Application of Geographic Information System for the Identification of Flood and Landslide Mitigation in Badeng Watershed

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Abstract: Badeng River is the path of the Mount Pendil catchment area which can potentially bring avalanche material and runoff water from upstream to downstream so that it can cause floods and even flash floods. The mapping of flood and landslide-prone areas in the Badeng Watershed is non-structural disaster control. The research objective is the identification of disaster mitigation in areas prone to flooding and landslide-prone areas in the Badeng Watershed with Geographic Information Systems. The study was conducted using descriptive methods consisting of surveys and map overlays, while the identification of flood-prone and landslide-prone areas using a scoring method by weighting refers to the formula of flood and landslide susceptibility. The results showed that the flood water supply area of Badeng watershed with 32.2% prone conditions was found in the villages of Desa Sumber Arum, Sumber Bulu, Sumber Baru, Songgon, Parang Harjo, Bedewang, Kemiri, Benelan Kidul, Bubuk, Cantuk, Gintangan, Singojuruh, Alas Malang, Bayu, and Gladag. For areas prone to flooding with very prone conditions 28.43% was found in the villages of Sumber Arum and Bayu, and landslide susceptibility areas with moderately vulnerable conditions 2.7% was in the villages of Sumber Arum, Songgon, Bayu, and Sumberbulu. Disaster mitigation was recommended upstream in the form of vegetation conservation and mechanical conservation buildings and downstream in the form of river dredging and flood awareness training for communities in vulnerable areas.

1 INTRODUCTION

Natural disasters are one of the phenomena that can occur at anytime, anywhere, and anytime, causing risks or dangers to human life, both property losses and human lives (Faizana *et al*., 2015). Therefore, the role of disaster mitigation is needed to reduce the impact of disasters that occur. In-Law Number 24 of 2007 concerning Disaster Management which is published on the official website of the National Disaster Management Agency states that a disaster is an event or series of events that threaten and disrupt people's lives and livelihoods caused by both natural factors and non-natural factors and human factors resulting in human casualties, environmental damage, property losses, and psychological impacts (BNPB, 2007).

The Banyuwangi flash flood in 2018 in Alas Malang was one of the many natural disasters that caused losses. This flash flood was caused by weathering of material on the slopes of Mount Pendil, which flows with a current to the Badeng River. Badeng River is the Mount Pendil catchment area and flows up to Alas Malang. Flash floods can be destructive. The flow of water currents that are not too deep but are fast and turbulent (turbulent) brings subtle soil material and drag material in the form of more massive rocks to cause damage.

Geographic Information Systems (GIS) can provide geospatial data such as objects on the surface of the earth quickly while providing an accurate spatial analysis system. So, mitigation efforts can be made to prevent the risk of potential disasters or reduce the effects of disasters.

This Geographic Information System has been widely used for similar research purposes, such as research from, Faizana (2015); Todingan *et al*., (2015); Susanti (2016); Novialiadi (2016); Hendi

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(2014); Erwanto *et al.*, (2020); Erwanto and Lestari (2020); and also Erwanto *et al.*, (2021). Therefore, this research is a mitigation effort that produces maps of flood and landslide disaster-prone and recommendations for disaster risk reduction.

1.1 Problems

How to identify disaster mitigation in flood-prone areas and landslide-prone areas in the Badeng Watershed with Geographic Information System?

1.2 Research Purpose

The research objective is to identify disaster mitigation in flood-prone areas and landslide-prone areas in the Badeng Watershed with Geographic Information System.

2 THEORETICAL BASIS

2.1 Disaster Mitigation

Disaster mitigation is an effort to reduce the impact of disasters, whether natural disasters, human-made disasters, or a combination of both in a country or society. Disaster mitigation identification is useful for determining mitigation policies that will be used in vulnerable areas. The identification method used is scoring and layering in the Geographic Information System (GIS) software by processing spatial data and attribute data. Analysis of landslide and flood hazards based on the scoring method (Paimin *et al*., 2009).

2.2 Flood Prone Areas

The identification of flood hazard is divided between the identification of areas prone to flooding (flooding) and areas of flood water supply or potential floodwater (Paimin *et al*., 2009). It is vital to facilitate the way of identifying sources of disaster systematically so that effective and efficient control techniques are obtained. Characterization of flood-prone areas is done by giving a score of each parameter on the digital map unit. Scoring in potential areas of flood water supply can be seen in Table 1 and scoring in areas prone to flooding in Table 2 (Paimin *et al.*, 2009).

Table 1: Formula of Flood Water Supply Potential.

No.	Parameters / Weights	Classification	Category	Score
NATURAL 60%				
a.	Average Rainfall (mm / year) (35%)	< 20 mm	Low	1
		21-40 mm	A Bit Low	2
		42-75 mm	Moderate	3
		76-150 mm	A Bit High	4
		> 150 mm	High	5
b.	Watershed Form (5%)	Oval	Low	1
		A Little Oval	A Bit Low	2
		Moderate	Moderate	3
		Slightly Round	A Bit High	4
		Round	High	5
c.	River Gradient (10%)	< 0,5 %	Low	1
		0,5-10 %	A Bit Low	2
		1,1-1,5 %	Moderate	3
		1,6-2,0 %	A Bit High	4
		> 2,0 %	High	5
d.	Drainage Density (5%)	Rarely	Low	1
		A Bit Sparse	A Bit Low	2
		Moderate	Moderate	3
		A Bit Tight	A Bit High	4
		Tightly	High	5
e.	Watershed Mean Slope (5%)	< 8 %	Low	1
		8-15%	A Bit Low	2
		16-25 %	Moderate	3
		26-45%	A Bit High	4
		> 45%	High	5
MANAGEMENT 40 %				
a.	Land Use	Protection / Conservation Forest	Low	1
		Production Forest / Plantation	A Bit Low	2
		Yard / Bush / Scrub	Moderate	3
		Rice Fields / Moor-Terracing	A Bit High	4
		Moor / Settlement-City	High	5

Table 2: Formula of Potential for Flood-Prone Areas.

No.	Parameters / Weights	Classification	Category	Score
NATURAL 55%				
a.	Land Form (30%)	Mountains, Hills	Low	1
		Fan and Lava	A Bit Low	2
		Plains, terraces	Moderate	3
		Plains, Terraces (Slopes <2%)	A Bit High	4
		Alluvial Plains, Alluvial Valleys, Bend Paths	High	5
b.	River Slope Left and Right (10%)	> 8 (Very smooth)	Low	1
		2 - 8 (Somewhat smoothly)	Moderate	3
		< 2 (Hampered)	High	5
c.	Meandering Sinusity (P) = Length of river distance according to curve / straight distance (5%)	1.0 – 1.1	Low	1
		1.2 – 1.4	A Bit Low	2
		1.5 – 1.6	Moderate	3
		1.7 – 2.0	A Bit High	4
		> 2.0	High	5
d.	Dams By Branching Rivers / Tides (10%)	None	Low	1
		Branches of the main river	A Bit Low	2
		Branch of the main river	A Bit Low	3
		Main river / Bottleneck	Moderate	4
		Tide	A Bit High	5

Table 2: Formula of Potential for Flood-Prone Areas(Cont.).

No.	Parameters / Weights	Classification	Category	Score
MANAGEMENT 45 %				
a.	Irrigation Buildings	Reservoir + Embankment High and Good	Low	1
		Reservoir	A Bit Low	2
		Dike / Corner / Flood Canal	Moderate	3
		New Embankment	A Bit High	4
		Without buildings, shrinkage of river dimensions	High	5

The flood hazard level is analyzed with each parameter and is weighted according to field conditions and classified in five levels of vulnerability, including vulnerable, vulnerable, somewhat vulnerable, slightly vulnerable, and not vulnerable.

2.3 Landslide Vulnerable Areas

The potential for landslides to occur on slopes depends on the condition of the rock and soil preparation, geological structure, rainfall, and land use. Characterization of landslide-prone areas is done by giving a score on each parameter on the digital map unit by field conditions (Paimin *et al.*, 2009). Scoring in landslide-prone areas can be seen in Table 3.

Table 3: Formula of Landslide-Prone Area Potential.

No.	Parameters / Weights	Classification	Category	Score
NATURAL (60%)				
a.	Average Rainfall (mm / year) (25%)	<50 mm	Low	1
		50-90 mm	A Bit Low	2
		100-199 mm	Moderate	3
		200-300 mm	A Bit High	4
		> 300 mm	High	5
b.	Slope (%) (15%)	< 25 %	Low	1
		25-44 %	A Bit Low	2
		45-64 %	Moderate	3
		65-85 %	A Bit High	4
		> 85 %	High	5
c.	Geology (Rock) (10%)	Alluvial plains	Low	1
		Limestone hills	A Bit Low	2
		Granite hills	Moderate	3
		Sedimentary rock hill	A Bit High	4
		Basalt hill - Clay flakes	High	5
d.	The presence of faults / gawirs (5%)	None	Low	1
		Exist	High	5
e.	Soil Depth to Impermeable Layer (cm) (5%)	< 30 cm	Low	1
		30-60 cm	Moderate	2
		60-90 cm	A Bit High	4
		> 90 cm	High	5
MANAGEMENT (40%)				
a.	Land Use (20%)	Natural forests	Low	1
		Shrub/Shrub/Grass	A Bit Low	2
		Forests/Plantations	Moderate	3
		Moor/Yard	A Bit High	4
		Rice Fields/ Settlements	High	5
b.	Infrastructure (If Slope <25% = score 1) (15%)	No Way	Low	1
		Cutting the slopes/Clipped slopes	High	5
c.	Settlement density (people/ km^2) (If Slope <25% = score 1) (5%)	< 2000	Low	1
		2000 – 5000	A Bit Low	2
		5000 – 10000	Moderate	3
		10000 – 15000	A Bit High	4
		> 15000	High	5

The level of landslide vulnerability is analyzed with each parameter and is weighted according to field conditions and classified into five levels of vulnerability, including very vulnerable, vulnerable, somewhat vulnerable, slightly vulnerable, and not vulnerable.

3 METHODOLOGY

3.1 Data Collection

Primary data in the form of field survey results and coordinates of flood-prone and landslide-prone areas in the study area and secondary data in the form of spatial data are digital map data obtained from the Regional Development Planning Agency of Banyuwangi Regency.

3.2 Step Work

1) Identification of Flood Prone Areas. Flood vulnerability identification was carried out to determine areas or areas that may be affected by flooding due to the overflow of the Badeng watershed. Identification of flood hazard is divided between the identification of flood-prone areas (flooded) and areas of flood water supply or potential floodwater using scoring methods by processing spatial database maps on Geographic Information Systems.
2) Identification of Landslide Vulnerable Areas. The identification of landslides was carried out to determine areas where landslides are possible identification using the scoring method by processing spatial data on Geographic Information Systems.
3) Making Map of Flood and Landslide Prone Using GIS. Making a map of flood-prone and landslide-prone was an effort to identify non-structural mitigation, which was done by overlaying a basic map to model flood-prone and landslide-prone

areas in the Badeng watershed. This overlay used the Geographic Information System application by utilizing secondary data. The result of this overlay was a map of flood-prone and landslide-prone used as a reference for field analysis or field survey in the data validation process.

3.3 Flowchart

The research flowchart starts with the study of literature and secondary data collection in the form of digital maps to be used at the scoring stage of flood hazard and landslide susceptibility parameters with the help of GIS to be weighted to the database each digital map. Scoring was based on a formula prone to flooding and prone to landslides (Paimin *et al.*, 2009). Then do a digital map overlay to make the location of flood-prone areas and landslides vulnerable to Badeng Watershed. The research flowchart could be seen in Figure 1.

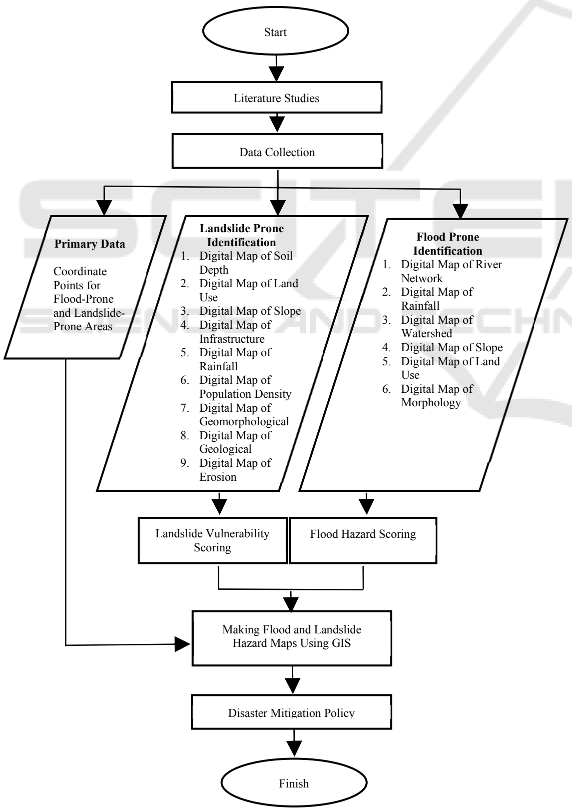

Figure 1: Flowchart of Research.

4 RESULT AND DISCUSSION

4.1 Rainfall

The intensity and distribution of the rain distribution determine the potential points of areas prone to flooding and landslides. Rainfall condition factors in Table 4, such as the intensity and distribution of rainfall distribution, determine the level of flood vulnerability and landslide susceptibility of the Badeng Watershed.

Table 4: Score of Rainfall Intensity Vulnerability.

Rainfall (mm/ year)	Flood Water Supply Area		Landslide-Prone Areas		Area (Km^2)	% Area
	Score	Level of Vulnerability	Score	Vulnerable Level		
94	4	A Bit High	3	Moderate	10.459	19.967
90	4	A Bit High	3	Moderate	41.036	78.338
95	4	A Bit High	3	Moderate	0.887	1.694

Rainfall in the Badeng Watershed in Table 4 shows the intensity of daily rainfall in the wet month is 90-95 mm / day.

4.2 Slope

The steeper the slope, the slope will experience enormous load pressure, making it unstable to withstand loads above it from the influence of gravity. The slope of the watershed affects the amount and time of flow to reach the outlet. The slope scoring in the Badeng Watershed is shown in Table 5.

Table 5: Scoring of Slope Vulnerability.

Slope (%)	Flood Water Supply Area		Landslide-Prone Areas		Area (Km^2)	% Area
	Score	Level of Vulnerability	Score	Vulnerable Level		
0 – 2	1	Low	1	Low	2.974	5.678
2 – 8	1	Low	1	Low	23.69	45.240
8 – 15	2	A Bit Low	1	Low	6.914	13.199
15 – 25	3	Moderate	1	Low	7.977	15.229
25 – 40	4	A Bit High	2	A Bit Low	4.109	7.844
> 40	5	High	3	Moderate	6.708	12.806

The slope in the study area is spread and varies from flat slope to steep slope. The vulnerability score on slope <25% is one because it is classified as a gentle slope so that the level of landslide vulnerability is low.

4.3 River Gradients

River gradients are calculated using the Benson method (1962). The river gradient formula (α) is as follows:

$$\alpha = \frac{h85 - h10}{0,75\ Lb} x100\%$$

With,

Lb = Main River Length (m)

h10 = River length at 0.1 Lb

$h85$ = River length at 0.85 Lb

Where Lb is obtained from the length of the main river in Badeng River, which is 35744.822 m. Then to look for values and are as follows:

1. Find the length of the river at 0,1 Lb ($h10$)
   $h10 = 0{,}1\ Lb$
   $h10 = 0{,}1\ x\ 35744{,}822\ m$
   $h10 = 3574{,}4822\ m$
2. Find the length of the river at 0,85 Lb ($h85$)
   $h85 = 0{,}85\ Lb$
   $h85 = 0{,}85\ x\ 35744{,}822\ m$
   $h85 = 30383{,}987\ m$
3. Calculate the river gradient (α)
   $$\alpha = \frac{h85 - h10}{0,75\ Lb} x\ 100\%$$
   $$\alpha = \frac{30383{,}987\ m - 3574{,}4822\ m}{(0{,}75\ x\ 35744{,}822\ m)} x\ 100\%$$
   $\alpha = 1\ \%$

The river gradient value obtained is 1%, then the river gradient category is rather low, with a score of 2.

4.4 Morphology

The land shape is an essential aspect in identifying areas prone to flooding because of the flatter the shape of the land in an area, the higher the potential for surface runoff that can cause flooding the scoring vulnerability of landforms in the Badeng watershed in Table 6.

Table 6: Scoring of Land-Shaped Vulnerability.

Morphology	Score	Level of Vulnerability	Area (Km^2)	% Area
Mountainous	1	Low	6.708	12.806
Flat	4	A Bit High	2.974	5.678
Wavy	5	High	7.977	15.229
Sloping	3	Moderate	23.697	45.240
Hilly	1	Low	4.109	7.844
Choppy	5	High	6.914	13.199

In Table 6, the shape of the land is spread out and varies from flat to mountainous.

4.5 Land Use

In general, the role of land cover can trigger floods and landslides and depend on the management aspects. Scoring of land use vulnerability in Badeng watershed in Table 7.

Table 7: Scoring of Land Use Vulnerability.

Land Use	Flood Water Supply Area		Landslide-Prone Areas		Area (Km^2)	% Area
	Score	Level	Score	Level		
Forest	1	Low	1	Low	32.34	61.758
Rice fields	4	A Bit High	5	High	13.68	26.126
Plantation	2	A Bit Low	3	Moderate	1.922	3.669
Garden	3	Moderate	3	Moderate	1.257	2.401
Settlement	5	High	5	High	2.438	4.655
Inland waters	4	A Bit High	0	Low	0.171	0.327
Avalanche	5	High	5	High	0.557	1.064

The most significant land use in the Badeng Watershed is forest, with an area of 61.8%. Land use in the form of forests can relatively maintain land stability because of the root system that maintains compactness between soil particles, soil particles with bedrock, and can regulate water runoff.

4.6 Population Density

From the Banyuwangi Population and Civil Registry Office data, the density of settlements in the Badeng Watershed can be seen as follows:

a. The population density of Songgon District
$$Density\ of Settlement = \frac{Total\ Population}{Catchment\ Area}$$
$$= \frac{59.491}{52{,}381\ Km^2}$$
$$= 1135{,}719\ Person/Km^2$$

b. The population density of Singojuruh District
$$Density\ of Settlement = \frac{Total\ Population}{Catchment\ Area}$$
$$= \frac{54.055}{52{,}381\ Km^2}$$
$$= 1031{,}942\ Person/Km^2$$

c. The population density of Rogojampi District
$$Density\ of Settlement = \frac{Total\ Population}{Catchment\ Area}$$
$$= \frac{57.757}{52{,}381\ Km^2}$$
$$= 1102{,}616\ Person/Km^2$$

The calculation shows that the level of landslide vulnerability in the density parameter of settlements in the Badeng Watershed is low because <2000 Person/Km^2 and the landslide vulnerability score 1.

4.7 Rock Type

Rock differences are one of the parameters causing landslides because rocks have different porosity and permeability. Scoring of rock type vulnerability in Badeng watershed in Table 8.

Table 8: Scoring of Rock Types Vulnerability.

Rock Type	Score	Level of Vulnerability	Area (Km^2)	% Area
Kalibaru Formation	4	A Bit High	15.350	29.304
Raung Volcano Rock	5	High	12.280	23.444
Alluvium	1	Low	2.257	4.309
Pendil Volcano Rock	4	A Bit High	22.493	42.940

The most extensive distribution of rock types is Pendil volcano rock with a large percentage of 42.94%, and the highest vulnerability category is the type of Raung volcano rock with an area of 23.44%.

4.8 Fault/Gawirs

Areas with geological structures such as the presence of faults or gawirs will have the potential to cause landslides scoring of the vulnerability of faults/gawirs in the Badeng watershed in Table 9.

Table 9: Scoring of Faults/Gawirs Vulnerability.

The Existence of Gawir	Score	Level of Vulnerability	Area (Km^2)	% Area
There is Gawir	5	High	0.557	1.064
No Gawir	1	Low	51.824	98.935

The geological structure in the Badeng Watershed is in the form of a landslide with an area of 0.557 Km^2.

4.9 Soil Depth

Landslides occur due to the launching of a soil volume on a steep slope above a water-saturated (rain) waterproof layer. Water entering the soil cannot penetrate the rock layers (watertight) and will flow or spread laterally, scoring soil depth vulnerability in the Badeng watershed in Table 10.

Table 10: Scoring of Soil Depth Vulnerability.

Soil Depth	Score	Level of Vulnerability	Area (Km^2)	% Area
30 - 60 cm	1	Low	1.423	2.717
60 - 90 cm	1	Low	16.168	30.861
>90 cm	5	High	34.797	66.420

Soil depth <100 cm is a low hazard class with a score of 1, and >90 is a high hazard class with a landslide vulnerability score of 5.

4.10 Distribution of Potential Flood Water Supply in Badeng Watershed

The results of the scoring and weighting shown in Table 11 are categorized according to the classification of hazard classes in the new attribute data, which is then obtained by the extent of the area's potential as a floodwater supply area. The distribution of areas prone to Badeng watershed flood water supply is shown in Table 11.

Table 11: Area Prone To Flood Water Supply.

Classification	Area (Km^2)	% Area
Prone	16.852	32.170
Moderately Prone	3.179	6.069
Less Prone	32.351	61.759
Total	**52.383**	**100**

Vulnerable classes dominate the total area and percentage level of prone floodwater supply by 32.17%. Whereas for the smallest level of floodwater supply is a Moderately Prone hazard class at 6.07%. The distribution is shown in Figure 2.

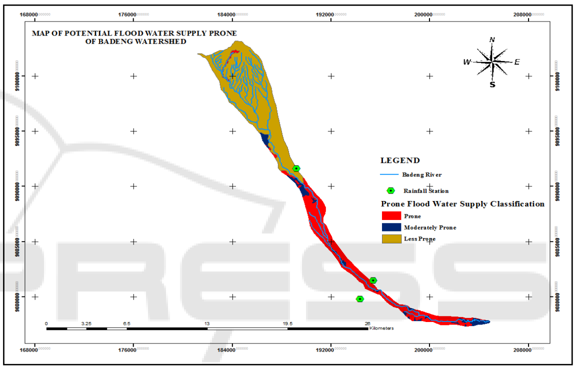

Figure 2: Map of the Distribution of Areas Prone to Flood Water Supply.

Potential prone to the floodwater supply is concentrated in the middle to downstream areas, including in twelve villages, namely Songgon, Sumberbulu, Parangharjo, Sumberwaru, Bedewang, Kemiri, Cantuk, Singojuruh, Alas Malang, Benelan Kidul, Bubuk, and Gladag. Potentially vulnerable areas have a slope of 0-8%, making vulnerable areas, including sloping areas. The shape of the watershed, which tends to be oval, makes the flow concentration characteristic longer to reach the outlet point. The river gradient index has a value of 1 and has a flat riverbed slope characteristic so that the flow velocity tends to be slow, and the majority of land use and settlement types cause the area to have a high runoff index. The condition of potential floodwater supply areas in Figure 3 is in Sumberbulu Village, Songgon District at coordinates 8^0 12' 29.538" S, 114^0 10' 10.3656" E.

Figure 3: Flood in the Badeng River, Sumberbulu Village In 2018.

Figure 3 is the fact that the area occurred by flash floods due to high rainfall intensity and landslides on the slopes of Mount Pendil.

4.11 Distribution of Potential Areas Affected by Floods in Badeng Watershed

The intersect index of natural and artificial parameters in determining areas classified as flood hazard classes in the Badeng Watershed. The distribution of areas prone to flooding in the Badeng watershed in Table 12.

Table 12: Area Prone To Flooding In The Badeng Watershed.

Classification	Area (Km^2)	% Area
Very Prone	14.891	28.429
Prone	26.672	50.919
Moderately Prone	10.817	20.651
Total	52.383	100

Vulnerable classes of 50.919% dominate the level of the floodwater hazard in Table 12 in this area. The distribution is shown in Figure 4.

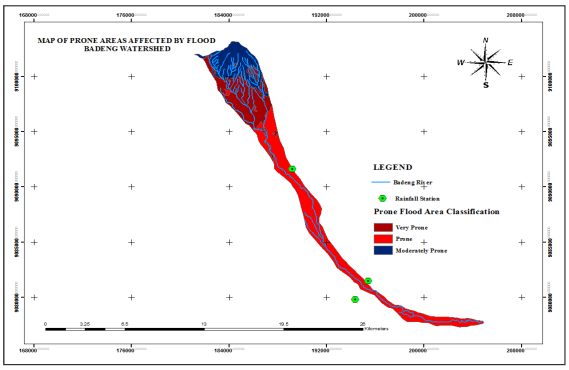

Figure 4: Map of Potential Distribution of Flood-Prone Areas in Badeng Watershed.

Figure 4 shows the results of the classification of areas very prone to flooding in Sumber Arum Village and Bayu Village. The condition of the vulnerable areas on the map in the survey to prove the actual field conditions, the results of the field survey in the Bayu Village, Songgon District at the coordinates 8^0 12' 34.8948" S, 114^0 11' 2.1084" E. This area has a sloping land shape with a slope of 2% - 8%, containment by river branches is absent, and there are no water structures such as dykes or reservoirs. The condition of the river flow is classified as straight, and many bends increase the distance of water to get to the outlet causing the area to have a high runoff index.

4.12 Distribution of Vulnerable Areas of Landslides

The results of the intersect index of natural and artificial parameters in determining areas classified as landslide susceptibility class in Badeng Watershed. The distribution of landslide-prone areas in the Badeng watershed in Table 13.

Table 13: Area Prone to Landslides.

Classification	Area (Km^2)	% Area
Moderately Vulnerable	1.408	2.688
Slightly Vulnerable	50.973	97.311
Total	**52.383**	**100**

The level of landslide susceptibility in this area is dominated by a slightly vulnerable class of 97.31%. Whereas for the smallest level of landslide susceptibility, the vulnerability class is moderately vulnerable to 2.69%. The distribution is shown in Figure 5.

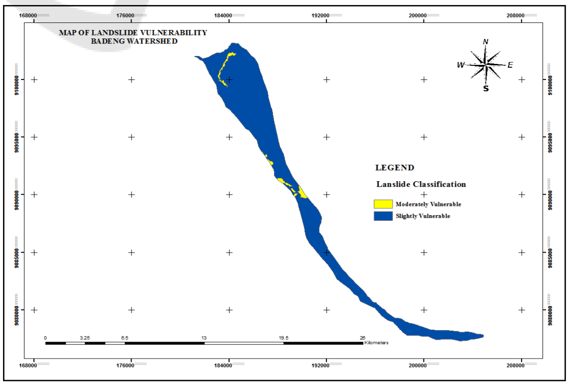

Figure 5: Map of the Distribution of Landslide Vulnerable Areas in Badeng Watershed.

The results showed that the area of landslide susceptibility in the Badeng Watershed is divided into two classes, namely, Moderately Vulnerable and

Slightly Vulnerable. Landslide prone areas are dominated by slope >40% so that it affects surface water flow velocity. The results showed that the higher the slope, the higher the level of landslide vulnerability. In the study area, the level of landslide susceptibility is slightly vulnerable, dominated by residential land use and rice fields. Settlements and rice fields have vegetation that cannot maintain surface stability because it is inundated and has a shallow root system that does not maintain soil particles' compactness.

4.13 Mitigation Policy

Based on a map of flood and landslide hazards in the Badeng Watershed, steps can be taken to prevent flood and landslide disasters based on Regulation of the Minister of Home Affairs of the Republic of Indonesia No. 33 of 2006 in Table 14 and Table 15. One of the mitigation policy recommendations is the innovation of interlock bricks with a mixture of bagasse ash without combustion used to control land erosion in the upper reaches of the Badeng River (Erwanto *et al.*, 2020).

Table 14: Recommendations for Badeng Watershed Flood Mitigation Policy.

Mitigation Steps	Responsible Agency	Prone Location	Reference
Supervision Land Use and Site Planning	Ministry of Public Works, Provincial / Regency Government	Sumber Arum	Flood Hazard Map, Flood Water Supply Prone Area Map, and Base Map.
The Construction of drainage channels and reservoirs.	Ministry of Public Works, Provincial / Regency Government	Alas Malang, Singojuruh, and Songgon	Public awareness of the possibility of floods and how to overcome them.
Infrastructure development and vegetative and mechanical conservation in the upstream area of the river and conservation buildings in the form of a check dam / Gully plug, and sloping terrace.	Ministry of Public Works, Provincial / Regency Government, Department of Environment	Sumber Arum, Bayu and Songgon	Plan and readiness of facilities that are safe from flooding.
River dredging, making river banks with open channels.	Ministry of Public Works, Provincial / Regency Government	Gladag, Alas Malang, Singojuruh, Sumberbulu, and Songgon	Early warning, District / City Master Plan.
Staff training in disaster management, Medical engineering, Support.	Ministry of Social Affairs, Ministry of Health	Sumber Arum, Bayu, Sumber Bulu, Parang Harjo, Bedewang, Cantuk, Benelan Kidul, Bubuk, Gladag, Alas Malang, Gintangan, Kemiri, Parangharjo, Singojuruh and Songgon	It is increasing the quantity and quality of Human Resource, Health, and others.
Flood vigilance training	Ministry of Research and Technology, Technology Assessment and Application Agency, Indonesian Institute of Sciences, Ministry of Public Works	Sumber Arum, Bayu, Sumber Bulu, Parang Harjo, Bedewang, Cantuk, Benelan Kidul, Bubuk, Gladag, Alas Malang, Gintangan, Kemiri, Parangharjo, Singojuruh and Songgon	The Early Warning System, Master Plan of City Drainage.
Flood disasters evacuation preparation such as boats and other rescue equipment	Ministry of Social Affairs, Ministry of Health, Ministry of Public Works, National Search and Relief Agency	Sumber Arum, Bayu, Sumber Bulu, Parang Harjo, Bedewang, Cantuk, Benelan Kidul, Bubuk, Gladag, Alas Malang, Gintangan, Kemiri, Parangharjo, Singojuruh and Songgon	It is increasing the quantity and quality of Human Resource, Health, and others.

Table 15: Recommendations for Badeng Watershed Landslide Mitigation Policy.

Mitigation Steps	Responsible Agency	Vulnerable Locations	Reference
Introduction of Landslide-prone areas.	Ministry of Research and Technology, Technology Assessment and Application Agency, Indonesian Institute of Sciences, Ministry of Public Works	Sumber Arum, Bayu, Sumber Bulu, Parang Harjo, Bedewang, Cantuk, Benelan Kidul, Bubuk, Gladag, Alas Malang, Gintangan, Kemiri, Parangharjo, Singojuruh and Songgon	Emergency plan to deal with landslides, Map of landslide vulnerable areas.
Identification of areas that are actively moving can be recognized by the existence of horseshoe-shaped cracks (horseshoe)	Ministry of Research and Technology, Technology Assessment and Application Agency, Indonesian Institute of Sciences, Ministry of Public Works	Sumber Arum	Appropriate and successful applied technology to prevent, reduce the impact of landslides.
Closing fissures on the slope to prevent water from entering quickly into the ground	Ministry of Public Works, Provincial / Regency Government, Ministry of Forestry, Department of Agriculture	Sumber Arum	Landslide Prone Map, Disaster Risk Map.

Table 15: Recommendations for Badeng Watershed Landslide Mitigation Policy (Cont.).

Mitigation Steps	Responsible Agency	Vulnerable Locations	Reference
Greening With Plant The System The Roots Are Inside	Ministry of Forestry, Department of Agriculture, Department of Environment	Sumber Arum, Bayu, and Sumber Bulu	Citizen's awareness will possible landslide disaster and how to handle it.
Terracing	Ministry of Public Works, Provincial / Regency Government, Ministry of Forestry	Sumber Arum, Sumber Bulu, and Songgon	Emergency Plans in Facing Landslides.

5 CONCLUSIONS

Identification of disaster mitigation in areas prone to flooding and landslide-prone areas in the Badeng Watershed with a Geographic Information System concluded:

a. The distribution of floodwater supply areas consists of a prone of 32.170% spread in the Villages of Sumber Arum, Sumber Bulu, Sumber Baru, Songgon, Parang Harjo, Bedewang, Kemiri, Benelan Kidul, Bubuk, Cantuk, Gintangan, Singojuruh, Alas Malang, Bayu and Gladag, the risk level is Moderately Prone at 6.069% in the villages of Songgon, Bayu, Bubuk, Benelan Kidul, Gladag, Sumberbulu, Sumber Arum, Sumber Baru, Bedewang, Kemiri, Singojuruh, and Gintangan. The level of risk is Less Prone at 61.759% in the Villages of Sumber Arum, Sumber Bulu, and Bayu. Disaster mitigation in flood water supply areas in the form of river dredging, land use monitoring and location planning in prone areas, and flood awareness training for vulnerable communities.

b. Distribution of locations prone to flooding there is a very prone risk level of 28.43% in the villages of Sumber Arum and Bayu, a risk-prone level of 50.919% spread in the villages of Sumber Arum, Bayu, Sumber Bulu, Sumber Baru, Songgon, Parang Harjo, Bedewang, Kemiri, Benelan Kidul, Bubuk, Cantuk, Gintangan, Singojuruh, Gladag and Alas Malang and then the risk level is Moderately Prone at 20.651% in the Villages of Sumber Arum and Bayu. Disaster mitigation in areas prone to flooding in the upstream area of the Badeng Watershed in the form of vegetative and mechanical conservation development in the upper river and conservation buildings in the form of check dam/gully plugs, and terraces. Also, building construction of drainage channels and reservoirs around the banks of the Badeng river.

c. Distribution of landslide vulnerability maps for the Badeng Watershed, there is a Moderately Vulnerable risk level of 2.688% spread in the Village of Sumber Arum, Sumber Bulu, Bayu, and Songgon and than a Slightly Vulnerable risk level of 97.311% spread in the Villages of Sumber Arum, Bayu, Sumber Bulu, Sumber Baru, Songgon, Parang Harjo, Bedewang, Kemiri, Benelan Kidul, Bubuk, Cantuk, Gintangan, Singojuruh, Gladag, and Alas Malang. Areas with a high level of risk of landslides are areas where there are fractures of land due to landslides that have previously occurred in the area. Disaster mitigation in landslide-prone areas in the form of terracing, and greening by stabilizing slopes and closing fissures on slopes to prevent water from entering quickly into the ground.

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