, describes the study area as having a moderate level of erosion and a high level of tectonic activity. Asymmetry Factor (AF) 51.32773109 km2 The research area has a high level of structure, namely first class and the research area has experienced uplift due to tectonic activity. Based on flood disaster risk analysis, the research area, especially Karanggayam village, has a high - to medium-risk level, which is directly proportional to the research results.

Fig 2. The point where the river water overflows is in the landform area of the river body and the point where the river water overflows.

Mitigation is very important to increase community resilience in facing flood disasters and to overcome or reduce the risk of disasters that will be posed to the community (Retongga et al., 2024a). Non-structural mitigation that is appropriate to the conditions and level of high risk of flood disasters in the Karanggayam area:

1. Installation of a flood disaster early warning system (Alfiani et al., 2020), a case example of the installation of a flood early warning system based on the HC-SR04 ultrasonic sensor and IoT, has been successfully installed at a flood monitoring post on the Boyong River. The flood early warning system installed at the flood monitoring post consisted of three subsystems. These subsystems are the one-power subsystem, data acquisition subsystem, and display subsystem. The power subsystem functions as a voltage source for the early flood warning system. The data acquisition subsystem collects, processes, and transmits sensor data information. The display subsystem displays the results of data processing. One power subsystem component includes the battery, charger adaptor, kit cut-off, and step-down. The data acquisition subsystem components include the Node MCU microcontroller and HC-SR04 sensor, whereas the display subsystem components include blinks on the application smartphone. The accuracy obtained by the flood early warning system (99.95 %) exceeded the Indonesian National Standard (SNI) value, which was ≥ 95%. In addition, this value also exceeded the International Standard (SI) value, that is, ≥ 97%. Therefore, a flood early warning system based on the HC-SR04 ultrasonic sensor and IoT installed on the Boyong River is suitable for use. Installation of an early flood warning system based on the HC-SR04 ultrasonic sensor and IoT at the confluence of the main river at coordinates 343453 and 9160097 in the central Karanggayam area. Installing an early warning system for flood disasters is very important, and there must be an early warning system for flood disasters to minimize the risk of flood disasters.
2. There are evacuation routes and direction boards. According to Sudiana, (2020), an evacuation route plan is created by considering the analysis of path accessibility and the fastest route. Previously, a route survey had been conducted in the field. From the results of the network analysis and analysis of route accessibility, it was found that points require evacuation signs/directions to the gathering point to make it easier for people to evacuate; there must be evacuation routes and directional boards for evacuation routes to high areas as routes for people to save themselves in the event of a flood disaster; route evacuation must be good and not damaged, and there is a board pointing to the evacuation route to the gathering point in each area with a high level of risk of flood disasters.
3. Flood disaster outreach
   The lack of public knowledge regarding threats, vulnerability, resilience, exposure to flood disaster risks, mitigation, and disaster management; therefore, the importance of socializing about flood disasters to the community. This socialization must be carried out in the Karanggayam area, and the community must understand disaster management to minimize risks. flood disasters.
4. Installation of warning boards in areas prone to flood disasters. It is important to install flood-prone warning boards in the Karanggayam area

to increase public awareness and minimize casualties if a flood occurs. There are no flood-prone warning boards in areas with a high level of flood risk, specifically the Karanggayam area

4. Conclusion

The potential for flood disasters is related to the morphological aspects, morphogenesis, and morphotectonics as controlling factors for flood disasters in the research area. Based on the potential for flood disasters in the research area, it is necessary to carry out non-structural mitigation in the research area. Appropriate nonstructural mitigation of flood disasters based on field facts, such as installing an early warning system for flood disasters, having evacuation routes and signs pointing to evacuation routes, socializing flood disasters, and installing warning boards in areas prone to flood disasters to minimize the risk of flood disasters in the Karanggayam area.

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