eISSN: 3031-9471 | pISSN: 3032-7245 | DOI: 10.69606/geography.v1i2.70

Pubsains Journal of Geographical Sciences and Education

https://journal.pubsains.com/index.php/jgs

[Research Article]

Spatial Modeling of Flood Prone Areas in Huamual Sub-district, Seram Bagian Barat Regency, Indonesia

Heinrich Rakuasa

Department of Geography, National Research Tomsk State University, Russian Federation

*Correspondance: heinrich.rakuasa@yandex.ru

Article Info:

Received:
11 November 2023

Accepted:
28 November 2023

Published:
1 December 2023

Keywords:
flood;
GIS;
Hunimual;
MCA;
spatial modeling.

Abstract

Modeling of flood-prone areas is needed to provide information as an initial step in future flood disaster mitigation efforts. This research aims to spatially analyze the level of flood vulnerability and affected settlements in the Hunimual Sub-district. The method used is Multi-Criteria Analysis (MCA) by weighting the value of each variable. The variables that influence flooding in this study consist of land elevation, slope, land cover, distance from the river, geology, and rainfall. The determination of weights and scores in this study is an expert judgment. The weighting results are then overlaid to obtain a flood vulnerability map. The results show that the level of flood vulnerability is dominated by the very low vulnerability level of 69.09%, low vulnerability of 22.50%, and high vulnerability of 8.41% of the total area of the research location. The area of settlements affected by flooding is 556.47 ha. The results of this study are expected to be used as a basis for future flood disaster mitigation efforts to minimize losses, both casualties and physical damage in Hunimual District.

Informasi Artikel:

Diterima:
11 November 2023

Disetujui:
28 November 2023

Dipublikasi:
1 Desember 2023

Kata kunci:
banjir;
GIS;
Hunimual;
MCA;
pemodelan spasial.

Abstrak

Pemodelan daerah rawan banjir diperlukan untuk memberikan informasi sebagai langkah awal dalam upaya mitigasi bencana banjir di masa yang akan datang. Penelitian ini bertujuan untuk menganalisis secara spasial tingkat kerentanan banjir dan permukiman yang terdampak di Kecamatan Hunimual. Metode yang digunakan adalah Multi-Criteria Analysis (MCA) dengan melakukan pembobotan terhadap nilai pada setiap variabel. Variabel yang mempengaruhi terjadinya banjir dalam penelitian ini terdiri dari ketinggian lahan, kemiringan lereng, tutupan lahan, jarak dari sungai, geologi dan curah hujan. Penentuan bobot dan skor pada penelitian ini bersifat expertise judgement. Hasil pembobotan kemudian ditumpangsusunkan untuk mendapatkan peta kerentanan banjir. Hasil penelitian menunjukkan bahwa tingkat kerentanan banjir didominasi oleh tingkat kerentanan sangat rendah sebesar 69,09%, kerentanan rendah sebesar 22,50% dan kerentanan tinggi sebesar 8,41% dari total luas wilayah lokasi penelitian. Luas permukiman yang terdampak banjir adalah 556,47 ha. Hasil penelitian ini diharapkan dapat digunakan sebagai dasar dalam upaya mitigasi bencana banjir di masa yang akan datang untuk meminimalisir kerugian, baik korban jiwa maupun kerusakan fisik di Distrik Hunimual.

INTRODUCTION

Climate change has increased the frequency of hydrometeorological disasters in Indonesia, one of which is flooding (Klipper et al., 2021). Floods are water runoff that exceeds the normal water level, so that it overflows from the riverbed causing inundation of low land on the side of the river (Cabrera & Lee 2020). Flooding is simply defined as the event or state of inundation of an area or land due to increased water volume in the rainy season (Muin & Rakuasa, 2023). In general, floods that occur in Indonesia are caused by high rainfall causing water drainage systems including rivers, natural tributaries and artificial channel systems to be unable to accommodate the accumulation of rainwater that comes so that it overflows and causes flooding (Tambunan et al., 2017; Sugandhi & Rakuasa, 2023).

The causes of flooding generally consist of two, the first is caused by nature itself which consists of erosion, sedimentation, and the influence of river physiography/geophysics, and the second is caused by humans, namely inadequate river/drainage capacity and also land use change/inappropriate land use change in riverbank areas that greatly contribute to surface flow (Tambunan 2018; Rakuasa et al., 2022). Floods can cause significant losses, such as infrastructure damage, economic losses, and even loss of human life (Piadeh et al., 2022). Therefore, mapping and identification of flood-prone areas is very important in disaster mitigation and management efforts (Rakuasa & Latue, 2023). Huamual sub-district, located in Seram Bagian Barat Regency, Indonesia, is one of the areas prone to flooding. The area is located on Seram Island, which has geographical characteristics that are prone to natural phenomena such as flooding. Factors such as high rainfall, flat or gently sloping topography, and poor drainage patterns, contribute to the risk of flooding in this sub-district (Muin & Rakuasa, 2023).

Huamual District is located in Seram Bagian Barat Regency which has an annual flood cycle caused by high rain intensity and poor river conditions and is not balanced with good water absorption so water overflows causing flood disasters (Idfi et al., 2023). When the rainy season occurs, the Huamual Sub-district becomes an area that often causes flood disasters, this is certainly greatly influenced by hydrometeorological factors and the physical condition of the existing area. Heavy rainfall in the last three months has caused flooding in several villages in Huamual Sub-district. In May, five houses in Laala Sub-Village, Loki Village, Huamual Sub-District, West Seram Regency, Maluku were washed away by floods and around 200 families had to evacuate after hundreds of houses were reportedly submerged in floods as high as one meter. In May, floods caused by heavy rains also hit Temi and Limboro Hamlets, Luhu Village, and Huamual Sub-district, causing damage to buildings such as houses, kindergartens, and bridges that were damaged and around 120 families had to evacuate to safe places (BNPB, 2023).

Floods that often occur in Huamual District can cause damage to buildings and environmental damage. Flood damage and its impacts are very detrimental to the community, thus flood disaster mitigation efforts are needed to minimize the impact that occurs (Monger et al., 2022). Densely populated areas are more likely to experience flooding, and the impact will be greater than in other areas (Bajracharya et al., 2021; Rakuasa et al., 2022). To mitigate flood risks and reduce their impacts, it is important to have a good understanding of the areas that are vulnerable to flooding (Rokaya et al. 2022; Muin & Rakuasa, 2023). One approach used to conduct this mapping and analysis is spatial modeling. Spatial models utilize geographic mapping and spatial analysis technologies to identify and visualize areas that are potentially subject to flooding (Latue et al., 2023).

The research aims to provide more detailed information on flood-prone areas in the Hunimual sub-district. The information provided by the model will assist the government and relevant stakeholders in making better decisions in terms of spatial planning, disaster risk mitigation, and emergency management. The development of the model involved the collection of spatial data, such as rainfall data, surface elevation, soil type, and drainage patterns (Idfi et al., 2023). This data was then integrated and analyzed using spatial modeling and geographic mapping techniques. The results of this modeling are expected to enable the government and related parties to identify areas most vulnerable to flooding in Huamual Sub-district. This information can be used to direct mitigation efforts, including better drainage planning, maintenance of waterways, infrastructure improvements, and public awareness of flood risks. Thus, it is expected to reduce losses caused by flooding and increase preparedness in the face of flood disasters in Huamual Sub-district, Seram Bagian Barat Regency.

METHOD

This research was conducted in Huamual District, Seram Bagian Barat Regency which is geographically located at 3°28'20" - 3°5'0" South latitude and 128°11'40" - 128°16'40 East longitude. Huamual District administratively consists of Ariate, Iha, Lokki, and Luhu villages with an area of 39,533, 22 ha. The software used for data processing and analysis in this research is Microsoft Office 365 and ArcGIS 10.8. The variables that affect the occurrence of flooding in this study consist of land elevation, slope, land cover, distance from the river, geology, and rainfall, the complete research variables, data used, and their sources can be seen in Table 1.

Table 1. Research Data

No	Variables	Data	Source
1	Village Administration Boundary	Administrative Boundaries of Indonesian Villages	Geospatial Information Agency
2	Slope	National Digital Elevation Model (DEMNAS) Seram Island sheets 2612_42, 2612_44, 2612_51, 2612_53 Spatial resolution: 0.27-arcsecond or 8 meters	Geospatial Information Agency
3	Land Elevation	National Digital Elevation Model (DEMNAS) Seram Island sheets 2612_42, 2612_44, 2612_51, 2612_53 Spatial resolution: 0.27-arcsecond or 8 meters	Geospatial Information Agency
4	Land Cover	Worldview -2 satellite image of 2023, with a spatial resolution of 50 cm.	Maxar Technologies
5	Jarak dari Sungai	Topographical map, Indonesia (RBI) of West Seram Regency, Scale: 1: 50.000	Geospatial Information Agency
6	Geology	Geologic Map System, Indonesia Sheet: Ambon 2612-2613 Scale: 1.250.000	Indonesian Geological Agency
7	Rainfall	Monthly Rainfall Data	Meteorology Climatology and Geophysics Agency

Based on the data obtained, is then processed into variables that affect the level of flood hazard and the level of exposure to residential areas in Teluk Ambon Baguala Sub-district which are referred to from previous studies (Haryani et al., 2012; Kusumo & Nursari, 2016; Aziza et al., 2021; Rakuasa et al., 2023).

These variables were then subjected to spatial analysis using weighting and scoring methods that refer to previous studies. The method used is Multi-Criteria Analysis (MCA) by weighting the values in each variable. The determination of weights and scores in this research is expertise judgment, which takes the opinion of experts or previous research. The research variables consist of land elevation, slope, distance from the river, geology, land cover, and rainfall. The greater the score on each variable means the greater the level of influence on flooding in the Hunimual District area. Details of the scores and weights in this study can be seen in Table 2.

Source: (Lianxiao & Morimoto 2019; Rakuasa et al., 2023). The weighting of flood vulnerability in Huamual Sub-district is calculated using an arithmetic formula modified from the research of (Aziza et al., 2021; Rakuasa et al., 2022) as follows:

$$Flood\ Vulnerability = 10 \times Slope + 20 \times land\ cover + 20 \times Rainfall + 10 \times Geology + 20 \times Elevation + 20 \times Distance\ from\ River \quad (1)$$

The interval of flood vulnerability level in Teluk Ambon Baguala Sub-district is classified using the formula from Aziza et al. (2021) as follows:

$$Width\ of\ Interval: \frac{a}{b} \quad (2)$$

where a: range or the difference between the highest data value minus the lowest data, and b: number of class interval.

Table 2. Flood vulnerability variables

No	Variables	Class	Score	Weight
1	Slope	0- 8 %	5	10
		8-15 %	4	
		15-25 %	3	
		25-40 %	2	
		>40 %	1	
2	Elevation	0-20 masl	5	20
		21-50 masl	4	
		51-100 masl	3	
		101-300 masl	2	
		>300 masl	1	
3	Land Cover	Built-up Land	3	20
		Open field	4	
		Agricultural land	2	
		Forest	1	
		Waterbody	5	
4	Distance from the River	0 -25 m	5	20
		25-50 m	4	
		50-75 m	3	
		75-100 m	2	
		>100 m	1	
5	Geology	Alluvium	5	10
		Coral Limestone	4	
		Ultramafic Rocks	3	
		Taumusa Complex	2	
		Ambon Volcano Rocks	1	
6	Rainfall	>3000mm/month	5	20

The level of flood vulnerability in the Huamual Sub-district is classified into 3 classes consisting of low, medium, and high. The existing flood-prone area map was 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.

RESULT AND DISCUSSION

Flood Vulnerability Variables

Flood vulnerability variables refer to factors that are used to measure or determine the extent to which an area or population is vulnerable to flooding (Lianxiao & Morimoto 2019; Rakuasa et al., 2023). In this context, flood vulnerability variables refer to aspects that can increase the potential for damage or negative impacts caused by flooding. One of the variables that affect flooding in the Hunimual Sub-district is land elevation. Land height or elevation in Hunimual Sub-district at an altitude of 100-300 meters above sea level has the largest area, namely 19,697.55 ha or 58%, elevation > 300 masl has an area of 7,198.93 or 21.50%, elevation 51 - 100 masl has an area of 2,635.06 ha or 7.87%, elevation 21 - 50 masl has an area of 1,862.43 ha or 5.56% and elevation with an altitude of 0 - 20 masl has an area of 2,093.36 or 6.25%. Low elevation greatly affects flood overflow in an area. The low elevation of an area can affect water flow and drainage capacity, which in turn contributes to flood risk. The complete six variables that cause flooding in the Hunimual Sub-district can be seen in Figure 1.

The variable slope of the Hunimual sub-district is classified into five classes, namely slopes with a slope of 0-8% covering 3,046.05 ha or 9.10%, slopes of 8-15% covering 1,602.53 ha or 4.79%, slopes of 15-25% covering 3,484.29 ha or 10.40%, and slopes of >40% covering 13,089.07 ha or 39.09%. Areas with steep slopes tend to have faster water flow during heavy rains (Abass et al., 2022). Rainwater flows directly from slopes to lowlands or rivers, increasing the risk of flooding as natural drainage capacity may not be able to accommodate high water flows (Sugandhi et al., 2023) The variable distance from the river is classified into five classes, namely areas that are 0-25 m from the river have an area of 1,362, 49 ha or 4.07%, areas that are

21-50 m from the river have an area of 1,378, 06 ha or 4. 12 %, the area within 51 - 75 m from the river has an area of 2,776.88 ha or 8.29 %, the area within 76 - 100 m from the river has an area of 10,441, 72 ha or 31.18 % and the area >100 m from the river has an area of 17,527.41 ha or 52.34 %. Areas close to rivers are the most potential areas for flooding (Motta et al., 2021; Latue & Rakuasa, 2023). One of the factors that cause flooding in Huamual Sub-district is frequent flooding, namely high rainfall which causes the existing watershed to forget, and based on field observations it is known that many settlements located close to the river are flooded.

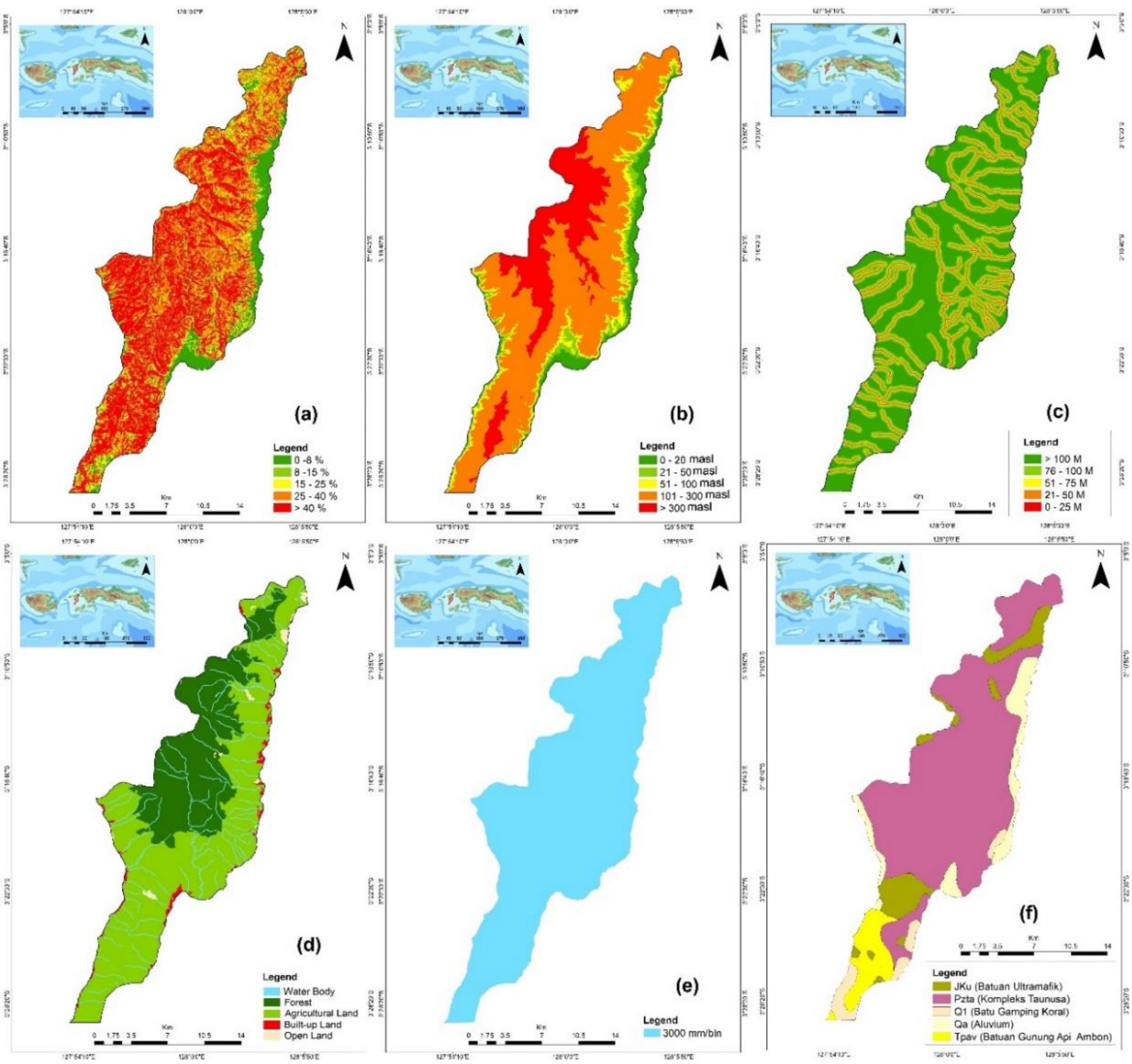

Figure 1. Research Variables: (a) Elevation, (b) Slope, (c) Distance from River, (d) Land Cover, (e) Rainfall, and (f) Geology.

Land cover in Hunimual Sub-district is classified into five classes consisting of forests covering 14,016.42 ha or 35.45%, agricultural land covering 24,342.81 ha or 61.58%, built-up land covering 656.98 ha or 1.66%, open land covering 369.49 ha or 0.93% and water bodies covering 147.51 ha or 0.37%. Land cover has a significant relationship with flooding (Letedara et al., 2023). Changes in land cover can affect the hydrological cycle of an area and cause changes in water flow, water absorption, and the ability of the soil to hold water (Gibson & Shelley, 2020).

The rainfall map of the Hunimual Sub-district is made based on average rainfall data and Isohyet maps from BMKG Kairatu Station, the results show that the rainfall of the Hunimual Sub-district is evenly distributed. The average rainfall in Hunimual Sub-district in 2023 is 3018 mm/month, causing this area to fall into the category of very prone to flooding. Rainfall is one of the main factors that have a major influence on the occurrence of flooding in an area (Rakuasa & Rinaldi, 2023). The amount and intensity of rainfall can affect the volume and speed of water flow, drainage capacity, and groundwater storage (Marasabessy et al., 2020).

Based on the Geological Map of Indonesia, sheet: Ambon 2612-2613, the geology of Hunimual Sub-district consists of Ultramafic Rocks with an area of 3,061.25 ha or 9.14%, Taunusa Complex covering 23,882.26 ha or 71.32%, Coral Limestone covering 1,396.75 ha or 4.17%, Alluvium covering 2,786.51 ha or 8.32% and Ambon Volcano Rocks covering 2,360.58 ha or 7.05%.

Flood Vulnerability Level

Flood vulnerability is defined as a measure or indicator of how vulnerable an area is to flood. It reflects the potential for the area to experience flooding, how often flooding occurs, and the level of impact on people, animals, the environment, and property. The six parameters are then overlaid to classify the total score with a formula to divide into three flood vulnerability classes, namely high vulnerability class, medium vulnerability class, and high vulnerability class. Based on the results of the classification of flood disaster vulnerability areas in Hunimual Sub-district, the area in the low vulnerability class has an area of 23,137.38 ha or 69.09%, this is because this area has a hilly topography, Ambon volcanic rocks, and dominating land cover, namely agricultural and forest areas, and a long distance from the river makes flood runoff difficult to inundate this area. The spatial map of flood disaster vulnerability in Huamual Sub-district can be seen in Figure 2.

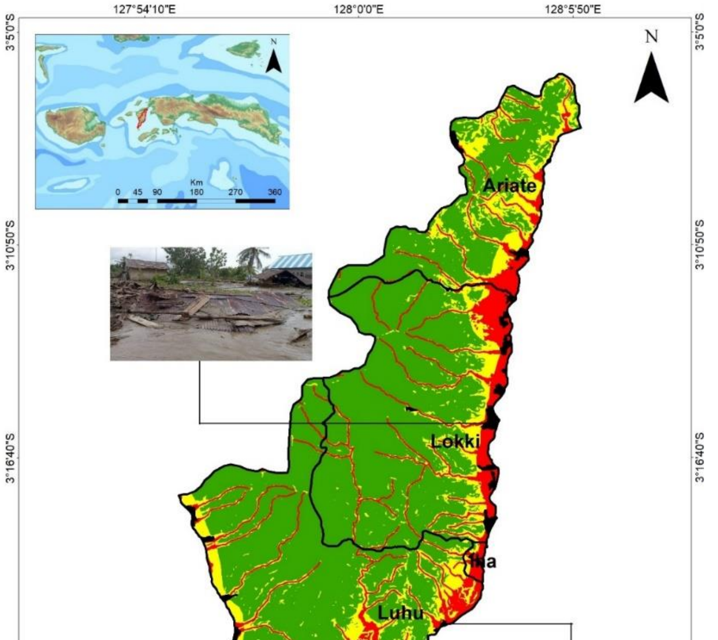

Figure 2. Flood vulnerability map

Table 3. Per-Village Flood Vulnerability Level

Village	Vulnerability Level	Area	
		Ha	Percentage (%)
Ariata	Low	3.437,65	61,16
	Medium	1.709,29	30,41
	High	474,01	8.43
	Total area	5.620,95	100,00
Iha	Low	798,98	43,37
	Medium	874,20	47,46
	High	1.68,89	9,17
	Total area	1842.08	100,00
Lokki	Low	8.400,47	75,68
	Medium	1.573,78	14,18
	High	1.125,27	10,14
	Total area	11.099.52	100,00
Lohu	Low	10.500,28	70,35
	Medium	3.375,81	22,62
	High	1.048,70	7,03
	Total area	14.924,79	100,00

The medium vulnerability class has an area of 7,533.08 ha or 22.50%. This is because this area is located in the lowlands and the dominating land cover is open land and settlements, the slope and height of the land are flat and gentle, and the geological structure is ambon volcanic rock and taumusa complex rock with slow infiltration making this area flooded for a long time. The area with high vulnerability is 2,816.88 ha or 8.41%. Most of these areas are located in coastal areas that have sloping and flat landforms and elevations and are very close to watersheds. The type of land cover in this area is also dominated by residential land and open land, and the type of rock is dominated by alluvium and coral limestone, which influence flood conditions in this area.

Based on Table 3, the level of flood vulnerability in Hunimual Sub-district, Lokki village has the largest area at the high vulnerability level, which is 1,125.27 ha, followed by Lohu village with an area of 1,048.70 ha, Iha village with an area of 1,68.89 ha and Ariata village with an area of 474.01 ha. At the moderate level of vulnerability, Lohu village has the largest area of 3,375.81 ha, followed by Ariata village with an area of 1,709.29 ha, Lokki village with an area of 1,573.78 ha, and Iha village with an area of 874.20. At the low-moderate flood vulnerability level, Lohu village has the largest area of 10,500.28 ha, followed by Lokki village of 8,400.47 ha, Ariata village of 3,437.65 ha, and Iha village of 798.98 ha. Based on data obtained from BNPB, Lokki Village and Lohu Village are the two villages in the Hunimual Sub-district that have had a very high percentage of flooding in the last five years.

Based on data from the National Management Agency, Hunimual Sub-district is at a high flood hazard intensity, therefore flood disaster mitigation must be carried out to anticipate the impacts and losses caused, both material losses and casualties (BNPB, 2021). One form of anticipation is to predict how much built-up land/settlements are located in flood-prone areas. The results of the analysis show that settlements affected by the high flood class have the highest percentage of the area of 4,65.43 ha or 83.64%, a medium class of 80.96 ha or 14.55%, and low-affected settlements of 10.08 ha or 1.81%.

Spatial modeling of flood-prone areas in the Hunimual Sub-district has various benefits that are important for flood disaster management and overall regional development. Some of the benefits of spatial modeling of flood-prone areas include:

a) Identification and understanding of flood-prone areas: Spatial modeling enabled the identification and mapping of areas vulnerable to flooding (Islam et al., 2016). This helps the government and stakeholders to better understand the affected areas and the level of flood risk in each part of the Hunimual sub-district.
b) Disaster planning and mitigation: Information from spatial modeling enables

the creation of more effective flood mitigation and prevention plans (Yodsuban & Nuntaboot, 2021). The government and relevant agencies can use this data to prioritize actions, such as the construction of better drainage systems, levees, or appropriate spatial arrangements.

c) Evaluation of flood infrastructure and resilience: Spatial modeling can assist in assessing the performance of existing flood control infrastructure and facilities (Chen et al., 2021). This allows for a better understanding of whether existing infrastructure is adequate or needs to be upgraded to deal with future floods.
d) Evidence-based decision-making: By having accurate spatial modeling, disaster management, and regional development decisions can be made based on scientific data and evidence, making them more scalable and based on careful analysis (Ponting et al., 2021).
e) Outreach and education: Information from spatial modeling can be used to provide flood information to the public, build awareness about risks, and educate them on actions to take in the face of flooding (Waqas et al., 2021).
f) Flood loss reduction: With proper spatial modeling, potential losses due to flooding can be minimized. By knowing the flood-prone areas, people can avoid building infrastructure or property in these areas, thereby reducing financial and human losses (Taufik et al., 2022).

To take advantage of the benefits of spatial modeling of flood-prone areas, it is important to have accurate and up-to-date data and involve various parties such as the government, research institutions, and local communities in the analysis and decision-making process.

CONCLUSION

Based on the results of the research of flood-prone areas in Hunimual Sub-district using the six parameters modified from previous researchers, it shows that areas with high vulnerability are areas located on flat and gentle elevations and slopes, land elevations >20 meters above sea level, proximity to rivers, dominated by alluvium and coral limestone, and high rainfall intensity. Lokki village has the largest area at the high vulnerability level and settlements affected by the high flood class have the highest percentage of area at 83.64%. Areas with a high level of vulnerability and settlements that are predicted to be affected are evenly distributed in coastal areas with flat and sloping topography, on the other hand, with medium and low levels of vulnerability where farther from the river and on a hilly topography it is very unlikely to be flooded. The results of the research are expected to help the government of Seram Bagian Barat Regency and related agencies, especially the Hunimual Sub-district government in flood disaster mitigation efforts in the future and disaster mitigation-based spatial planning efforts. The results of this research are expected to be useful and become a reference for researchers who conduct similar research in the future and are expected to add other parameters to analyze more flood-prone areas in the future.

REFERENCE

Abass, K., Dumedah, G., Frempong, F., Muntaka, A. S., Appiah, D. O., Garsonu, E. K., & Gyasi, R. M. (2022). Rising Incidence and Risks of Floods in Urban Ghana: Is Climate Change to Blame?. *Cities* 121: 103495. https://www.sciencedirect.com/science/article/pii/S0264275121003942.

Aziza, S.N., Somantri, L., & Setiawan, I. (2021). Analisis Pemetaan Tingkat Rawan Banjir di Kecamatan Bontang Barat Kota Bontang Berbasis Sistem Informasi Geografis. *Jurnal Pendidikan Geografi Undiksha* 9(2): 109–20.

Bajracharya, S. R., Khanal, N. R., Nepal, P., Rai, S. K., Ghimire, P. K., & Pradhan, N. S. (2021). Community Assessment of Flood Risks and Early Warning System in Ratu Watershed, Koshi Basin, Nepal. *Sustainability 13*(6), 3577. https://doi.org/10.3390/su13063577

BNPB. (2021). IRBI (Indeks Resiko Bencana Indonesia) Tahun 2021. *Direktorat Pengurangan Risiko Bencana, BNPB*: 115. https://www.bnpb.go.id//uploads/renas/1/BUKU RENAS PB.pdf.

BNPB. (2023). Banjir Di Kab. Seram Bagian Barat (SBB), Prov. Maluku." *BNPB*: 1. Retrieved from https://pusdalops.bnpb.go.id/2023/07/14/infografis090723-banjir-di-kab-seram-bagian-barat-sbb-prov-maluku/ (July 17, 2023).

Cabrera, J. S., & Lee, H. S. (2020). Flood Risk

Assessment for Davao Oriental in The Philippines Using Geographic Information System-based Multi-criteria Analysis and the Maximum Entropy Model. *Journal of Flood Risk Management* 13(2), e12607 https://doi.org/10.1111/jfr3.12607

Chen, Y., Liu, T., Ge, Y., Xia, S., Yuan, Y., Li, W., & Xu, H. (2021). Examining Social Vulnerability to Flood of Affordable Housing Communities in Nanjing, China: Building Long-Term Disaster Resilience of Low-Income Communities. *Sustainable Cities and Society* 71, 102939. https://doi.org/10.1016/j.scs.2021.102939

Gibson, S., & Shelley, J. (2020). Flood Disturbance, Recovery, and Inter-Flood Incision on a Large Sand-Bed River. *Geomorphology* 351, 106973. https://doi.org/10.1016/j.geomorph.2019.106973.

Haryani, N. S., Zubaidah, A., Dirgahayu, D., Yulianto, H. F., & Pasaribu, J. (2012). Model Bahaya Banjir Menggunakan Data Penginderaan Jauh di Kabupaten Sampang. *Jurnal Penginderaan Jauh dan Pengolahan Data Citra Digital*, *9*(1).

Rakuasa, H., Sihasale, D. A., Mehdila, M. C., & Wlary, A. P. (2022). Analisis Spasial Tingkat Kerawanan Banjir di Kecamatan Teluk Ambon Baguala, Kota Ambon. *Jurnal Geosains dan Remote Sensing, 3*(2), 60-69. https://doi.org/10.23960/jgrs.2022.v3i2.80

Idfi, G., Setyawan, E., Suwarno, E., & Al Ansyorie, M. M. (2023). Perbandingan Model Unsteady dan Steady Flow Aliran Banjir Sungai Way Laala Sebagai Dasar Solusi Penanganan Pasca Bencana. *Bangunan, 28*(1), 1–12.

Islam, R., Kamaruddin, R., Ahmad, S. A., Jan, S., & Anuar, A. R. (2016). A Review on Mechanism of Flood Disaster Management in Asia. *International Review of Management and Marketing, 6*(1), 29-52. https://www.proquest.com/scholarly-journals/review-on-mechanism-flood-disaster-management/docview/1762628141/se-2.

Klipper, I. G., Zipf, A., & Lautenbach, S. (2021). Flood Impact Assessment on Road Network and healthcare Access at The Example of Jakarta, Indonesia. *AGILE: GIScience Series*, 2, 1–11. https://agile-giss.copernicus.org/articles/2/4/2021/.

Kusumo, P., & Nursari, E. (2016). Zonasi Tingkat Kerawanan Banjir Dengan Sistem Informasi Geografis Pada DAS Cidurian Kab. Serang, Banten. *STRING (Satuan Tulisan Riset dan Inovasi Teknologi), 1*(1): 29–38.

Latue, P. C., & Rakuasa, H. (2023). Identification of Flood-Prone Areas using the Topographic Wetness Index Method in Fena Leisela District, Buru Regency. *Journal Basic Science and Technology, 12*(2), 20-24.

Latue, P. C., Imanuel Septory, J. S., Somae, G., & Rakuasa, H. (2023). Pemodelan Daerah Rawan Banjir di Kecamatan Sirimau Menggunakan Metode Multi-Criteria Analysis (MCA). *Jurnal Perencanaan Wilayah dan Kota*, *18*(1), 10–17.

Letedara, R., Rakuasa, H., & Latue, P. C. (2023). 2023. Cellular Automata Markov Chain Application for Prediction of Land Cover Changes in The Wae Batu Gantung Watershed, Ambon City, Indonesia. *Journal of Multidisciplinary Science, 2*(2), 113-122.

Lianxiao, & Morimoto, T. (2019). Spatial Analysis of Social Vulnerability to Floods Based on the MOVE Framework and Information Entropy Method: Case Study of Katsushika Ward, Tokyo. Su*stainability, 11*(2), 529. https://doi.org/10.3390/su11020529

Marasabessy, M., Pallu, M. S., Lopa, R. T., & Thaha, M. A. (2020). Development of flood forecasting model and warning systems at Way Ruhu–Ambon. In *IOP Conference Series: Earth and Environmental Science* 419(1): 12115. http://dx.doi.org/10.1088/1755-1315/419/1/012115.

Monger, F., V Spracklen, D., J Kirkby, M., & Schofield, L. (2022). The Impact of Semi-Natural Broadleaf Woodland and Pasture on Soil Properties and Flood Discharge. *Hydrological Processes*, *36*(1), e14453. https://doi.org/10.1002/hyp.14453

Motta, M., de Castro Neto, M., & Sarmento, P. (2021). A Mixed Approach for Urban Flood Prediction using Machine Learning and GIS. *International Journal of Disaster Risk Reduction,* 56, 102154. https://doi.org/10.1016/j.ijdrr.2021.102154

Muin, A., & Rakuasa, H. (2023a). Pemetaan

Daerah Rawan Banjir di Desa Lokki Kecamatan Huamual Kabupaten Seram Bagian Barat. *Gudang Jurnal Multidisiplin Ilmu* 1(2), 47–52.

Muin, A., & Rakuasa, H. (2023b). Evaluasi Rencana Tata Ruang Wilayah Kota Ambon Berdasarkan Aspek Kerawanan Banjir. *ULIL ALBAB: Jurnal Ilmiah Multidisiplin, 2*(5), 1727-1738.

Muin, A., & Rakuasa, H. (2023c). Pemanfaat Geographic Artificial Intelligence (Geo-AI) untuk Identifikasi Daerah Rawan Banjir di Kota Ambon. *Gudang Jurnal Multidisiplin Ilmu*, *1*(2), 58-63.

Tambunan, M. P., Pin, T. G., Permana, B., Zikrullah, A., & Maulana, A. (2016, November). Spatial and Temporal Pattern of Flood Area in Cisadane Watershed, Banten Province. In *1st International Conference on Geography and Education (ICGE 2016)* (pp. 70-75). Atlantis Press. http://www.atlantis-press.com/php/paper-details.php?id=25875175.

Tambunan, M. P. (2018). Characteristic of rainfall in the flood period in DKI Jakarta in 1996, 2002, and 2007. In M*ATEC Web of Conferences* (Vol. 229). EDP Sciences. https://www.matec-conferences.org/10.1051/matecconf/201822902012.

Piadeh, F., Behzadian, K., & Alani, A. M. (2022). A Critical Review of Real-Time Modelling of Flood Forecasting in Urban Drainage Systems. *Journal of Hydrology* 607: 127476. https://doi.org/10.1016/j.jhydrol.2022.127476

Ponting, J., Kelly, T. J., Verhoef, A., Watts, M. J., & Sizmur, T. (2021). The Impact of Increased Flooding Occurrence on The Mobility of Potentially Toxic Elements in Floodplain Soil – A Review. *Science of The Total Environment* 754, 142040. https://doi.org/10.1016/j.scitotenv.2020.142040

Rakuasa, H., & Rinaldi, M. (2023). Pemetaan Daerah Potensi Genangan Banjir di Kecamatan Gunugputri, Kabupaten Bogor Menggunakan Data DEMNAS dengan Metode Topographic Wetness Index. *ULIL ALBAB: Jurnal Ilmiah Multidisiplin, 2*(6), 2269-2280.

Rakuasa, H., Helwend, J. K., & Sihasale, D. A. (2022). Pemetaan Daerah Rawan Banjir Di Kota Ambon Menggunakan Sistim Informasi Geografis. *Jurnal Geografi: Media Informasi Pengembangan dan Profesi Kegeografian* 19(2), 73–82. https://doi.org/10.15294/jg.v19i2.34240

Rakuasa, H., Somae, G., & Latue, P. C. (2023). Pemetaan Daerah Rawan Banjir di Desa Batumerah Kecamatan Sirimau Kota Ambon Menggunakan Sistim Informasi Geografis. *ULIL ALBAB: Jurnal Ilmiah Multidisiplin*, *2*(4), 1642–53.

Rakuasa, H., Wahab, W. A., Kamiludin, K., Jaelani, A., Ramdhani, R., & Rinaldi, M. (2023). Pemetaan Genangan Banjir di Jalan TB. Simatupang, Jakarta Selatan Oleh Unit Pengelola, Penyelidikan, Pengukuran Dan Pengujian (UP4) Dinas Sumber Daya Air DKI Jakarta. *Jurnal Altifani Penelitian dan Pengabdian kepada Masyarakat, 3*(2), 288–95.

Rakuasa, H., & Latue, P. C. (2023). Analisis Spasial Daerah Rawan Banjir di Das Wae Heru, Kota Ambon. *Jurnal Tanah dan Sumberdaya Lahan, 10*(1), 75–82. https://jtsl.ub.ac.id/index.php/jtsl/article/view/845.

Rokaya, P., Lindenschmidt, K. E., Pietroniro, A., & Clark, M. (2022). Modelling of Ice Jam Floods Under Past and Future Climates: A Review. *Journal of Hydrology X*, 15, 100120. https://doi.org/10.1016/j.hydroa.2022.100120

Sugandhi, N., & Rakuasa, H. (2023). Utilization of Geogle Earth Engine for Flood Hazard Analysis in DKI Jakarta Province. *Jurnal Riset Multidisiplin dan Inovasi Teknologi*, 1(2), 40–49.

Sugandhi, N., Rakuasa, H., Zainudin, Z., Abdul Wahab, W., Kamiludin, K., Jaelani, A., Ramdhani, R., & Rinaldi, M. (2023). Pemodelan Spasial Limpasan Genangan Banjir Dari DAS Ciliwung di Kel. Kebon Baru dan Kel. Bidara Cina DKI Jakarta. *ULIL ALBAB : Jurnal Ilmiah Multidisiplin*, *2*(5), 1685–1692.

Taufik, S. R., Yatrib, M., Harman, A. N., Kesuma, T. N. A., Saputra, D., & Kusuma, M. S. B. (2022, February). Assasment of flood hazard reduction in DKI Jakarta: Bendungan Hilir Village. *IOP Conference Series: Earth and Environmental Science* 989(1), 012018. https://iopscience.iop.org/article/10.1088/

1755-1315/989/1/012018.

Waqas, H., Lu, L., Tariq, A., Li, Q., Baqa, M. F., Xing, J., & Sajjad, A. (2021). Flash Flood Susceptibility Assessment and Zonation Using an Integrating Analytic Hierarchy Process and Frequency Ratio Model for the Chitral District, Khyber Pakhtunkhwa, Pakistan. *Water*, *13*(12), 1650. https://doi.org/10.3390/w13121650

Yodsuban, P., & Nuntaboot, K. (2021). Community-Based Flood Disaster Management for Older Adults in Southern of Thailand: A Qualitative Study. *International Journal Of Nursing Sciences*, *8*(4), 409-417. https://doi.org/10.1016/j.ijnss.2021.08.008