Flood Risk Indices Mapping of Lebak Regency, Banten Province

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ABSTRACT

Indonesia, as a developed country, has water-related disaster problems. Flood is one of them and it occurs in mostly province, including Banten province. Lebak Regency as the region of Banten Province has history of flood occurrences. According to the Banten Provincial BPBD (2021), among 2015-2020 period, twenty-nine flood events occurred in Lebak Regency. The severest flood of that period occurred in 2020. A total 2389 residents' homes and forty-five units of public facilities were damaged. Flood in Lebak regency historically also resulted in nine deaths, and two people were declared missing. The objective of this study is to be figuring out the flood risk profile and which districts have the highest risk in Lebak Regency by develop the risk indices map. Risk indices map informs the risk of flooding in each sub-district, hence the policies taken can be delivered by the authority properly. The method used in this study used overlays based on Perka BNPB No. 2 of 2012. This research obtains the map of the flood hazard, vulnerability, and capacity level that generates through QGIS. According to the results of the study, the risk index of Lebak district is low with three states. The sub-districts with the non-risk category are seven sub-districts with a percentage of 25%, while the sub-districts that fall into the slightly risky category are 10 sub-districts with a percentage of 35.7% and the sub-districts that are in the fairly risky category are 11 sub-districts with a percentage of 39.3%. These results given the conclusion that Lebak Regency is not considerable risk on hydrological flood events. Moderate level on vulnerability should gives note to the authorities to enhance the disaster resiliences.

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1. INTRODUCTION

Indonesia is a country that has water-related disaster problems. As one of the water-related problems, a flood occurs in Indonesia frequently. Flood is the condition of overflowing from the stream flow; hence it causes the pond in lowland [1]. The occurrence of floods in Indonesia tends equally to the

the entire province; no exception is Banten Province. Lebak Regency of Banten Province has water-related problems, such as floods that occur every year.

Regional Disaster Management Agency (BPBD) Banten Province in 2021 recorded that during the period of 2015-2020, there were twenty-nine (29) flood occurrences in Lebak Regency. According to data, a severe flood occurred in 2020. Approximately 2389 community houses and forty-five (45) public facilities are affected by the flood. Flood also causes the fatalities of at least nine (9) people and the missing of two (2) people.

Historical data of flood occurrence combined with environmental, demography, and economics can measure the degree of flood risk. This analysis produces a flood risk indices map. By flood risk indices map, the region that needs priority for flood mitigation and prevention can be figured out.

In order to risk and loss diminish due the flood disasters, the government needs to know the regions that have considerable risk of flooding. Therefore, mapping risk indices of flooding is prominent conduct as the basis of information for local governments to build water-related disaster policies.

The earlier paragraphs are the background of this work. Lebak Regency in Banten Province was taken as the research object. The research aims to quantify the level of flood risk in Lebak Regency. The code that was used in this research was the regulation of the National Disaster Management Agency (Perka BNPB No. 2, 2012).

2. METHODS

2.1 Flood

A flood is a stream overflowing that results pond in the lowland [1]. In another point of view, a region can be stated as flooding if the pond occurs due to stream overflow or high intensity of rainfall [2]. In simple words, a flood is a region that is usually in dry condition, then turns to pond [3]. Floods are usually influenced by at least four (4) factors that follow the excessive rainfall intensity, the mistake of stream regime development, stream shallowing, and watershed resistance degradation [4].

2.2 Risk Index

The risk of water-related disaster is a likelihood of total loss due to disaster. The loss due to disaster can include physical injuries, illness, loss of safety, life threatened, refugees, loss and damage of goods, disruption to community activities and even mortality [5]. The risk indices (R) have the hazard (H), vulnerability (V), and capacity (C) indices. The connection of the results in the equation of risk indices (R) as [3],

$$R = \frac{H \times V}{C}. \quad (2.1)$$

2.3 Hazard Index

A hazard is defined as a certain condition that results in life loss, environmental degradation, or goods loss [7]. In this terminology, hazard indices can be stated as threat indices. Both have similar points of view. Hazard indices are assembled according to three (3) components that follow the depth, duration, and frequency of flood [5]. Each component has a score according to field data. For flood hazard indices, Figure 1 gives a guide for hazard factors scoring [18].

Type of Index	Sub-Index	Parameter	Classification	Score
Hazard Index	Hazard based on depth of pond	Depth of pond < 0,76 m	Low	1
		Depth of pond between 0,76 m - 1,5 m	Moderate	3
		Depth of pond > 1,5 m	High	5
	Hazard based on duration of pond	Duration of pond < 1 day	Low	1
		Duration of pond 1 s/d 2 days	Moderate	3
		Duration of pond > 2 days	High	5

Figure 1. Hazard Indices Scoring Parameter

2.4 Vulnerability Index

Vulnerability is the condition where the community does not have the ability to deal with risk threats and hazards. In other words, it means that a community can be affected by disaster easily [2]. Vulnerability indices connect to economy, social, environmental, and physical state directly, and it runs through equation

$$V = 0.25V_P + 0.4V_S + 0.25V_{EC} + 0.1V_E. \tag{2.2}$$

V_P denotes the physical state. It quantifies the value of housing (S_H), public facility (S_{PF}), and critical facility score (S_{CF}). All of them result in the physical state of a relationship,

$$V_P = 0.4S_H + 0.3S_{PF} + 0.3S_{CF}. \tag{2.3}$$

Social vulnerability V_S relates to the density of population (S_{PD}), the ratio of manner (S_{RM}), the ratio of poverty (S_{RP}), the ratio of disabled (S_{RD}), and the ratio of age group (S_{RA}). Using equation

$$V_S = 0.6\frac{\log\frac{S_{RA}}{0.1}}{\log\frac{100}{0.01}} + 0.1S_{RM} + 0.1S_{RP} + 0.1S_{RD} + 0.1S_{RA}, \tag{2.4}$$

The social state will dawn as the second component of vulnerability indices.

The economic state V_{EC} is measured according to productive land and regional gross domestic product (GDP). Both will give the economic state according to equation

$$V_{EC} = 0.6S_{PL} + 0.4S_{GDP}. \tag{2.5}$$

The last component of vulnerability indices is the environmental state. It is influenced by managed forest (S_{MF}), natural forest (S_{NF}), mangrove forest $\left(S_{MgF}\right)$, swamp (S_S), and scrub (S_C). This state focuses on emphasizing the areas of forest. The area of the forest gives a score that will run in the equation

$$V_E = 0.3S_{MF} + 0.3S_{NF} + 0.1S_{MgF} + 0.1S_C + 0.2S_S. \tag{2.6}$$

Vulnerability indices are measured according to equation (2.3) until (2.6). Similar to hazard indices measuring, vulnerability indices raised from the scoring in Figure 2 [18].

Type of Index	Sub-Index	Parameter	Classification	Score
Vulnerability Index	Demography Vulnerability	Population Density		
		< 500 Peoples/Km^2	Low	1
		500 - 1000 Peoples/Km^2	Moderate	3
		> 1000 Peoples/Km^2	High	5
		Ratio of Gender		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
		Ratio of Poverty		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
		Ratio of Disabled		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
		Ratio of age group		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
	Economic Vulnerability	Productive Lands		
		< 50 Million	Low	1
		50 - 200 Million	Moderate	3
		> 200 Million	High	5
		GDRP		
		< 100 Million	Low	1
		100 - 300 Million	Moderate	3
		> 300 Million	High	5
	Physical Vulnerability	Living House		
		< 400 Million	Low	1
		400 - 800 Million	Moderate	3
		> 800 Million	High	5
		Public Facility		
		< 500 Million	Low	1
		500 Million - 1 Billion	Moderate	3
		> 1 Billion	High	5
		Critical Facility		
		< 500 Million	Low	1
		500 Million - 1 Billion	Moderate	3
		> 1 Billion	High	5
	Environmental Vulnerability	Protected Forest		
		< 20 Ha	Low	1
		20 - 50 Ha	Moderate	3
		> 50 Ha	High	5
		Natural Forest		
		< 25 Ha	Low	1
		25 - 75 Ha	Moderate	3
		> 75 Ha	High	5
		Mangrove Forest		
		< 10 Ha	Low	1
		10 - 30 Ha	Moderate	3
		> 30 Ha	High	5
		Scrub		
		< 10 Ha	Low	1
		10 - 30 Ha	Moderate	3
		> 30 Ha	High	5
		Swamp		
		< 5 Ha	Low	1
		5 - 20 Ha	Moderate	3
		> 20 Ha	High	5

Figure 2. Vulnerability Indices Scoring Parameters

Type of Index	Sub-Index	Parameter	Classification	Score
Capacity Index		Institutional Rules About Mitigation Disaster	Low	1
		Early Warning System and Study of Disaster Risk	Moderate	3
		Educational of Disaster	High	5
		Reduction of Base Risk Factor	For All Parameter	
		Awareness Development in All Stakeholder Level		

Figure 3. Capacity Indices Scoring Parameter

2.5 Capacity Index

Capacity indices are a region and community's ability to deal with the likelihood of water-related disaster occurrence. Capacity indices mean the scale of regions and community preparedness to loss potential and disaster hazard [8]. Therefore, the ability of local government and community to conduct many things in order to diminish disaster effect will give the capacity indices [6].

2.6 Geographic Information System (GIS)

Geographic Information System (GIS) is a system or technology that assists in mapping matters [10]. The GIS that was used in this research was Quantum GIS or, in abbreviation, QGIS. QGIS is an open-source software under GNU General Public Licensing. This software can run on operating systems.

1.7 Research flow chart

The research has structures, as Figure 4 describes through the research flowchart.

1.8 Research Location

The research location was in twenty-eight (28) sub-districts of Lebak Regency. Those are Those are Bojongmanik, Cibadak, Cigemblong, Cijaku, Cikulur, Cileles, Warunggunung, Cilograng, Cimarga, Banjarsari, Wanasalam, Cipanas, Curugbitung, Gunungkencana, Bayah, Kalang Anyar, Lebak Gedong, Leuwidamar, Maja, Cibeber, Malingping, Muncang, Cihara, Panggarangan, Rangkasbitung, Cilograng, Sajira, and Sobang.

The details of the location will show in Figure 5 as the Banten Province map (left side) and the Lebak Regency map (right side).

Figure 4. Research Flowchart

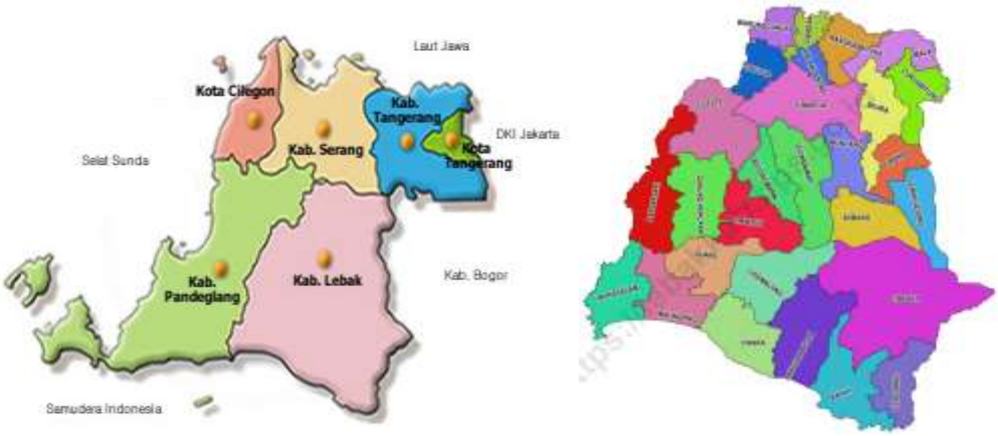

Figure 5. Research Location

1.8. Data collection

Data collection is necessary due to research ease. The data holds primary data and secondary data.

a. Primary data was obtained from direct interviews with the chief of each sub-district. The interview focuses on five (5) indicators of local government capacity for water-related disaster preparedness, especially on hydrologic flood hazards.

b. Secondary data was gathered on Indonesia Central Bureau of Statistics (BPS) Banten Province and Regional Disaster Management Agency (BPBD) Banten Province. BPS provides data on vulnerability indicators. On the other hand, BPBD provides the historical data on flood occurrence in Lebak Regency.

3. RESULTS AND DISCUSSION

The research used three (3) primary variables that follow hazard, vulnerability, and capacity indices. Those are the results of the risk indices as the aim of this research. According to Figure 4, hazard, vulnerability, and capacity indices obtained from the terminology are shown in part 2 of this article. QGIS transforms the indices through digital map and gives the hazard map, vulnerability map, and capacity map.

Using the overlay technique that is provided on QGIS, those three variables transform the risk indices map. According to this result, the information of risk level in each sub-district will appear and become the fundamental argument and interpretation about flood risk spreading in Lebak Regency.

3.1 Hazard Indices Quantification

Hazard indices were quantized by three (3) parameters. Those are the depth of the pond, its duration, and frequency. On hazard indices quantification, the weight of all parameters obeys Figure 1.

The hazard indices are divided into five (5) risk categories. These categories appear in Table 1.

Table 1 Risk Categories of Flood Hazard

Indices	Interval	Categories
1	0-1	Extremely low
2	1-2	Low
3	2-3	Moderate
4	3-4	High
5	4-5	Extremely high

According to quantification, there are seven (7) sub-districts that have extreme low categories and denote as dark green on the map (Figure 6). Eight (8) sub-districts that have low categories denote as yellow sign on the map. Then, the remaining are thirteen (13) sub-districts that have high categories and denote as orange.

Cileles, Cilograng, Curugbitung, Kalanganyar, Maja, Panggarangan, and Warunggunung are not the flood hazard sub-districts. While, Bayah, Cihara, Leuwidamar, Sobang, and Wanasalam are the sub-districts that have moderate condition. Then, Malingping, Cibadak, Banjarsari, Cibeber, Bojongmanik, Cigemblong, Cikulur, Cimarga, Cijaku, Cirinten, Gunung Kencana, Cipanas, Lebak Gedong, Muncang, Rangkasbitung, and Sajira have high flood hazard.

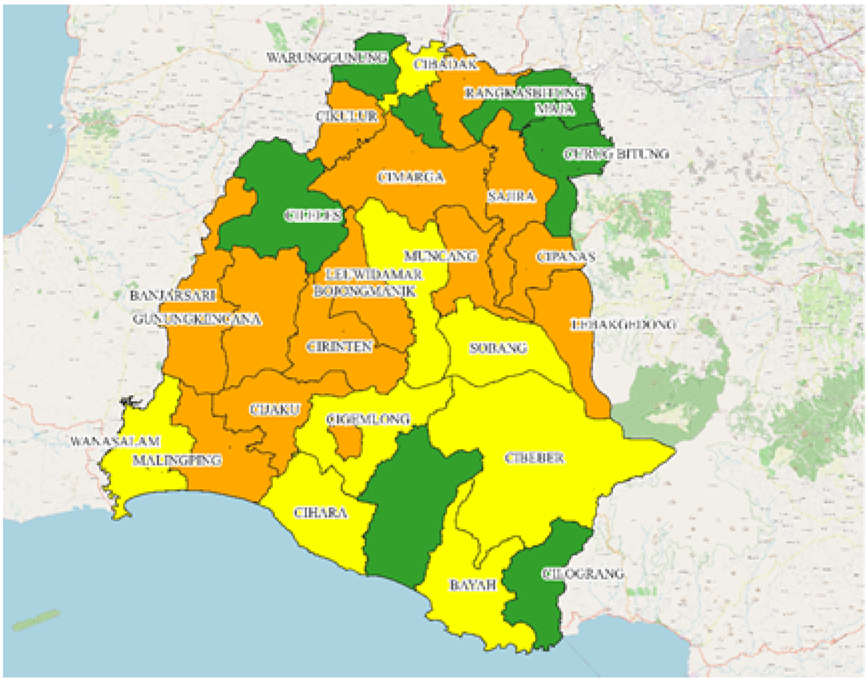

Figure 6. Hazard Indices Map

3.2 Vulnerability Indices Quantification

Vulnerability indices predict the level of damage if a flood occurs. Environmental, social, economic, and physical factors were analyzed by equation (2.3) until (2.6). The result was compiled until obtaining the vulnerability indices using equation (2.2).

Vulnerability indices quantification delivers the result into vulnerability categories according to Table 2.

Table 2. Risk Categories of Flood Vulnerability

Indices	Interval	Categories
1	0 - 1	Extremely low
2	1 - 2	Low
3	2 - 3	Moderate
4	3 - 4	High
5	4 - 5	Extremely high

Generally, at least twenty-six (26) sub-districts have flood vulnerability in moderate conditions. Those are Kalanganyar, Banjarsari, Bayah, Cihara, Bojongmanik, Cibadak, Cibeber, Cijaku, Warunggunung. Cikulur, Cileles, Cipanas, Cirinten, Curugbitung, Gunung Kencana, Lebak Gedong, Cilograng, Leuwidamar, Maja, Muncang, Panggarangan, Rangkasbitung, Sajira, Sobang, Wanasalam, and Cigemblong. Whereas Malingping and Cimarga sub-district are in high vulnerability. Those details appear as Figure 7

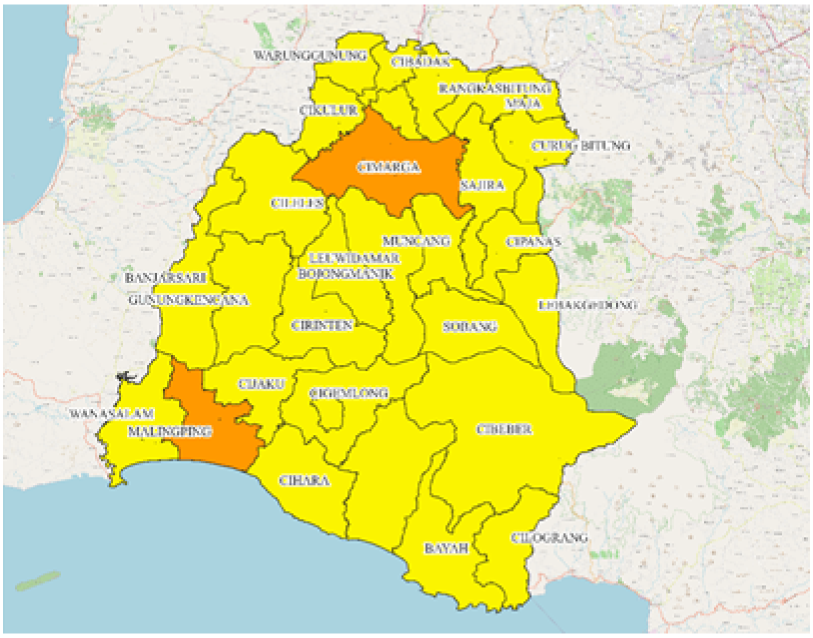

Figure 7. Vulnerability Indices Map

3.3 Capacity Indices Quantification

According to a direct interview with the chief of each sub-district in the entire Lebak Regency using Hyogo-HFA indicators, capacity indices were generated through Figure 3 term. Table 3 gives the provision of flood disaster resilience categories.

According to the result, most sub-districts in Lebak Regency have a good resilience to deal with flood disaster. Whereas Cimarga, Sobang, and Banjarsari sub-district have moderate level. Figure 8 gives the description of capacity indices in Lebak Regency.

Table 3. Risk Categories of Capacity

Indices	Interval	Categories
1	0 - 1	Extremely low
2	1 - 2	Low
3	2 - 3	Moderate
4	3 - 4	Good
5	4 - 5	Extremely good

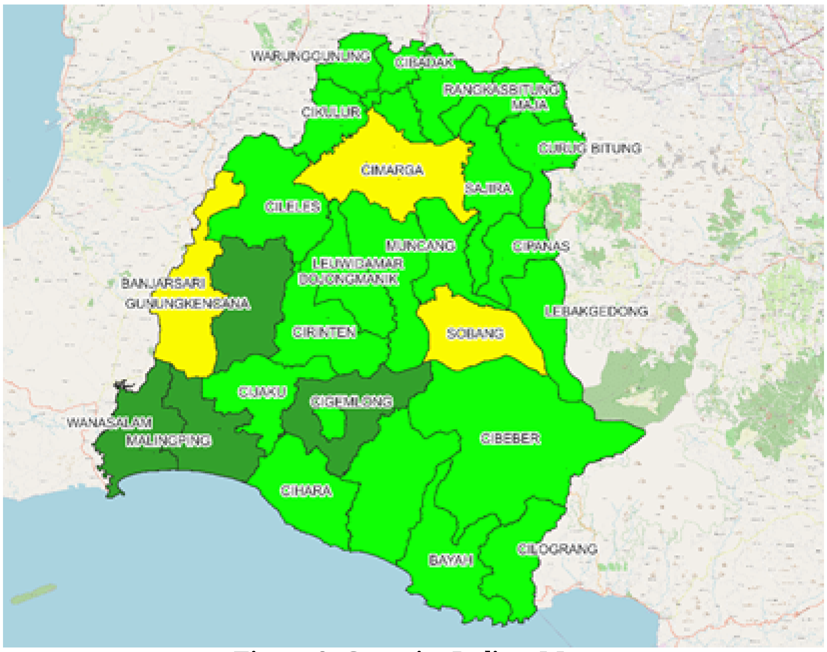

Figure 8. Capacity Indices Map

3.4. Risk Indices Generating

The risk indices were the final analysis in this research that it runs through equation (2.1). Combining hazard, vulnerability, and capacity indices give risk categories that are simplified in Table 4.

Table 4. Risk Categories

Indices	Interval	Categories
1	0 - 1	Extremely insignificant risk
2	1 - 2	Insignificant risk
3	2 - 3	Moderate risk
4	3 - 4	Significant risk
5	4 - 5	Extremely significant risk

Due to the fact that most sub-districts in Lebak Regency have good resilience in flood disaster preparedness, it gives an insignificant risk category in many sub-districts. However, there are eleven (11) sub-districts that have moderate risk. This will become a particular note as the sub-districts with higher likelihood in damaging due to flood occurrence.

Figure 9 is the final map of flood risk indices in Lebak Regency. This map should give information respect with to the level of risk in each sub-district. Therefore, the local government can develop policies related to flood disaster preparedness and mitigation. Implementation of them should have integration and connection to the local community.

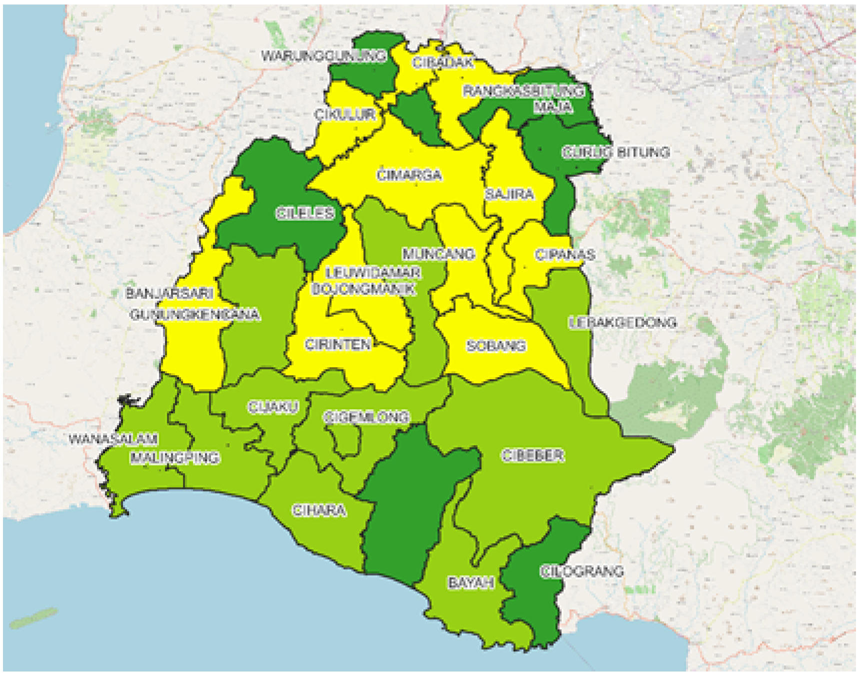

Figure 9. Risk Indices Map

4. CONCLUSION

According to the results, flood risk indices in Lebak regency are dominant on insignificant risk. As a deeper information, only eleven (11) sub-districts have moderate risk. Moreover, none of the sub-districts have a significant and extremely significant risk level. However, this condition still needs to be emphasized in policy enforcement with respect to flood disaster preparedness and mitigation. Enhancement of capacity level is still necessary.

Future research can conduct the following research development:

1. Research can be conducted to measure flood risk at the village level.
2. Considering the use scenario level in capacity indices measuring.
3. In a similar location, other disasters should be conducted.

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