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Analysis of Flood Hazards and Risk in the Sirimau District Ambon City

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Abstract

This study aims to target the threat and risk of flooding in Sirimau District, Ambon City from a multi-criteria perspective using a Geographic Information System (GIS). Important flood hazard characteristics include land use, elevation, slope, distance from rivers, soil, and rainfall. Two risk factors, namely population density and land use as well as flood hazard characteristics are used in flood risk analysis. Map aggregation procedure for flood risk and hazard analysis uses the Weighted Linear Combination (WLC) approach. The results of the flood hazard at the study site revealed that the flood hazard category was very high and high, namely 12.26%, and the flood hazard category was very low and low, namely 87.84% and only. The results of the flood risk in the research location revealed that the flood risk with very high and high-risk categories was around 17.28%, and very low and flood low-risk categories (82.77%). This is because the Sirimau District is mostly dominated by hilly and mountainous areas.

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INTRODUCTION

Floods are a disaster that occurs quite intensively in Indonesia due to their intensity and distribution, reaching around 40% of other natural events in one year (Musfida et al., 2021; Madani et al., 2022). This is a sustainable problem that significantly affects the condition of the community on all fronts, both economically, socially, and environmentally (Sholikha et al., 2022). Over the past few decades, flood disasters have increased. Around 44% of all catastrophic flooding events worldwide from 2000 to 2019 affected 1.6 billion people, which is the highest figure for any type of disaster.

In 2020, there were approximately 1,518 flood incidents in Indonesia, resulting in approximately 4,624,979 deaths, disappearances, injuries, evacuations, and construction damage totaling around 30,634 structures. (BNPB, 2021; Madani et al . al., 2022). Flood hazard and vulnerability are two terms that are often used in flooding. Flood susceptibility indicates the tendency of an area, based on its geographic physical characteristics (Rahman et al., 2019)machine learning, and multi-criteria decision analysis, including artificial neural network (ANN. Meanwhile, vulnerability refers to the intrinsic characteristics of the receptor of a hazard (people, infrastructure, economic activity, or other) (Parry et al., 2007; Meng et al., 2022).

Much research has been conducted recently to construct flood hazard maps as a tool for managing flood risk. Additionally, it serves as one of the early warning systems for preventing and reducing future flood crises, as well as identifying the most vulnerable locations (Vojtek, 2019). Maps showing flood hazards and risk areas can be used for early warning and planning based on mitigation. Improvements in remote sensing technologies, mapping, and satellite-based flood monitoring further support the usefulness of geographic information systems (GIS) for swiftly and precisely mapping flood-prone areas (Primayuda, 2006; Kwak, 2017).

The various environmental problems identified in Ambon City concern: the development of the city which tends to occupy flat land areas, a fairly high concentration of population, and increased land cover by buildings in hilly areas. The risks and dangers of flooding in Ambon City are then assessed by combining a Geographic Information System with a multi-criteria analysis and their urgency, which may be utilized as a standard for local governments when creating flood-reduction measures.

METHOD

This study was conducted in the Sirimau District which has a total area of 24.5 km ^{2} which is administratively divided into 14 villages or sub-districts and is located in Ambon City, Ambon Island (Figure 1). Astronomically located between 3 ^{0} and 4 ^{0} South Latitude (LS) and 128 ^{0} and 129 ^{0} East Longitude (BT). In this study, the materials and tools consisted of Landsat imagery in 2012 and 2022; rainfall data (2012-2022), and Digital Elevation Model (DEM) to extract Slope Map and Elevation Map, Soil map; Population density map. River buffer maps, and Administration maps. While the tools used are a geological compass, digital camera, GPS Handheld Garmin, field stations, and software, including Ms. Excel, ArcGIS 9.3, Er *mapper,* and *Global Mapper* to collect relevant data to analyze flood hazard and risk carried out by field observations and document reviews.

Data collection was obtained from the BAPPEDA, Public Works Agency, Meteorology and Climatology Agency, and, BPS, Landsat Image from the website of *www.glovis.USGS.gov*. and DEM data from the website *www. Tanahair. Indonesia.go.id/demons*. Furthermore, the data that has been obtained is analyzed by weighting, scoring, and overlapping. In analyzing the data, the determination of values and weights is carried out so that the multiplication of the two can obtain a total score. By using a standard classification scheme *equal intervals* ranging from 1 - 5, for each parameter and classified into five classes. Meanwhile, the factors that have the most effects on the degree of danger and the probability of flooding decide the weighting. *The overlay* is a step of merging data from various parameters that are more than one layer (Matondang et al., 2013).

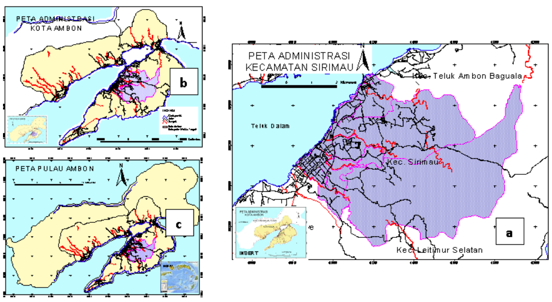

Figure 1. a) Sirimau District Map, b) Ambon City Map and c) Ambon Island Map Table 1. A Score of Factors Causing Flood Hazard

Table 1. Research Variable

No	Causative factor	Score	No	Causative factor	Score
I. Elevation			IV. Rainfall		
1	0 - 25 meters from sea level	5	1	Very dense (>100 mm)	5
2	25 - 75 meters from sea level	4	2	Dense (51-100 mm)	4
3	75 - 150 meters from sea level	3	3	Medium (21-50 mm)	3
4	150 - 250 meters from sea level	2	4	Lightweight (5-20 mm)	2
5	> 250 meters from sea level	1	5	Very Light (> 5 mm)	1
II. Slope			V. Land Use		
1	0–3%	5	1	Awakened Area	5
2	3–8%	4	2	Mixed Gardens and Plantations	4
3	8–15%	3	3	Farming Land	3
4	15–30%	2	4	Bush	2
5	>30%	1	5	Forest	1
III. Type of soil			VI. Area Distance to River		
1	Alluvial, Cambisol, Regosol, Gleysol	4	1	0–25 m	5
2	Cambisol, Litosol, Regosol	3	2	25–50 m	4
3	Rensina, Cambisol, Litosol	2	3	50–75 m	3
4	Litosol, Cambisol	1	4	75–100 m	2
			5	>100 m	1

Table 2. 9 Point *Pairwise* Comparison Scale**.**

Intensity of Interest	Definition	Description
1.	These two components are very important	The goal is equally influenced by two factors
3.	One component is slightly more important than the other	One element on top of another that differs is only slightly supported by experience and judgment.
5.	One factor is crucial compared to other aspects	Experience and assessment. knowledge and commitment to favor one factor over another
7.	One component is more important than the other	One component has substantial support, and its dominance is evident.
9.	The importance of one component over another cannot be disputed.	The strongest level of affirmation is seen in the evidence supporting one element over another

Notes: 2,4,6,8. between the two closest problems, and between the middle values. Source: (Saaty, 1977; Mudin et al., 2015).

Table 3. Table of *Random Consistency Index in Pairwise* Comparison

n	1	2	3	4	5	6	7	8	9	10
R1	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: (Saaty, 1977; Mudin et al., 2015)

To analyze the flood hazard at the research site, based on literature studies, observations, and discussions with experts and residents. Each parameter (slope, rainfall, elevation, soil, distance from rivers, and land use), was reclassified based on flood hazard and risk which was given a score of 5 for the high hazard category to 1 for low hazard (Table 1). To analyze flood risk obtained from flood hazard, population density, and type of use as three important factors and reclassified with a value of 5 to 1.

In this study, the *weighted linear combination* (WLC) method, devoted to the *Analytical Hierarchy Process* (AHP) model, was integrated using a Geographic Information System (GIS). AHP uses a standardized comparison scale for numerous pairwise comparisons. Consistently compare and order nine points concurrently (Table 1). Based on the best information from the decision maker's expertise and experience, pairwise judgments are produced (Mudin et al., 2015).

RESULT AND DISCUSSION

Rating and Weighting Parameters Causes of Floods

The fundamental principle of AHP is to organize the elements of a complex problem into a hierarchy or rank. The bigger the score, the more of an effect these elements have on the probability of flooding (Mudin et al., 2015). As the main input for each research criterion, AHP uses the opinions of experts or informants who are considered experts. The six flood parameters obtained from the calculation results of the AHP method, especially in Table 4, Table 5, and Table 6, are then given weights based on the comparison scale between the agreed criteria.

The results of pairwise comparison matrix analysis from the comparison scale values between the flood parameters are produced, added together, and divided by the number. The findings are then re-analyzed to determine the weight. The AHP consistency test was carried out after getting the weight values for each criterion. the results are contrasted with the *Random Consistency Index* to measure consistency (RI). Where RI is a random index, the consistency ratio is defined as CI/RI. It can be said that the AHP analysis is said to be consistent if the consistency ratio of CR (0.045) is 0.1.

Flood Hazard Analysis

Factors Causing Flood Hazard

Land usage is one of the causes of flooding. In the classification process, the built-up area receives the highest land use category (value 5), indicating a very high level of risk, while the forest receives the lowest land use category (value 1), indicating a very low level of risk (Table 6). Actual land use in 2022 in Sirimau District is dominated by mixed gardens and forests with an area of 1346,684 ha (27.53%, 1346,684 ha) (36.37%) and the land use with the smallest scale is for shrubs, which has an area of 117,022 ha (3.16%), while the most extensive land use for settlement has an area of 907,497 ha (24, 51%). the primary causes of floods due to rising urbanization increasing impermeable cover, and declining forests resulting in annireasedd run-off that

Table 4. Rating of Factors Causing Flood Hazard

Flood hazard factor	Land use	Slope	Type of soil	Rainfall	Distance from river	Elevation
Land use	1	3	3	5	7	8
Slope	0.33	1	3	3	5	6
Type of soil	0.33	0.33	1	3	3	5
Rainfall	0.20	0.33	0.33	1	3	5
Distance from river	0.14	0.20	0.33	0.33	1	3
Elevation	0.13	0.17	0.20	0.20	0.33	1
Total	2.13	5.03	7.87	12.53	19.33	28.00

Source: Data Processing Results, 2022.

Table 5. *Pairwise Matrix* Weighting Normalization

Flood Danger Factor	Land Use	Slope	Type of soil	Rain-fall	River Distance	Eleva-tion	Priority	Percent	Eigen-value
Land use	0.47	0.60	0.38	0.40	0.36	0.29	0.42	42	0.20
Slope	0.16	0.20	0.38	0.24	0.26	0.21	0.24	24	0.05
Type of soil	0.16	0.07	0.13	0.24	0.16	0.18	0.15	15	0.02
Rainfall	0.09	0.07	0.04	0.08	0.16	0.18	0.10	10	0.01
River distance	0.07	0.04	0.04	0.03	0.05	0.11	0.06	6	0.00
Elevation	0.06	0.03	0.03	0.02	0.02	0.04	0.03	3	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100	0.27

Source: Data Processing Results, 2022.

Table 6. Booting, Scoring, and Area of Flood Hazard Area

Parameter	Weight	Parameter Reclassification	Scoring	Danger	Area (Ha)	Percent
Land use	42%	Awakened Area	5	Very high	907,497	24.51
		Mixed Gardens, Plantations	4	Tall	1019,326	27.53
		Farming Land	3	Currently	312,056	8.43
		Bush	2	Low	117,022	3.16
		Forest	1	Very low	1346,684	36.37
Slope	24%	0–3%	5	Very high	209.351	5.69
		3–8%	4	Tall	336,674	9.16
		(8–15%	3	Currently	1010.199	27.47
		15–30%	2	Low	1732,485	47.12
		>30%	1	Very low	388.135	10.56
Type of soil	15%	Alluvial, Cambisol, Regosol,	4	Tall	361,965	9.84
		Gleysol	3	Currently	2915.43	79.29
		Cambisol, Litosol, Regosol	2	Low	174.468	4.74
		Rensina, Kambisol, Litosol	1	Very low	225,152	6.12
		Litosol, Cambisol				
Rainfall	10%	Very dense (>100 mm)	5	Very high	0.00	0.00
		Dense (51-100 mm)	4	Tall	0.00	0.00
		Medium (21-50 mm)	3	Currently	3677,017	100.00
		Lightweight (5-20 mm)	2	Low	0.00	0.00
		Very Light (< 5mm)	1	Very low	0.00	0.00
Distance from river	6%	0–25 m	5	Very high	104,875	2.85
		25–50 m	4	Tall	103.041	2.80
		50–75 m	3	Currently	102.239	2.78
		75–100 m	2	Low	103.123	2.80
		>100 m	1	Very low	3263,739	88.76
Elevation	3%	0 - 25 meters from sea level	5	Very high	1012,253	27.53
		25 - 75 meters from sea level	4	Tall	1463,936	39.82
		75 - 150 meters from sea level	3	Currently	1064,743	28.96
		150 - 250 meters from sea	2	Low	120,462	3.28
		level	1	Very low	15,108	0.41
		> 250 meters from sea level				

Source: Data Processing Results, 2022.

can further increase flooding (Hall et al., 2014).

The comparison between the vertical distance (elevation) and the horizontal distance is known as the slope of the slope (Rimba et al., 2017). For the slope factor, it was reclassified into five classes with the lowest category with a value of 5 because it has a very high danger of flooding while the highest slope category with a value of 1 because it has a very low hazard (Table 6). The slope of widest slope is 15 - 30% with an area of 1732,485 ha (47.12%), while the smallest area is on a slope of 0 - 3% with an area of 209.351 ha (5.69%). Spatially it can be seen in Figure 3b.

Different types of soil have different capacities, wherein, water moves down the slope as *runoff* so that it can cause flooding (Ouma & Tateishi, 2014). Characteristics of each group based on soil units are reclassified into five classes with a very high value that causes flooding with a value of 5 and a very low value of 1. For the Sirimau District, almost the entire area is composed of Kambisol, Latosol, and Regosol soil types covering an area of 2915,430 ha (79.29%) with a value of 3 because they have medium hazard. The coastal areas have Alluvial, Cambisol, Regosol, and Gleysol species covering an area of 361,965 ha (9.84$) and are at a value of 4 because they have a high hazard (Figure 3c).

Areas with relatively high rainfall conditions have an impact on flood events; the greater the rainfall, the greater the flood hazard (Febrianti et al., 2022). Rainfall data were reclassified into five classes with the highest category (above 100 mm) with a value of 5 because it affected flood hazards and the lowest (below < 5 mm) with a value of 1 because it had a very low effect on flood hazard. Based on Table 6, according to data from the Ambon Pattimura Meteorological Station, the annual rainfall in Sirimau Regency averaged about 26,162 m over the last 10 years (2013–2022). Therefore, with an average of 21 to 50 m, the amount of rainfall at the research location falls into the moderate group. Geographically, it is seen in Figure 3d.

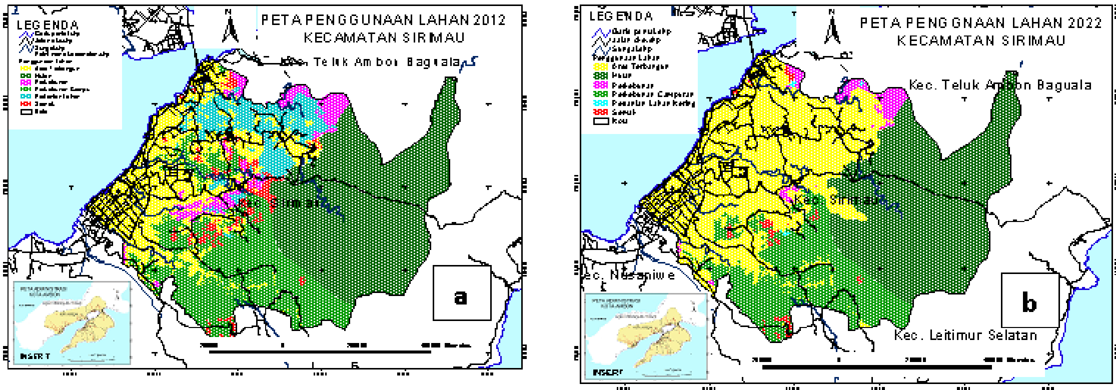

Figure 2. a) Land Use Map for 2012 (Landsat 7 and b) Land Use Map for 2022 (Landsat 8 Oli)

Areas near rivers are defined by buffers. The area is flooded more frequently the closer to the river flow. During the categorization procedure (Table 6), the river distance data **were** reclassified into five classes with the highest category (0 - 25 m) being at a very high value of 5 for flood hazard. Furthermore, the lowest category (below > 100 m) is a very low value of 1 for flood hazards. Sirimau District has four rivers, namely Way-Ruhu (±9.10 km) which is the longest river, Way-Batu Merah (±4.25 km), Way-Tomu (±4.20 km), and Way-Batu Gajah (±4.20 km). 3.10 km). The distance between the area and the nearest river in Sirimau District is 0-25 m, covering an area of 104,875 ha (Figure 3e).

Altitude is one of the factors causing flooding and has a key role in controlling directional movement (Nkonu et al., 2022). The elevation data were reclassified into five classes with the lowest altitude category at a value of 5 (0 – 25 meters from sea level) which is very high against flood hazards while the highest altitude category (250 meters from sea level) with a very low value of 1. Table 6 shows that a place is more dangerous if the altitude is lower. In this classification process, the highest land elevation in Sirimau District is at an altitude of 25 – 75 meters from sea level covering an area of 1463,936 ha (39.82%), while the lowest area of land elevation is at an altitude of > 250 meters from sea level with an area of 15,108 ha (3.28%) (Figure 3f).

Flood Hazard Mapping

The results of the flood hazard at the study site reveal that the flood hazard is as shown in Table 7, with a very high hazard category of 3.83% (146,163 ha), and a very low hazard category of 62.26% (2377,745 ha). This demonstrates that the majority of the proportion (87.84%) is made up of areas with low flood hazard categories and rarely flooding. This is because just around 12.26% of the Sirimau District is comprised of lowland lands, with hills and mountains making up the majority. Based on the level of flood hazard, the zoning of the area can be determined which can be seen in Table 7. The area that is least vulnerable to hazards, such as flooding, is the hazard zone that is not vulnerable. This is because this area is a forest and plantation area and is located at an altitude between 0 to 25 meters above sea level (Figure 4).

Flood Risk Analysis

Factors Causing Flood Risk

With the assumption that more people mean higher exposure to flood threats, each village's population density for the year 2022 has been divided into five groups. The category with the largest population density, therefore, has a value of 5, and the category with the lowest population density, so, has a value of 1. (Table 7). Very high density (206 – 238 ha) covering an area of 31.279 ha (0.85%) with the most populous village being Village Rijali, while the lowest population density is 78 – 110 population/ha, with an area of 1989,092 people/ha, with village/ha The most populous Village is Soya Village (Figure 4a).

Land use classes in the area were reclassified into five classes in analyzing flood risk. Thus, the highest category is in the built-up area with a value of 5 because it is very vulnerable to flood risk. Forest land use is given a value of 1 because it is very low and prone to flood risk. Land use is considered one of the contributing flood risk factors in Sirimau District (Table 7). Land flood risk was assessed as very low, medium, moderate, and very high for a variety of land uses, including forest, scrub, dryland plantations, mixed gardens, and built-up agriculture. Mixed gardens make up the majority of the land use in the Sirimau District, occupying an area of 1346,684 ha (27.53%), followed by settlements, which occu-

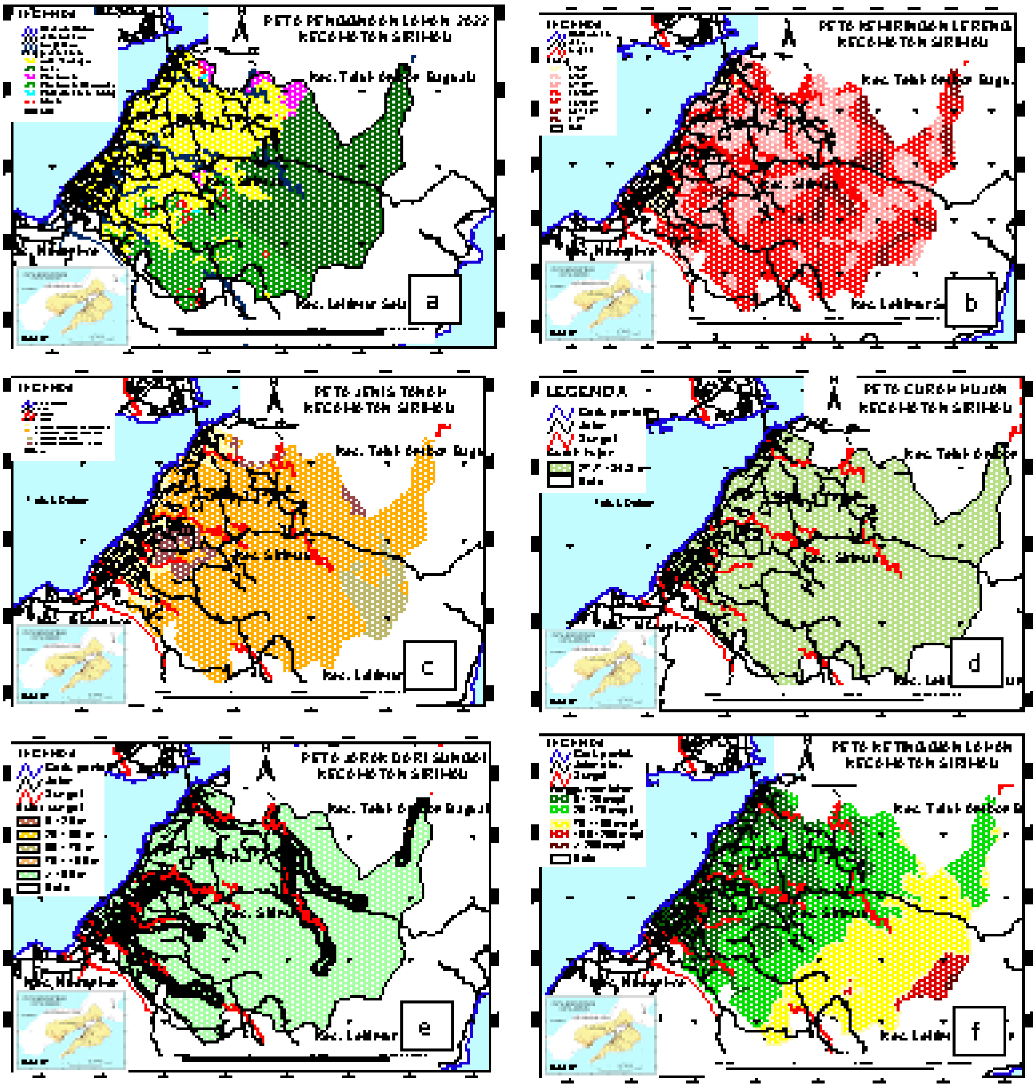

Figure 3. a) Land Use Map b), Slope Map, c) Soil Type Map, d) Rainfall Map e) Distance Map from Rivers and f) Elevation Map

py an area of 907.497 ha (24.51%), and bushes, which occupy the smallest area at 117,022 ha (3.16%) (Figure 4b).

Flood hazard is considered one of the factors causing flood risk in Sirimau District. Very high, high, medium, low, and very low flood hazard classes are classified as flood risk. Very high flood hazard is rated 5 because it has the highest hazard to flood risk (Table 7). Flood hazard is very low with a value of 1 because it has the lowest hazard to flood risk. The highest flood risk has an area of 146.163 ha (3.82%), while the lowest has an area of 2377.745 ha (25.58%). Spatially it can be seen in Figure 4c.

Table 7. Weighting, Scoring, and Area of Flood Risk Area

Parameter	Weight	Parameter Reclassification	Scoring	Danger	Area (Ha)	Percent
Flood Danger	33.33%	Very high	5	Very high	146,163	3.83
		Tall	4	Tall	108.637	2.84
		Currently	3	Currently	209,502	5.49
		Low	2	Low	977,034	25.58
		Very low	1	Very low	2377,745	62.26
Population density	33.33%	206 – 238/ Ha	5	Very high	31,279	0.85
		174 – 206/ Ha	4	Tall	49,271	1.34
		142 – 174 /Ha	3	Currently	251.443	6.84
		110 – 142 /Ha	2	Low	1355,929	36.88
		78 – 110 /Ha	1	Very low	1989.092	54.10
Land use	33.39%	Awakened Area	5	Very high	907,497	24.51
		Mixed Gardens, Plan-	4	Tall	1019,326	27.53
		tations	3	Currently	312,056	8.43
		Farming Land	2	Low	117,022	3.16
		Bush	1	Very low	1346,684	36.37
		Forest				

Source: Data Processing Results, 2022.

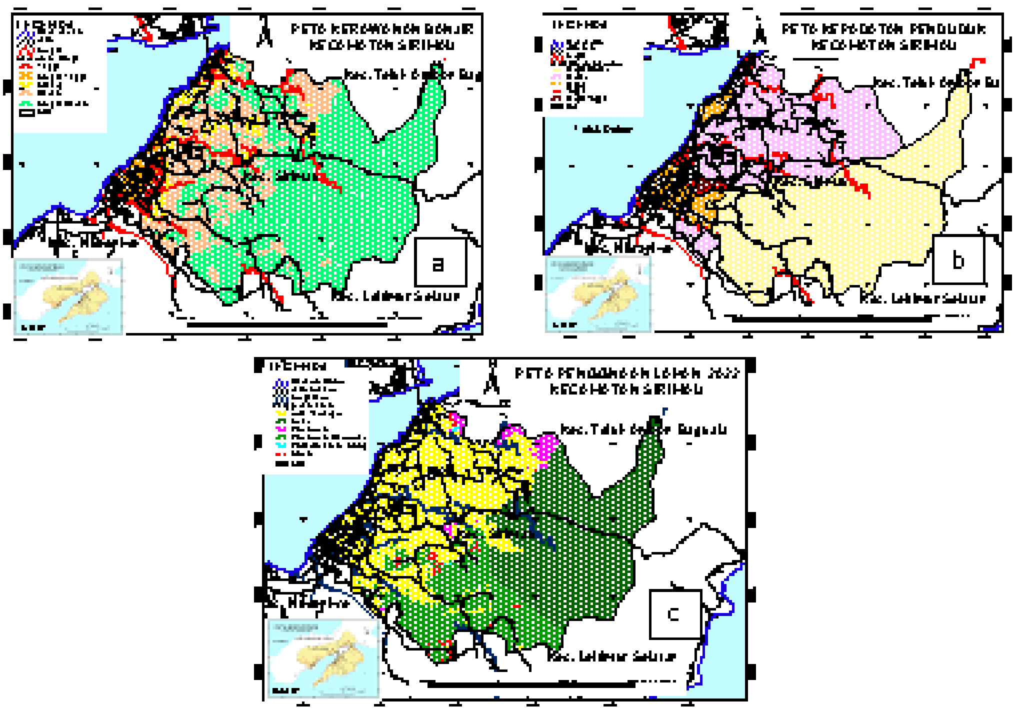

Figure 4. a) Flood Hazard Map, b) Population Density Map, and c) Land Use Map

Flood Risk Mapping

The results of the flood risk in the research location reveal that the flood risk as shown in Table 8, with a very high-risk category of 1.31 % (51,192 ha), high-risk category of 6.38 % (249,417 ha), moderate risk category of 9.55 % (373,586 ha), category low risk 19.21 % (751,273 ha), and very low-risk category 63.56 % (2486,008 ha). This indicates that low-category and very low flood-risk locations (82.77%) make up the majority of the proportion. This is because the Sirimau District is primarily composed of hilly and mountainous terrain, with only 17.28% of its land being low-lying with a significant danger of floods (Figure 5).

Table 8. Flood Risk Area

Flood Risk	Area (Ha)	Percent
Very high	51,192	1.31
Tall	249,417	6.38
Currently	373,586	9.55
Low	751.273	19.21
Very low	2486,008	63.56
Total	3911,476	100.00

Source: Data Processing Results, 2022.

Discussion

A very intensive disaster that occurs and is the biggest in the world is flooding. To maintain healthy and sustainable growth, it is very important to analyze flood hazards and risks. This then becomes a theme that is always debated in the field of natural science and technology globally (Fatih, 2022). Many experts prove that changes in land use/land cover are one of the main contributors to the occurrence of flood hazards due to the increasing expansion of cities, increasing waterproof cover and decreasing forest cover in urban areas also contributing to the increase in *run-off* (Hall et al., 2014). The amount that precipitation runoff exceeds the rate of infiltration determines how likely flooding is in a given location that is impacted by land use.

According to (Gigović et al., 2017) rapid population growth, an unregulated municipal system and an unplanned change of land use belong to the highly sensitive areas where floods cause devastating economic and social losses. The aim of this paper is to present a reliable GIS multi-criteria methodology for hazard zones' mapping of flood-prone areas in urban areas. The proposed methodology is based on the combined application of geographical information systems (GIS Elevation has a big impact on the direction of the overflow and the depth of the water. The slope significantly affects the rate and duration of water flow since flat surface areas are more prone to floods than steeper ones. The qualities of the soil in a particular area, such as the soil moisture, permeability, infiltration rate, and layer thickness, have a direct impact on the runoff process during the rainy season (Rimba et al., 2017). The surface zone's slope is a crucial indicator of its flooding susceptibility. The pace and duration of water flow are significantly influenced by the slope. In comparison to a steeper slope, a flatter surface allows water to travel more slowly, collect, and accumulate longer, increasing the likelihood of flooding (Gigović et al., 2017)rapid population growth, an unregulated municipal system and an unplanned change of land use belong to the highly sensitive areas where floods cause devastating economic and social losses. The aim of this paper is to present a reliable GIS multi-criteria methodology for hazard zones' mapping of flood-prone areas in urban areas. The proposed methodology is based on the combined application of geographical information systems (GIS.

A comprehensive flood risk assessment is a synthetic evaluation that takes into account a variety of elements, such as the vulnerability of the conveying body, the danger of the disaster's triggering sources, and the disaster's fostering environment (Fatih, 2022). Population density, type of use, and flood risk are three parameters that are crucial for mapping flood risk in this study. These three factors are equally significant in the weighted overlay method (Wondim, 2016). Flood vulnerability is a vulnerability to damage or loss, dangers to human life, property, or human activity, while flood hazard factors represent physical processes (Arfani, 2022). The created flood risk map helps residents in the study area locate appropriate flood risk reduction measures, as well as policymakers and relevant authorities.

The availability of land use plans enables the incorporation of flood risk information into choices and assessments by developers and planners by providing direction on which areas can be developed for which uses (Sela & Tilaar, 2017). Given that urbanization is a major factor in the world's population growth, flood hazard is both related to and exacerbated by it (Savitri, 2019). Drivers of change like population increase and settlement patterns have an impact on how vulnerable humans are to flooding. (Santato et al., 2013). Rapid population growth in both small and large cities, as well as expanding settlements in watersheds and valley bottoms, are cited as factors contributing to the risk of urban flooding. These factors greatly alter drainage patterns and cause slope destabilization, which increases the risk of flooding and landslides (Wilby & Keenan, 2012)increased catchment wetness and sea level rise. This paper reviews steps being taken by actors at international, national, regional and community levels to adapt to flood risk from tidal, fluvial, surface and groundwater sources. We refer to existing inventories, national and sectoral adaptation plans, flood inquiries, building and planning codes, city plans, research literature and international policy reviews. We distinguish between the enabling environment for adaptation and specific implementing measures to manage flood risk. Enabling includes routine monitoring, flood forecasting, data exchange, institutional reform, bridging organizations, contingency planning for disasters, insurance and legal incentives to reduce vulnerability. All such activities are ?low regret? in that they yield benefits regardless of the climate scenario but are not cost-free. Implementing includes climate safety factors for new build, upgrading resistance and resilience of existing infrastructure, modifying operating rules, development control, flood forecasting, temporary and permanent retreat from hazardous areas, periodic review and adaptive management. We identify evidence of both types of adaptation following the catastrophic 2010/11 flooding in Victoria, Australia. However, significant challenges remain for managing transboundary flood risk (at all scales.

Santato et al., (2013) By filling in natural drains and floodplains, some claim that growing population pressure might force large numbers of people into vacant land in cities in less developed nations, increasing the risk of flooding. According to (Jha et al., 2012), Independent of climate change, increased urbanization and urban growth may also raise the risk of flooding. The decisions and policies made by urban residents will affect how future urban growth will affect flood danger.

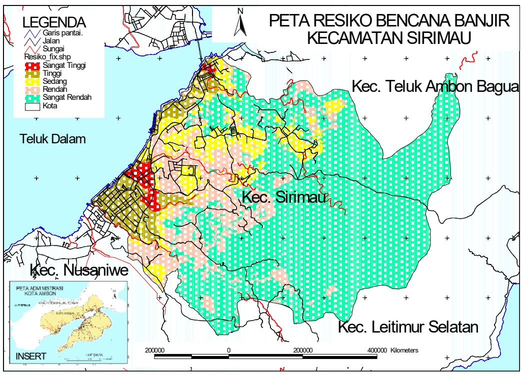

Figure 5. Flood Risk Map in Sirimau District

CONCLUSION

This study focuses on flood hazard and risk analysis from a multi-criteria perspective based on a Geographic Information System (GIS) in Sirimau District. Flood hazard factors are determined based on literature studies, field observations, and discussions with experts and residents. Soil, rainfall, elevation, slope, and distance from the river are all considered significant flood hazard elements at the study site. Flood risk analysis was carried out using flood hazard parameters and two risk elements: population density and land use. *The Weighted Linear Combination* (WLC) method is used in the process of aggregating criteria maps for flood hazard and flood risk.

The results of the flood hazard in the study area revealed that the flood hazard category with a very high level of hazard was 3.83% (146,163 ha), and a very low hazard category of 62.26% (2377,745 ha). This demonstrates that the majority of the proportion (87.84%) is made up of areas with low flood risk categories and rarely flooding. The results of the flood risk in the research location revealed that the flood risk category with a very high level of risk was 1.31 % (51,192 ha), high-risk category 6.38 % (249,417 ha), moderate risk category 9.55 % (373,586 ha), low-risk category 19.21 % (751,273 ha), and very low-risk category 63.56 % (2486,008 ha).

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