Unraveling the Contradictions of Conservation Land: Mapping High Flood Risk in the Buffer Zone of Merubetiri National Park (Case Study: Curahnongko Village)

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Abstract

Floods are hydrometeorological disasters that often hit various regions in Indonesia especially in low-lying areas, river basins, and areas with limited vegetation cover. Curahnongko Village is one of the areas vulnerable to flooding. This village is not supposed to have a high risk of flooding, as the area is a part of the Merubetiri National Park or a conservation area that is expected to have sufficient absorption capacity. In December 2024, floods inundated 400 households in Curahnongko Village. This research reveals the actual flood hazard vulnerability using the Weighted Overlay method. This research uses Google Earth Engine (GEE) to help process the flood modeling with several variable indicators such as land distance from water bodies, topographic position, elevation, vegetation index, and humidity index. The results of this study reveal that Curahnongko Village is dominated by the Medium risk category of 62.97% (6,467 ha) and the High risk category of 29.31% (3,011 ha). The mapping results also reveal that areas with low elevation levels, close proximity to water bodies, and low vegetation are more vulnerable to flood hazards. This research is expected to support decision-making for planning in areas that have a higher level of hazard in Curahnongko Village, Jember Regency.

Keywords: Disaster Risk Analysis, Flood Modelling, Enviromental Monitoring, Conservation Park.

A. INTRODUCTION

Indonesia is a country that has complex geographical, geological, hydrological, and climatological conditions. Various types of disasters such as floods, earthquakes, and volcanic eruptions often hit this region. The impact caused by the disaster not only threatens life safety, but also results in infrastructure damage, economic losses, and serious social and psychological problems. Therefore, disaster risk management is very important to ensure the sustainability of people's lives and development in Indonesia. Based on the Indonesian Disaster Management Law number 24 of 200, Article 1 Paragraph 1 defines a disaster as an event or series of events that threaten and disrupt people's lives and livelihoods caused by, either natural and/or non-natural factors, or human factors resulting in human casualties, environmental damage, property losses, and psychological impacts. More specifically, Article 1 Paragraph 2 emphasizes that natural disasters are a type of disaster caused by natural events, one example is floods.

Flood disasters are natural events that can cause widespread damage and adversely affect people's lives, both physically, socially, economically, and environmentally (Chen et al., 2021). In general, floods occur due to rising water levels in coastal areas, reservoirs, and rivers that exceed the carrying capacity of the area (Zhu & Zhang, 2022). The level of vulnerability to flood disasters

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is greatly influenced by factors such as high rainfall, reduction of conservation areas, the development of settlements on riverbanks, as well as the imbalance between the capacity of water catchment areas and the ability of drainage systems (Abass, 2022; Fitriyani & Wijayanti, 2024). Scientifically, flood disasters are a manifestation of an imbalance between the intensity of surface water flow and the absorption capacity of soil and drainage systems (Sun et al., 2023). Floods are generally influenced by several factors, hydrometeorological factors such as extreme rainfall patterns as well as anthropogenic factors such as deforestation, urbanization, and uncontrolled land use change (Ntontis et al., 2020).

Deforestation due to illegal logging and the conversion of land for agricultural activities has significantly reduced the ability of forests to absorb rainfall, thereby increasing surface runoff and flood risk. This has a direct impact on increasing the level of vulnerability of the region to flood disasters, especially in areas with decreasing forest cover, (Wu et al., 2020). Data reported by the National Disaster Management Agency (BNPB) shows that in the 2014-2024 period, flood disasters have experienced an upward trend both in terms of frequency and impact (BNPB, 2024). During this period, floods became one of the most intense types of disasters in Indonesia, causing great losses in social, economic, and environmental aspects, as well as increasing the burden that must be borne by the affected communities.

Areas with low topography and high rainfall tend to be more vulnerable to flood disasters, (Ridwan & Sarjito, 2024). Some regions even face floods as an annual phenomenon that routinely occurs with a significant impact on people's lives. Agricultural and plantation areas, especially in areas with high levels of deforestation, are very prone to flooding due to reduced rainwater catchment areas (Ansar et al., 2024). Curahnongko Village, which is located in Tempurejo District, Jember Regency, is one of the areas that is prone to flooding because this area is not only in an area close to the coast but also under the hills of Meru Betiri National Parks. Administratively, this village enters and intersects with the Meru Betiri National Park area. In 2024, Curahnongko Village will be recorded as the area with the highest flood impact in Tempurejo District, with a total of 400 households affected by this disaster (RRI, 2024). The geographical condition of the village adjacent to the river flow and the existence of several points with low elevation exacerbate the risk of inundation and increase the vulnerability of the community to the impact of disasters (Uddin & Matin, 2021).

The phenomenon of deforestation around Meru Betiri National Park, especially in Curahnongko Village, increases the threat to critical land which has implications for the risk of flood hazards (Ikhsan et al., 2025). Illegal logging, agricultural expansion, and uncontrolled land conversion have reduced the natural ability of forests to absorb rainfall. This forest degradation accelerates surface flow and reduces flood control capacity in the area. Meru Betiri has a very vital role as a catchment area that absorbs water so that there are no run-offs that cause flooding (TNMB, 2021). The permeability is supported by vegetation that absorbs water. Research by (Anggana et al., 2019) shows that the Meru Betiri forest ecosystem has an important role in flood mitigation, but continued deforestation threatens this ecological function and further increases the vulnerability of the surrounding area.

The application of geospatial information in flood hazard mapping has been applied to several previous studies using various methods, be it Analytical Hierarchy Process (AHP) (Vashist & Singh, 2024), Weighted Overlay (Alharbi, 2024), and Fuzzy Logic (Akay, 2021). The application of this mathematical function has benefits in providing decisions in hazard vulnerability assessments based on the data on which the assessment is based. The results in the previous study used a method that is relevant to what this study used using the Weighted Overlay method showing several hazard risk results.

A previous study by Arya & Singh, (2021) on a location study in the Uttar Pradesh Watershed, India showed that the flood hazard level was dominated by High Hazard Risk with coverage of 42% of the study area. Research in the Sidoarjo Regency area also with a weighting method shows areas dominated by medium risk with area coverage reaching 90% (Hariyanto et al., 2023). Previous research in the nearest study area was carried out in the Kencong District, Jember Regency using AHP showing that the hazard risk value was dominated by High risk with the coverage of the area reaching 52% of the study area.

The application of different methods provides a variety of mapping results. This study focuses on mapping the level of flood danger using the weighting method in the Curahnongko Village area. This study reveals the condition of the hazard distribution level considering the extent of the flooded area in previous disasters. This study also provides a comprehensive view from the perspective of disaster management in efforts to mitigate flood risk in the study area. This research also provides an argument to show how elevation, vegetation level, humidity, distance to water bodies and topography can affect the level of flood hazard vulnerability..

B. RESEARCH METHOD

This study uses a quantitative descriptive approach. The data from the mapping and processing will be analyzed and presented in the form of a narrative to describe the level of flood danger at the research site. The flood hazard level is assessed using the Weighted Overlay method, which is applied to the main variables relevant to the analysis. This method allows the integration and weighting of various variables to produce accurate flood hazard.

Study Area

The focus of this research is to assess and monitor the level of vulnerability to flood hazards by using variables that have been adjusted to the study. The research area is in Curahnongko Village, Tempurejo District, Jember Regency. Curahnongko Village itself is an area that intersects with the Meru Betiri National Park area as shown in Figure 1. In the previous flood in December 2024, at least 400 families were affected by the flood, not counting the economic losses where hundreds of hectares of agricultural land in the region were submerged by water (RRI, 2024).

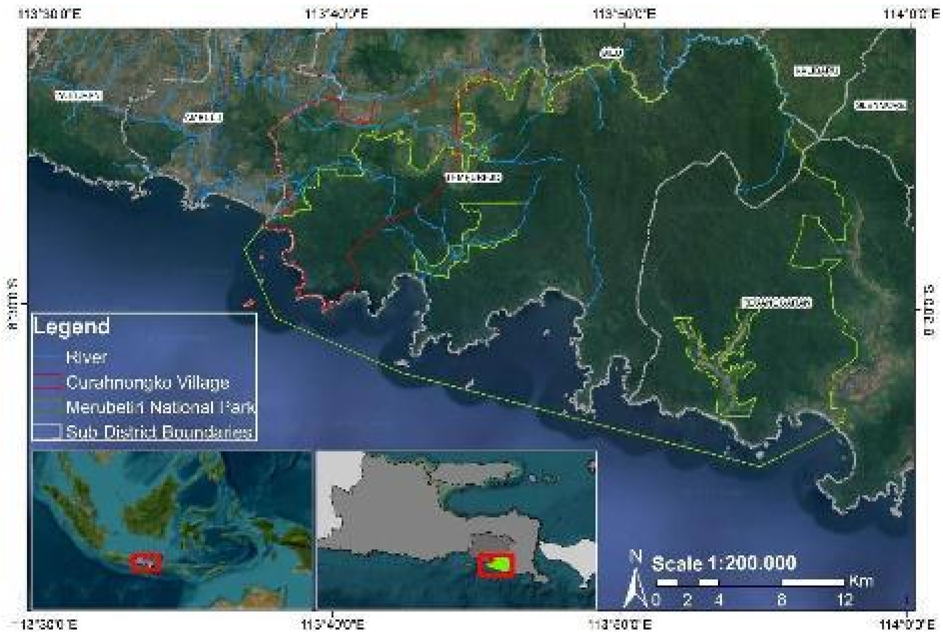

Figure 1. Research Location

The selection of this research site provides a framework for hazard assessment and flood management in areas that are vulnerable to flooding. This location study considers how the role of Meru Betiri National Park is vital in maintaining the stability of water absorption. Previous research also stated that the risk of flood danger also arises due to the change of vegetation from trees to small rooted vegetation such as rice and corn which do not have enough strength to store water reserves, causing land incompetence (TIMES, 2021).

Weighted Overlay Method

This study will use the Weighted Overlay method in mapping flood hazards. This mapping will use the help of Google Earth Engine software in its processing, and use ArcGIS 10.3 in the map layout. This study uses at least five variables that will be used in weighting the level of danger, namely; 1). Distance from water, 2). Topography Position Index (TPI), 3). Elevation Score, 4) Vegetation Score, and 5). Wetness Score. This study replicates the method in previous research by (Bello et al., 2024). Details of the classes and weighting values in this mapping are presented as follows.

Table 1. Distance from Water Criteria

Variable	Value	Conditions	Data Source
Distance From Water (m)	1	> 4000	JRC Global Surface Water
	2	3000 - 4000	
	3	2000 - 3000	
	4	1000 - 2000	
	5	≤ 1000	

Water bodies are one of the vital calculations in modeling flood vulnerability. This study uses JRC Global Surface Water data in looking at the distribution data of permanent water bodies in the study area. This information is very useful in assessing flood risk, both the size and presence of water are correlated with the level of flood vulnerability in an area (Agrawal et al., 2024; Babaei et al., 2018).

Table 2. Topography Position Indeks Criteria

Variable	Value	Conditions	Data Source
Topography Position Index	1	> 0	DEM SRTM 30m
	2	-0.2 to 0	
	3	-0.4 to -2	
	4	-0.6 to -0.4	
	5	≤ -0.8	

The Topography Position Index (TPI) reveals how the morphological shape of the region, both in the form of valleys and hills. The TPI value reveals how the relationship between landscape morphology and its influence on water dynamics. Areas with valley morphological forms have a higher susceptibility to flooding. TPI values that show positive values indicate the shape of hills and negative values indicate valley formations (Seif, 2014).

Table 3. Elevation Score Criteria

Variable	Value	Conditions	Data Source
Elevation Score	1	> 20	DEM SRTM 30m
	2	15 - 20	
	3	10 - 15	
	4	5 - 10	
	5	≤ 5	

The elevation value displays the level of altitude of an area. The elevation data in this research used the Shuttle Radar Topography Mission (SRTM). Areas with lower elevations will have a higher level of hazard risk in exposure to flood disasters (Diriba & Karuppannan, 2024). This variable plays an important component in flood risk mapping assessment.

Table 4. Vegetation Score Criteria

Variable	Value	Conditions	Data Source
Vegetation Score	1	NDVI > 0.8	Landsat 8
	2	0.6 < NDVI ≤ 0.8	
	3	0.4 < NDVI ≤ 0.6	
	4	0.2 < NDVI ≤ 0.4	
	5	NDVI ≤ 0.2	

The vegetation index displays information on the state, presence, and density of vegetation in a land cover. Vegetation has an important role in helping and increasing water absorption. Areas with lower vegetation density will be more vulnerable to flooding. This argument is supported by previous research where vegetation has an important role because of its ability to absorb and slow water movement, prevent soil erosion, and maintain the stability of riverbanks and floodplains (Soltani et al., 2021; Wang et al., 2015)

Table 5. Wetness Score Criteria

Variable	Value	Conditions	Data Source
Wetness Score	1	NDWI > 0.6	Landsat 8
	2	0.2 < NDWI ≤ 0.6	
	3	-0.2 < NDWI ≤ 0.2	
	4	-0.6 < NDWI ≤ -0.2	
	5	NDWI ≤ -0.6	

Wetness Score is related to the level of water saturation in an area or region. The level of water saturation shows how areas with high humidity have the potential to be the cause of flooding. In addition, this NDWI index displays how the water distribution conditions can also detect water bodies defined as flood conditions (Khalifeh Soltanian et al., 2019; Muhammad et al., 2023). The framework of the study is shown in Figure 2. The framework helps the research process so that the results and discussions can be presented in this vulnerability assessment.

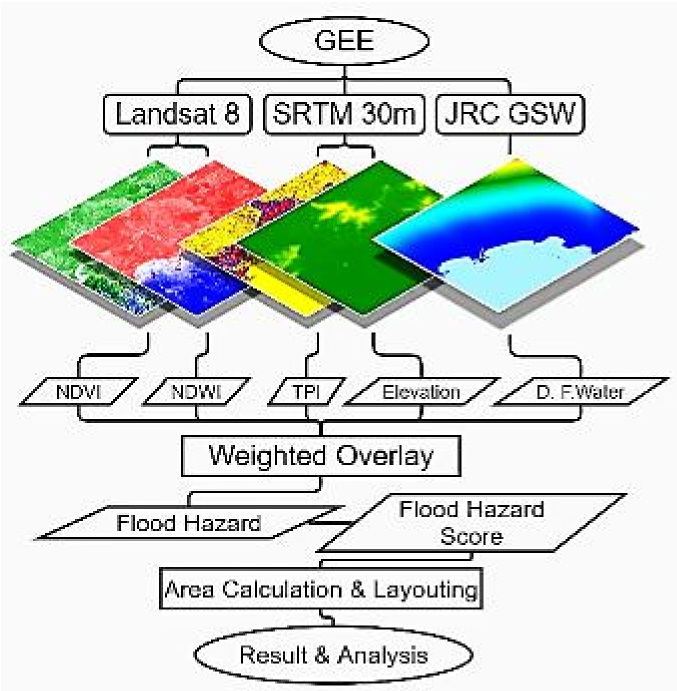

Figure 2. Research Workflow

C. FINDINGS AND DISCUSSION

Flood hazard measures the level of threat and potential level of likelihood of flooding. The flood hazard risk assessment in this study assesses from several layers that have a weight value as a calculation of the vulnerability. The results of the flood hazard risk mapping are visualized in Figure 3, where (a) shows the overall level of the score set without classification, while (b) displays the division that has been classified in 5 forms of scale, namely Very Low, Low, Medium, High, and Very High.

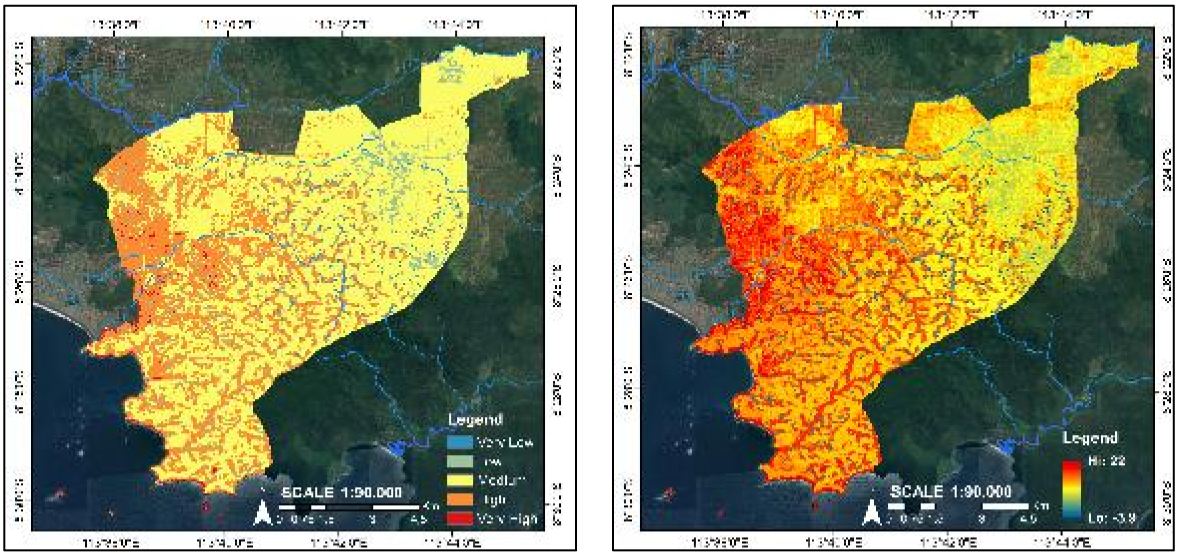

Figure 3. Classified Flood Hazard (left), Flood Hazard(right).

This classification provides an overview of the level of danger in the distribution that has been visualized in the form of a map. The figure also shows how areas with lower elevations are areas with a higher risk of flood hazards. It seems that areas with higher levels also tend to be in areas near water bodies such as rivers and seas. Map information also informs the area, where the area calculation is used using Google Earth Engine by calculating each flood hazard level class. Detailed information on the area is provided in Figure 4 as follows.

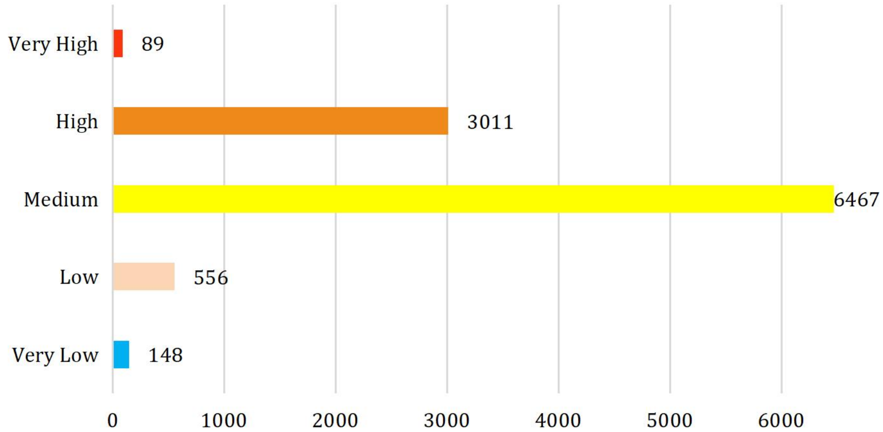

Figure 4. Calculation Results (/ha)

The results show that Curahnongko Village is overall at the Medium risk level with an area of 6,467 ha or 62.97% of the total area. Next is dominated by the High level with an area of 3,011 ha or 29.31% of the area coverage. Next in the low class of 556 ha or 5.41%, Very Low with an area of 148 ha or 1.44, and the last in the very high class with an area of only 89 ha or 0.87% of the coverage of the entire area.

Based on the results of the mapping, there is a need for a strategy in flood disaster management and strategic plans that are crucial in risk management and mitigation. The data from the analysis itself shows how the flood danger level in Curahnongko Village at the second dominance level is dominated by a high level of danger. Therefore, this requires proactive policy planning in disaster risk management and reduction following the mandate of the Sendai framework (UNDRR, 2015). The application of geospatial science provides priority assessment in determining areas with higher hazard exposure and helps in the analysis of disaster management in the study area. The efforts in this study are also relevant in supporting the 13th point of the SDGs, namely Climate Action, which requires action and planning to mitigate climate threats.

The flood danger level has several factors that cause flood disasters, such as anthropogenic factors and natural factors. The level of danger in Curahnongko Village is suspected to be related to illegal logging activities and changes in forest structure that occur in the Curahnongko area following previously disclosed information. Previous studies using assessments on the vegetation index found a downward trend which is interpreted as a decrease in the level of vegetation density indicated due to illegal logging activities that cause vital changes in forest structure (Mulyadi et al., 2025). This activity occurs because there is a limitation in the selection of resources that can be reached by the community to become economic value. People tend to carry out this illegal activity because they get quite instant profits from the forest. Community empowerment through fostered groups such as Jawara has been pursued in Meru Betiri National Park (KSDAE, 2020). However, there needs to be more efforts to promote the products of the community at large to add to their economic value (Nurrochmat et al., 2019).

The results of this study are none other than to provide an overview of the danger of flooding in Curahnongko Village. The results of this mapping are useful for the community and the government in understanding the risk of flood hazards in the study area. This utilization in detail can be in: (1) Providing a better understanding of the potential and vulnerability of hazards by understanding risks based on the distribution of hazards and patterns in areas with high flood hazards. (2) As a reference for area development with the application of disaster management understanding, such as paying attention to development areas in areas that have a lower risk of flood hazards. (3). This benefit is none other than how to build public awareness in areas with high risk of danger, awareness of disasters in the community can increase resilience to disasters.

D. CONCLUSION

The main factors affecting flood risk in this area are low elevation, proximity to water bodies, and deterioration in vegetation quality due to the conversion of land to small-rooted crops such as rice and corn. This study provides important information for flood mitigation and management planning, especially in the area adjacent to Meru Betiri National Park, which has an important role in maintaining water absorption capacity. The results of the analysis show that most of the Curahnongko Village area (62.97%) is in the medium-risk level, followed by the high-risk level (29.31%). Very Low and Very High-risk areas cover relatively small areas, amounting to 1.44% and 0.87% of the total area, respectively.

The application of Google Earth Engine (GEE) provides fast facilities for processing environmental data. This rapid process makes it easier for planners and policymakers to provide mitigation and rehabilitation plans in areas that are vulnerable to flood hazards. The role of geospatial science itself provides quite accurate modeling in seeing potential disasters that can be further explored in the decision support system. This methodology is not only specifically in the case study in Curahnongko Village but has a wider application for other areas in one form of data to support disaster information in more sustainable regional planning. We also expect a positive impact of this research to provide sustainable and resilient regional development design for disaster problems.

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