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Research Article

Utilization of GIS Technology for Mapping Flood-Prone Areas in Ambon Island, Indonesia

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Abstract.
Flooding is one of the most common natural disasters in Indonesia, including on Ambon Island, which can cause significant economic and social losses. This research aims to map flood-prone areas on Ambon Island using Geographic Information System (GIS) technology to map flood hazards and affected residential areas. This research uses variables of elevation, slope, rainfall, land cover, distance from rivers, and soil type. The weighted overlay method was used to produce maps of flood hazards and affected areas. The results showed that the low class flood had an area of 58,114.44 ha, the medium class had an area of 14,066.44 ha, and the high class had an area of 4,733.31 ha, while the built-up land area affected by flooding in the low class had an area of 907.92 ha, the medium class had an area of 3,445.92 ha, and the high class had an area of 1,681.40. The results of this study are expected to make a meaningful contribution to disaster risk management policies on Ambon Island and other areas with similar characteristics.

Keywords: Ambon, flood, GIS technology

1. Introduction

Flooding is one of the most common natural disasters in many parts of the world, including Indonesia. Flood is defined as a drastic increase in the flow of rivers, ponds, lakes, and others where the excess flow inundates the water body (1). When an event of water inundation in an area threatens and disrupts the lives and livelihoods of the community, resulting in human casualties, environmental damage, property losses, and psychological impacts, the flood can be called a flood disaster (2). This phenomenon can be caused by various factors, such as high rainfall, land use change, and vulnerable geographical conditions. In Indonesia, especially on Ambon Island, flooding often results in significant losses, both in economic and social terms (3).

Ambon Island administratively consists of Ambon City and Central Maluku Regency. Based on data from the Maluku Province National Disaster Risk Assessment 2022-2026, Ambon City is at moderate potential and Central Maluku Regency is at high potential for flood hazards (4). Therefore, mapping flood-prone areas is very important to reduce the risks and impacts caused by this disaster (5). Geographic Information System (GIS) technology has become an effective tool in mapping and spatial analysis (6). GIS enables the collection, processing, and analysis of geospatial data that can be used to identify areas at high risk of flooding. Using GIS, researchers can integrate different types of data, such as rainfall data, topography, land use, and hydrological data, to produce accurate and informative maps (7).

Mapping flood-prone areas on Ambon Island is particularly relevant given its diverse geographical characteristics. The island has many rivers and low-lying areas that are prone to inundation during the rainy season. In addition, population growth and rapid urbanization in Ambon also contribute to increased flood risk (8). Therefore, proper mapping can assist the government and communities in planning effective mitigation measures (9). In this context, research utilizing GIS technology for mapping flood-prone areas in Ambon Island is expected to make a significant contribution. By utilizing historical data and spatial analysis, this research can identify patterns of flooding that occurred in the past and predict the potential for future flooding. This is very important for spatial planning and sustainable natural resource management.

In addition, mapping flood-prone areas can also be used as an effective communication tool between the government and the community (10). The resulting maps can help communities understand the risks they face and encourage them to take the necessary precautions. Thus, the mapping serves not only as an analytical tool but also as a means of educating and raising public awareness. In this study, the approach used included primary and secondary data collection, as well as spatial analysis using GIS software. The data collected includes information on rainfall, topography, land use, and flood events on Ambon Island. Using this method, it is expected to produce a map showing the areas most vulnerable to flooding.

The importance of this research is also supported by previous studies that show that disaster risk mapping can improve disaster preparedness and response. Research conducted by Rakuasa et al (11), shows that accurate mapping can help in making better decisions in disaster risk management. In addition, research by Rakuasa et al (11), emphasized the importance of disaster mitigation through data-driven mapping and risk analysis. Thus, this research not only aims to produce maps of flood-prone areas but also to provide recommendations for the government and stakeholders in disaster mitigation efforts. It is expected that the results of this research can serve as a reference for disaster risk management policies in Ambon Island and other areas with similar characteristics. With the increasing frequency and intensity of natural disasters due to climate change, it is important that we continue to develop and apply technologies that can assist in disaster risk mapping and mitigation. This research is an important first step in that endeavor and is expected to make a meaningful contribution to the people and environment of Ambon Island.

2. Research Methodology

We conducted this research on Ambon Island, which administratively comprises Ambon City and Central Maluku Regency. Ambon City consists of the sub-districts of Sirimau, Ambon Bay, Baguala Bay, Nusaniwe, and Leitimur Selatan. The sub-districts of Central Maluku Regency located on Ambon Island consist of the Salahutu, Leihitu, and West Leihitu sub-districts. The data used in the study included administrative maps of Ambon City and Central Maluku Regency at a scale of 1:50,000, the Rupa Bumi Indonesia (RBI) Map of Ambon City and Central Maluku Regency at a scale of 1:50,000, and DEM (Digital Elevation Model). National spatial resolution of 8 meters obtained from the Geospatial Information Agency (BIG), PlanetScope satellite image data, which has a spatial resolution of 3 meters obtained from Planet Labs, rainfall data for the period January - October 2024 obtained from InfraRed Precipitation Data with Stations from the Climate Hazards Center (CHIRPS), soil type data obtained from the FAO-UNESCO Soil Map of the World. The software used for data processing and analysis in this research is Microsoft Office 365 and ArcGIS 10.8. Based on the data obtained, it is then processed into variables that affect the level of flood hazard and the level of exposure in residential areas on Ambon Island (Table 1).

The variables that influence the level of flood hazard in the study consist of elevation, slope, rainfall, land cover, distance from rivers, and soil type. The elevation analysis shows that areas with an elevation of 101-300 msl have the largest area of 30,650.66 ha, indicating that most of the areas in Ambon Island are located at this elevation. Meanwhile, areas with elevations of 0-20 msl and 21-50 msl have an area of 6,349.66 ha and 6,584.88 ha, respectively. This shows that while there are low areas that are prone to flooding, most of the higher areas can function as water retention areas.

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However, it is important to note that areas over 300 msl, despite their size of 23,540.51 ha, remain potentially affected by flooding in the event of extreme rainfall (12).

The slope data shows that areas with 25-45% slope have the largest area of 31,154.44 ha, followed by areas with 15-25% slope, which account for 14,431.01 ha. Steeper slopes can reduce the risk of waterlogging but can also increase the rate of water flow to lower areas. Meanwhile, areas with slopes of 0-8% and 8-15% account for 5,838.15 ha and 7,228.58 ha, respectively, indicating that flat areas are more vulnerable to flooding (13). Therefore, slope mapping is essential to understand the potential water flow and flood risk in Ambon Island.

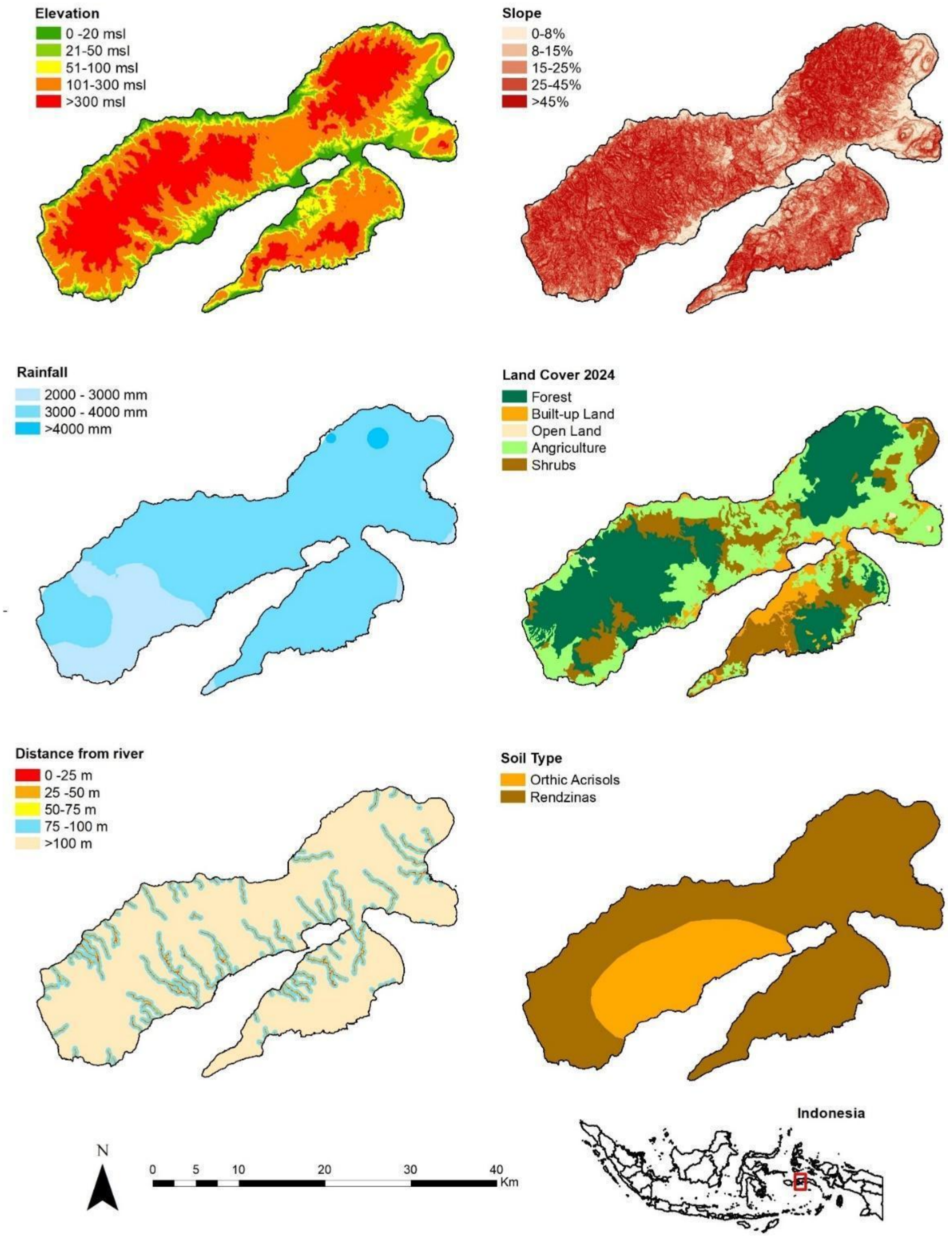

Figure 1: Research Variables.

Table 1: Research Variables.

No	Variables	Classification	Variable area (ha)	Score	Weight
1	Elevation	0-20 msl	6.349,66	5	20
		21-50 msl	6.584,88	4	
		51-100 msl	9.770,33	3	
		101-300 msl	30.650,66	2	
		>300 msl	23.540,51	1	
2	Slope	0-8%	5.838,15	5	10
		8-15%	7.228,58	4	
		15-25%	14.431,01	3	
		25-45%	31.154,44	2	
		>45%	18.225,05	1	
3	Rainfall	2000-3000 mm	12.446,95	2	15
		3000-4000 mm	63.402,92	3	
		>4000 mm	602,26	5	
4	Land Cover	Forest	30.578,04	1	25
		Built-up land	6.034,00	2	
		Open Land	204,61	3	
		Angriculture	25.268,38	3	
		Shrubs	15.200,25	2	
5	Distance from rifver	>25 m	1.076,99	5	20
		25-50 m	1.603,92	4	
		50-75 m	2.595,92	3	
		75-100 m	9.930,76	2	
		>100 m	61.705,38	1	
6	Soil Type	Orthic Acrisols	60.936,20	3	10
		Rendzinas	15.976,76	4	

Source: (14), (15), (16)

Rainfall is a key factor in flood vulnerability analysis. The data shows that areas with rainfall between 3,000-4,000 mm have the largest area, 63,402.92 ha, indicating that most areas in Ambon Island experience high rainfall. Meanwhile, areas with rainfall of 2000-3000 mm and more than 4000 mm have an area of 12,446.95 ha and 602.26 ha, respectively **(Figure 1)**. High rainfall has the potential to cause waterlogging, especially in areas with low elevation and flat slopes. Therefore, rainfall monitoring is essential for flood mitigation planning (17).

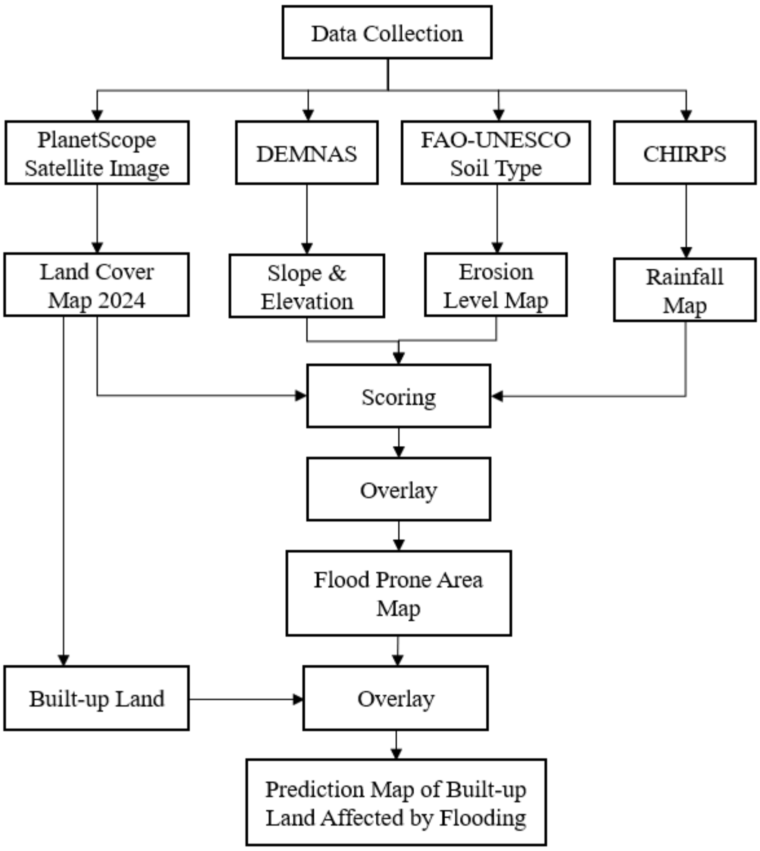

Figure 2: Workflow.

The land cover analysis shows that forests have the largest area of 30,578.04 ha, followed by agricultural land, which reaches 25,268.38 ha. Meanwhile, built-up land covers only 6,034.00 ha, indicating that infrastructure development is still limited. This diverse land cover can affect water flow and groundwater absorption. Forests serve as good water reservoirs, while built-up land can increase the risk of flooding by reducing the infiltration area (18). Therefore, sustainable land cover management is essential to reduce flood risk (19).

The results of the distance buffer analysis from the river show that the area more than 100 m from the river has the largest area, which is 61,705.38 ha. Meanwhile, the area within 0-25 m from the river only covers 1,076.99 ha. This shows that the further away from the river, the lower the flood risk (20). However, areas close to the river remain at high risk, especially during heavy rains. Therefore, it is important to consider the distance from the river in spatial planning and flood mitigation (21)

Soil types show that rendzinas have the largest area of 60,936.20 ha, while orthic acrisols cover 15,976.76 ha. These soil types affect the soil's ability to absorb water.

Rendzinas soils, which generally have a good structure, can absorb water more effectively, while orthic acrisols may have limitations in this regard (22). Therefore, an understanding of soil types is essential in planning flood mitigation strategies and natural resource management on Ambon Island.

All variables were then given scores and weights based on their influence on flooding on Ambon Island. Weighted scoring is done after the process of classifying the values in each variable. The six variables were then overlaid using the Weighted Overlay tool in ArcGIS software, which then performed spatial math calculations to obtain a map of flood-prone areas on Ambon Island using a formula:

$$Flood\ Hazard = (S1 + W1) * (S2 + W2) * (S3 + W3) * (S4 + W4)$$

$$*(S5 + W5) * (S6 + W6)(1)$$

Description = 1: Elevation, 2: Slope, 3: Rainfall, 4: Land Cover, 5: Distance from rifver, 6: Soil Type, S: Score, W: Weight.

The level of flood vulnerability on Ambon Island is classified into three classes: low, medium, and high. The existing flood-prone area map is then overlaid with built-up land/settlement data obtained from land cover data to determine the distribution of built-up land/settlement in the three flood-prone classes. The detailed workflow can be seen in Figure 2.

3. Research Result and Discussion

3.1. Flood Hazard Level in Ambon Island

Flood hazard levels are defined as normally dry land areas that are inundated by water due to heavy rainfall and increased water volume in the area. The results of the analysis of flood hazard levels on Ambon Island show significant variations between sub-districts, which can be divided into three categories: low, medium, and high. Leihitu sub-district has the largest area of low flood vulnerability, reaching 15,855.95 ha. This indicates that this area has better geographical conditions and more effective land use, reducing the risk of flooding. With more gentle slopes and a considerable distance from water bodies, Kecamatan Leihitu is one of the areas that is relatively safe from flooding. West Leihitu sub-district also shows significant numbers in the low flood vulnerability category, with an area of 9,362.13 ha. Despite having a sizable area of low vulnerability, the sub-district still has 941.82 ha in the medium vulnerability category and 142.66 ha Qin the high vulnerability category (**Figure 3)**. This shows that although most of the area is safe, there are some areas that remain vulnerable to flooding, especially during high rainfall. Therefore, it is important to conduct good monitoring and management in these areas (23).

Salahutu and Teluk Ambon sub-districts show higher potential flood risk. Salahutu has 4,274.64 ha for medium vulnerability and 1,146.49 ha for high vulnerability, while Teluk Ambon has 2,669.57 ha for medium vulnerability and 1,023.49 ha for high vulnerability. Both sub-districts are located in coastal areas with flat topography, making them highly vulnerable to inundation during heavy rains. More intensive mitigation efforts are needed in these areas to reduce the impact of flooding that may occur. Nusaniwe and Baguala Bay sub-districts also show significant vulnerability. Nusaniwe has 750.40 ha of moderate vulnerability and 275.69 ha of high vulnerability, while Baguala Bay has 1,436.90 ha of moderate vulnerability and 743.18 ha of high vulnerability. Although these two sub-districts have safer areas, their proximity to water bodies makes them still vulnerable to flooding (24). Therefore, it is important to undertake appropriate mitigation measures to reduce the impact of flooding in these areas (25).

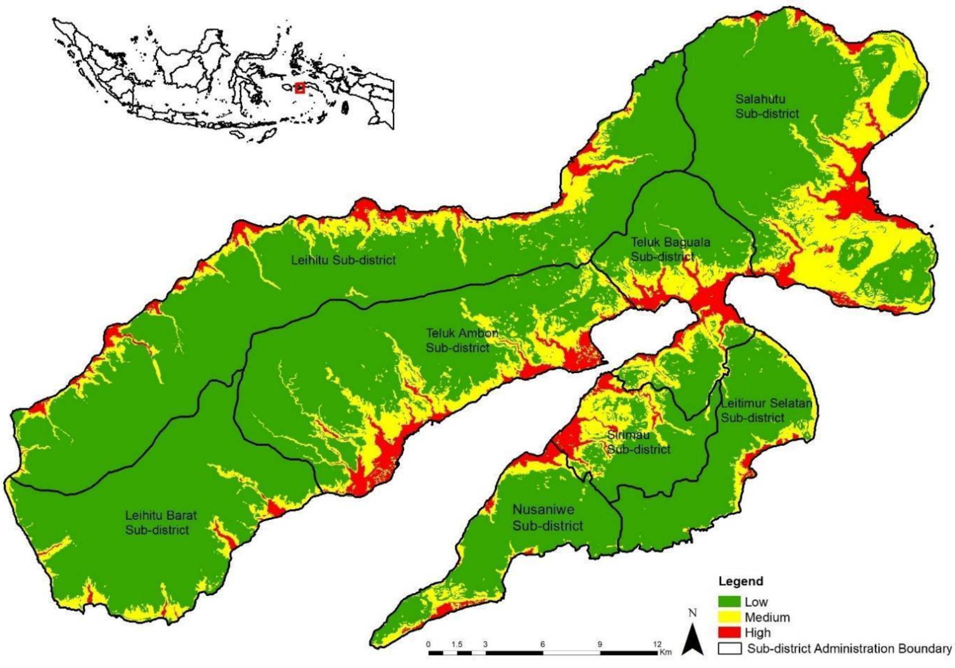

Figure 3: Flood Hazard Map of Ambon Island.

The sub-districts of Leitimur Selatan and Sirimau show smaller areas of flood vulnerability. Leitimur Selatan has 4,039.56 ha for low vulnerability, 561.14 ha for medium vulnerability, and 108.83 ha for high vulnerability. Meanwhile, Sirimau has 2,322.19

Figure 4: Flood Hazard Area of Ambon Island.

ha for low vulnerability, 1,011.97 ha for medium vulnerability, and 379.28 ha for high vulnerability. Although these two sub-districts are relatively safer from flood threats, good monitoring and management are still needed to keep flood risks from increasing in the future (26). Overall, the total area of Ambon Island identified as having flood vulnerability is 58,114.44 ha for the low category, 14,066.44 ha for the medium category, and 4,733.31 ha for the high category. This mapping provides a clear picture of the distribution of flood vulnerability on Ambon Island and can form the basis for more effective mitigation efforts. By understanding the characteristics of each sub-district, the government and community can work together to reduce the risk and impact of flooding in the region (27).

3.2. Prediction Map of Built-up Land Affected by Flooding

The results of overlaying flood hazard maps with built-up land in 2024 on Ambon Island show significant variations based on the level of flood hazard, namely low, medium, and high. West Leihitu sub-district has a low flood-affected built-up area of 10.36 ha, with 65.93 ha in the medium category and 15.13 ha in the high category. Despite having a low flood-affected area, this sub-district still needs to pay attention to potential flood risks that could affect built-up land, especially in more vulnerable areas. Leihitu sub-district shows a higher number in the flood-affected category. With 183.96 ha in the low category, 665.05 ha in the medium category, and 206.71 ha in the high category, this sub-district has a significant proportion of built-up land at risk of flooding. This suggests that while there are relatively safe areas, much of the built-up land is in areas of higher flood risk, requiring special attention in spatial planning and disaster mitigation.

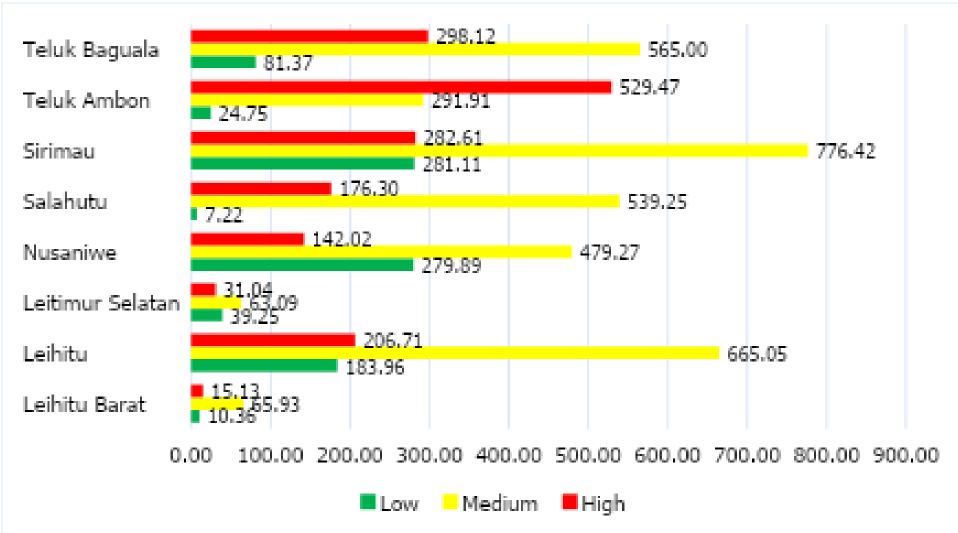

Figure 5: Area of Settlements Affected by Flood Hazard on Ambon Island.

Settlements in Leitimur Selatan are 39.25 ha in the low category, 63.09 ha in the medium category and 31.04 ha in the high category. Although the total built-up area affected by flooding in this sub-district is not as large as the other sub-districts, it is still important to conduct good monitoring and management to reduce the impact of flooding. The lesser availability of built-up land in the high category suggests that there is potential to better manage risks in this area. Nusaniwe sub-district shows higher numbers in the flood affected category, with 279.89 ha in the low category, 479.27 ha in the medium category, and 142.02 ha in the high category. This suggests that despite the presence of safer areas, much built-up land is at risk of flooding. It is therefore important to develop effective mitigation strategies to protect built-up land in this area from the impacts of flooding (7).

Flood-affected settlements in Salahutu sub-district are 7.22 ha in the low category, 539.25 ha in the medium category, and 176.30 ha in the high category (**Figure 6)**. With a larger proportion in the medium category, this sub-district shows that a lot of built-up land is located in risk areas. This indicates the need for more intensive mitigation measures to protect infrastructure and settlements in this area from potential flooding. Teluk Ambon and Teluk Baguala sub-districts show significant numbers in the high flood risk category. Teluk Ambon has 24.75 ha in the low category, 291.91 ha in the medium category, and 529.47 ha in the high category, while Baguala Bay has 81.37 ha in the low category, 565.00 ha in the medium category, and 298.12 ha in the high category. With the total area of built-up land affected by flooding reaching 1,681.40 ha, it is important for the government and community to work together to plan and implement effective mitigation measures to reduce the impact of flooding in this area (28). This prediction map can be a useful tool in spatial planning and disaster risk management on Ambon Island.

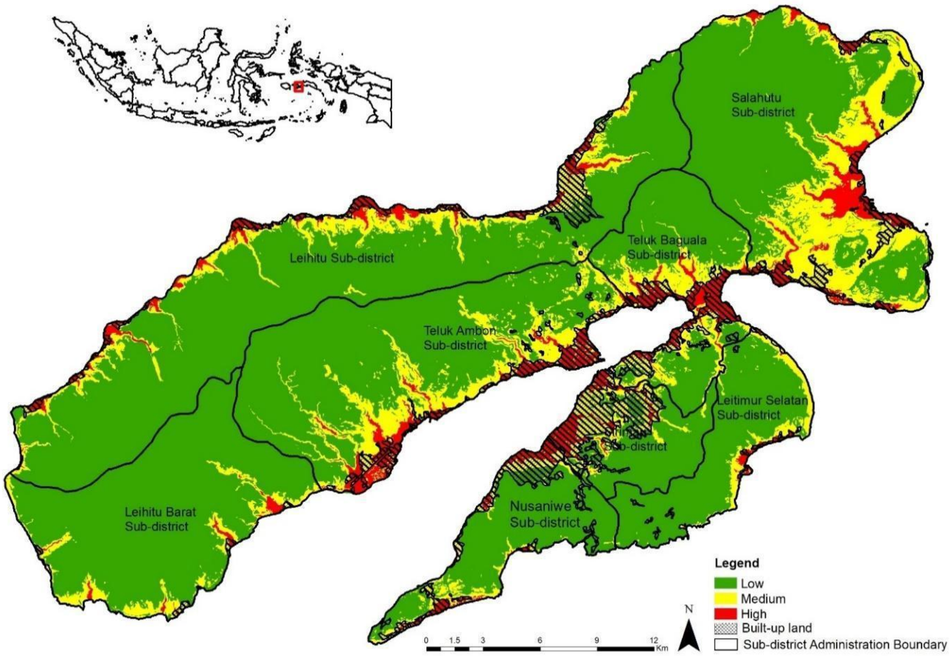

Figure 6: Flood Affected Settlements on Ambon Island.

Based on the results of this research, some policy recommendations that can be proposed to address flood risk in Ambon Island are as follows:

1. Flood Risk Map Development: Local governments need to develop and regularly update flood risk maps using GIS technology. These maps should be disseminated to the community and stakeholders to raise awareness of high-risk areas.

2. Improved Drainage Infrastructure: Investment in effective drainage infrastructure is essential to reduce waterlogging during the rainy season. The government should plan and construct drainage systems capable of accommodating high volumes of rainwater, especially in areas that have been identified as flood-prone

3. Land Use Regulation: Land use management policies should be strengthened to prevent development in areas at high risk of flooding. The establishment of no-build zones in flood-prone areas can help protect infrastructure and settlements.

4. Community Education and Training: Community education and training programs on disaster preparedness and flood mitigation measures should be held regularly.

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Communities should be involved in the planning and implementation of mitigation measures to increase ownership and responsibility.

5. Multi-Stakeholder Collaboration: Encourage collaboration between the government, communities and the private sector in flood risk mitigation efforts. This cooperation may include the development of mitigation programs, joint research, and fundraising for projects related to disaster risk reduction.

6. Monitoring and Evaluation: It is important to conduct regular monitoring and evaluation of the policies and programs that have been implemented. This aims to assess the effectiveness of mitigation measures taken and make necessary adjustments based on the evaluation results.

By implementing these policy recommendations, it is expected to reduce the impact of flooding on Ambon Island and increase community resilience to natural disasters.

4. Conclusion

The results of this study confirm that mapping flood-prone areas on Ambon Island is a crucial step in effective disaster mitigation efforts. By utilizing Geographic Information System (GIS) technology, this research successfully identified various factors that influence flood vulnerability, such as rainfall, topography, and land use. The analysis showed variations in the level of vulnerability across sub-districts, indicating the need for special attention to more vulnerable areas. Therefore, the results of this study serve not only as an analytical tool but also as a guide for the government and communities in planning appropriate mitigation measures, as well as raising awareness of flood risks, so as to reduce the negative impacts caused by this disaster in the future.

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