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Modeling of Tsunami Prone Areas in Kairatu Barat District, Seram Bangian Barat Regency

Heinrich Rakuasa*
National Research Tomsk State University, Russian Federation | heinrich.rakuasa@yandex.ru
Correspondence Author*

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Abstract

Modeling of tsunami-prone areas in Kairatu Barar Sub-district, Seram Bangian Barat Regency, is an important step in improving community safety and preparedness against tsunami threats. With this modeling, tsunami hazards can be better understood, more accurate early warning systems can be developed, and more effective risk reduction plans can be planned. In addition, the modeling also helps to improve people's understanding of tsunami hazards and the actions to be taken in emergency situations. The modeling results are instrumental in designing preventive measures, appropriate evacuation plans and improving disaster preparedness in the region, which can save lives and reduce damage from future tsunamis.

Keywords: Kairatu Barat, Tsunami, GIS

Introduction

A tsunami is a natural event that occurs when there is a major shift in the seabed that can produce large waves that hit beaches and coasts (BNPB, 2022). Tsunamis, often referred to as tsunami waves or tidal waves, can cause enormous damage, loss of life and significant material loss (Ward, 2020; Latue et al., 2023). The main cause of tsunami disasters is subduction earthquakes, which occur when submarine tectonic plates shift and cause vertical displacement of the seabed (Röbke & Vött, 2017; Behrens et al., 2021; Rakuasa & Lasaiba, 2023). Besides earthquakes, other causes include submarine volcanic eruptions, marine landslides, or even asteroid impacts on the ocean surface. These shifts generate huge energy that is transferred to seawater, creating tsunami waves (Behrens et al., 2021).

Kairatu Barat sub-district is located in Maluku Province, Indonesia, which is geographically located along the Banda Sea Subduction Line (Alhamidi et al., 2018). This geological phenomenon causes the potential for significant earthquakes and tsunamis. Therefore, modeling tsunami-prone areas in the Kairatu Barat sub-district is important to identify potential risks and protect the local population. Based on the history and records of earthquakes and tsunamis in Maluku Province where based on the Catalogue of Tsunamis on the Western Shore of the Pacific Ocean there have been 85 tsunami events in Maluku Province which constitutes 40% of the 210 tsunami events that have hit Indonesia (Solov′ev, 1974; BMKG, 2019). Apart from local tsunamis, tsunami events in the Maluku islands are also caused by the threat of remote tsunamis where the source of earthquakes that can cause tsunamis comes from plate movements in the Philippines, Japan and from the Pacific Ocean (Rakuasa et al., 2022).

The National Disaster Management Agency (BNPB, 2022), explained that the Seram Island Coastal Area is an area that has the highest disaster risk index in Maluku Province, this was previously explained in the history of earthquakes and tsunamis in Ambon written by Rumphius (1627-1702) which was mentioned as a tragedy on February 17, 1674 about 346 years ago, an earthquake that shook Ambon and its surroundings which resulted in damage to residents' homes and claimed an estimated 2,500 people who died (Rumphius, 1675; Sugandhi et al., 2023). As part of the Pacific Ring of Fire, Indonesia is in an area prone to earthquakes and tsunamis (Murjaya et al., 2021).

The Kairatu Barat sub-district has the highest risk index for tsunami disasters as evidenced by the geographical, geological and demographic conditions that affect this area which is very at risk of tsunamis as a disaster that is difficult to predict its arrival, this is reinforced by the results of the September Jala Citra Expedition in 2022 conducted by the naval hydro-oseanography center which found volcanic mountains as high as 3,400 meters under the Banda Sea, this certainly makes the Kairatu Barat area directly facing the Banda Sea the most potentially affected by tsunami disasters (CNN Indonesia, 2022: Latue & Rakuasa, 2022). Therefore, modeling tsunami-prone areas in the Kairatu Barat sub-district can provide a better understanding of the risk.

In addition, this modeling is also relevant in the context of global climate change. It is predicted that climate change can affect weather, sea surface temperatures and ocean flow patterns, all of which can affect the potential for earthquakes and tsunamis (Manakane et al., 2023). Therefore, this modeling should not only consider current conditions but also future projections in identifying risks (Latue & Rakuasa, 2023; Latue et al., 2023). Modeling of tsunami-prone areas can also serve as a foundation for spatial planning and safer infrastructure development (Sihasale et al., 2023). This will help to increase the resilience of the region to the tsunami threat, thereby reducing its impact (Rakuasa & Salakory, 2022).

The results of the tsunami hazard modeling in Kairatu Barat sub-district will be an important foundation for local governments, disaster management agencies and communities to develop disaster preparedness and mitigation plans. Public education and socialization on evacuation and preparedness measures in the face of tsunami hazards is essential (Rakuasa & Mehdila, 2023; Manakane et al., 2023). The development of a tsunami early warning system is also one of the critical steps in dealing with this hazard (Pakniany et al., 2022). An effective warning system will provide quick and accurate information to the public and allow sufficient time to avoid the impact of the disaster. This study aims to determine the level of tsunami hazard and built-up land predicted to be affected by tsunami in Kairatu Barat sub-district, Seram Island.

Research Method

This research was conducted in Kairatu Barat sub-district, Seram Bangian Barat district, Maluku province. Geographically, Kairatu Barat sub-district is located on Seram Island. This research uses descriptive quantitative research using tsunami modeling techniques that have been used by BNPB with the Tsunami Inundation Modeling method or spatial modeling with a Geographic Information System approach to predict tsunami-prone areas in Ambon City with mathematical calculations.

This research uses village administrative boundaries, coastlines and Digital Elevation Model (DEM) data obtained from the Geospatial Information Agency (BIG), high-resolution satellite image data used in this research is Worldview -2 in 2013 and 2023 obtained from Maxar Technologies, tsunami wave height simulation data are 6 meters, 10 meters, 12 meters and 18 meters. Tsunami hazard modeling in Kairatu Barat sub-district refers to the BNPB standard Tsunami Inundation Modeling and is developed based on simulations of tsunami wave heights that have occurred on Seram Island. The Tsunami Inundation Modeling method in this study is based on mathematical calculations developed by Berryman, (2006), based on the calculation of tsunami height loss per 1 m inundation height distance based on the value of distance to slope and surface roughness.

$$H_{loss} = \left(\frac{167\, n^2}{{H_0}^{1/3}}\right) + 5\, Sin\, S$$

Hloss = Tsunami height loss per 1 m inundation height distance
n = Surface roughness index
H0 = Tsunami wave height at the coastline
S = Magnitude of surface slope (degree)

The above equation shows a mathematical calculation developed by Berryman, (2006) based on the calculation of tsunami height loss per 1 m inundation height distance (Hloss). In this equation, the sin value of the slope (SinS) is required so that the degree value of the slope needs to be converted into radians. The conversion is done with the slope data with degree units multiplied by 0.01745 (the result of π/180). N shows the surface roughness index value obtained from land cover. roughness coefficient based on land cover type can be seen in Table 1.

Table 1. Roughness Coefficient by Land Cover Type

Land Cover Type	Surface Roughness Index
Water Body	0,007
Shrubs	0,040
Forest	0,070
Plantation	0,035
Open Land/Sand/Road	0,015
Rice Field	0,025
Settlement/Settlement	0,045

Source: Perka BNPB No. 2 Tahun 2011

H0 represents the maximum tsunami wave potential based on BNPB Regulation No. 2/2011. The Hloss value is required for the calculation of Cost Distance for the exposure area and evacuation safety zone limited by the maximum runup point. Shoreline data is inputted as the initial boundary of the Cost Distance measurement. The Cost Distance value is the coverage value of tsunami waves reaching the run-up point based on the Hloss result. The exposure area is obtained from the value of the maximum tsunami wave potential in the WEST KAIRATU sub-district minus the Cost Distance result. The value of the exposure area will decrease the further away from the coast. The results of tsunami hazard prediction in WEST KAIRATU sub-district based on tsunami wave heights of 6 meters, 10 meters, 12 meters and 18 meters are overlaid with built-up land data to determine how much built-up land is predicted to be affected.

Results and Discussion

The geographical location of WEST KAIRATU on the coast of Seram Island, Maluku, makes it vulnerable to potential tsunamis. The region is directly adjacent to the Banda Sea, which is known as one of the potential sources of tsunami events due to submarine geological activity. The results of tsunami modeling conducted in KAIRATU BARAT sub-district, Seram Island, were carried out using four tsunami wave height scenarios including 6 meters, 10 meters, 12 meters and 18 meters. The results of tsunami modeling with a 6-meter wave height scenario resulted in an inundation area of 258.82 ha, a tsunami affected area at a height of 10 meters of 465.16 ha, a tsunami height of 12 meters of 574.35 ha, and a tsunami affected area with a wave height of 18 meters of 905.67 ha. The results of the modeling of tsunami prone areas in West KAIRATU Sub-district, West Seram Bangian Regency can be seen in Figure 1.

Based on the results of tsunami hazard processing and supported by past tsunami records, the Kairatu Barat sub-district is located at a moderate tsunami hazard intensity. Tsunami disaster is a top priority threat that must be anticipated so that the adverse impacts of both casualties and building damage can be minimized. One form of anticipation is to predict the extent of residential areas located in tsunami-prone areas by overlaying tsunami data with built-up land data. The results of tsunami modeling with a 6-meter wave height scenario in the Kairatu Barat sub-district predicted that the affected built-up land is 64.52 ha, in the 10-meter wave height scenario the affected built-up land is 465.16 ha, in the 12-meter wave height scenario the affected built-up land is 574.35 ha and in the 18-meter wave height scenario the affected built-up land is 905.67 ha.

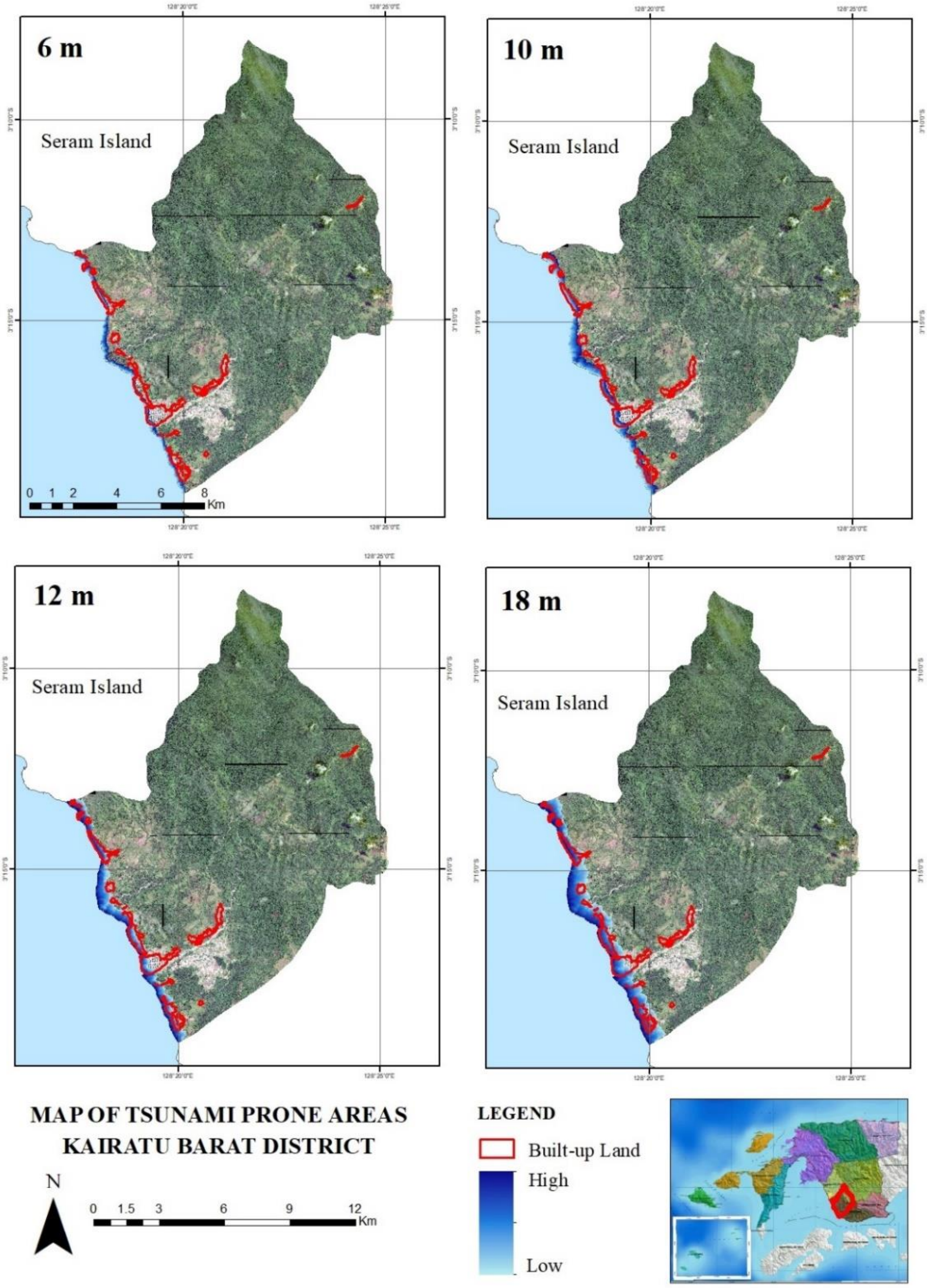

Figure 1. Map of Tsunami Prone Areas in Kairatu Barat District

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Distance from the coast plays a crucial role in determining the potential tsunami hazard in Kairatu Barat Sub-district, Seram Island, or other coastal areas. The closer an area is to the coast, the higher the risk of being affected by a tsunami (Syamsidik et al., 2015). The results showed that the settlement pattern in Kairatu Barat Subdistrict follows the coastline or is mostly located in coastal areas, this certainly increases the risk of future tsunami disasters in Kairatu Barat Subdistrict. Latue & Latue, (2023), added that topography is one of the important factors affecting the potential tsunami hazard. Topography is the shape and structure of the earth's surface in an area, including landforms, sea depths, valleys and mountains. The more sloping and flat the topography of an area, the higher the risk of future tsunami disasters. In addition to the distance from the coast variable, there is also a land surface roughness index variable. According to Rakuasa et al. (2022), the surface roughness index refers to the texture or characteristics of the land surface in a particular area. Areas with a high roughness index usually have many natural obstacles such as vegetation, buildings, or uneven land structures (Septory et al., 2023). In contrast, areas with a low roughness index tend to have smoother surfaces, less natural obstacles, and may be more easily hit by tsunami waves (Rakuasa et al., 2022).

The modeling of tsunami-prone areas in West KAIRATU Sub-district, West Seram Regency, has several important benefits. The following are some of the benefits of the modeling:

1) Better Understanding of Tsunami Hazards: Modeling of tsunami prone areas can help in better understanding of tsunami hazards in this region. By identifying potential hazard sources, such as submarine earthquakes or volcanic eruptions, modeling can provide a more detailed picture of how and when tsunamis can occur. This allows authorities to take better preventive measures and prepare more effective emergency plans.
2) Development of a More Precise Early Warning System: Tsunami modeling can be used to develop more accurate and responsive early warning systems. With a better understanding of the hazards and likely path of tsunamis, authorities can set up early warning systems that are more sensitive and quick to warn the local population. This can save lives and reduce the damage caused by tsunamis.
3) Risk Reduction Planning: Modeling tsunami-prone areas can also be used to design risk reduction plans. This includes determining safer areas for human settlement, designing buildings that are more resistant to tsunamis, and identifying efficient evacuation routes. With this modeling, risk mitigation efforts can be more targeted and effective.
4) Public Education and Awareness: The results of the modeling can be used to improve people's understanding of tsunami risks. Education and awareness programs can be built based on the modeling results to inform the community on actions to be taken in the event of a tsunami warning. This can help communities to be better prepared and reduce confusion in the event of a tsunami threat.

5) Better Disaster Preparedness: By modeling tsunami prone areas, the WEST KAIRATU sub-district can improve their overall level of disaster preparedness. This includes engaging various parties, including government, non-profit organizations and local communities, in evacuation drills and disaster simulations. Modeling helps in better planning and executing these exercises.

Conclusion

As a result of this study, it can be concluded that understanding and being prepared for tsunami hazards is becoming increasingly important in protecting people and their assets. The modeling provides deep insights into the potential threat, enabling the development of more efficient early warning systems and better risk mitigation plans. By involving communities in the education and awareness process, the modeling also plays a role in shaping higher levels of preparedness. Thus, modeling tsunami-prone areas is a powerful tool to minimize the impact of unexpected natural disasters, keep the population safe and reduce the losses that may occur due to tsunamis in the region.

References

Alhamidi, Pakpahan, V. H., & Simanjuntak, J. E. S. (2018). Analysis of tsunami disaster resilience in Bandar Lampung Bay Coastal Zone. *{IOP} Conference Series: Earth and Environmental Science*, *158*, 12037. https://doi.org/10.1088/1755-1315/158/1/012037

Behrens, J., Løvholt, F., Jalayer, F., Lorito, S., Salgado-Gálvez, M. A., Sørensen, M., Abadie, S., Aguirre-Ayerbe, I., Aniel-Quiroga, I., Babeyko, A., Baiguera, M., Basili, R., Belliazzi, S., Grezio, A., Johnson, K., Murphy, S., Paris, R., Rafliana, I., De Risi, R., … Vyhmeister, E. (2021). Probabilistic Tsunami Hazard and Risk Analysis: A Review of Research Gaps. *Frontiers in Earth Science*, *9*. https://doi.org/10.3389/feart.2021.628772

Berryman. (2006). *Riview of tsunami hazard and risk in new zealand. Lower hutt*. institute of geological and nuclear sciences.

BMKG. (2019). *Katalog Tsunami Indonesia Tahun 416-2018 per wilayah*. Badan Meteorologi dan Geofisika.

BNPB. (2022). *Indeks Risiko Bencana Indonesia (RBI) Tahun 2022*. Pusat Data, Informasi dan Komunikasi Kebencanaan Badan Nasional Penanggulangan Bencana.

CNN Indonesia. (2022). *Enam Gunung Api Ditemukan di Laut Banda*. CNN Indonesia.Com. https://www.cnnindonesia.com/nasional/20220722093151-20-824707/enam-gunung-api-ditemukan-di-laut-banda

Fuad, M. A. Z., Effendi, V. R., & Dewi, C. S. U. (2022). APPLICATION OF SAR REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS (GIS) IN COASTLINE CHANGE STUDIES–A CASE STUDY OF COASTLINE CHANGE DUE TO THE 2018 TSUNAMI IN TANJUNG LESUNG, BANTEN. *Asian Journal of Aquatic Sciences*, *5*(1), 87–98.

Georg Everhard Rumphius. (1675). *History of the Terrible Earthquake that Took Place Recently, and Some Time Before, but Principally on February 17, 1674 in and around the*

Island of Amboina.

Heinrich Rakuasa, Febermen Halawa, D. A. S. (2022). Pemodelan Spasial Ketersedian Lahan Dengan Kawasan Rawan Tsunami di Kota Ambon. *Geo Image*, *11*(2), 1–12. https://doi.org/10.15294/geoimage.v11i2.57809

Heinrich Rakuasa, M. S. (2022). Pemodelan Spasial Bahaya Tsunami dan Keterpaparanya Terhadap Permukiman di Kota Ambon. *Jurnal Sains Informasi Geografi (J SIG)*, *5*(1), 31–37. https://doi.org/10.31314/jsig.v5i1.1433

Latue, P. C., Manakane, S. E., & Rakuasa, H. (2023). Policy Review and Regional Development in Disaster Mitigation (Case Study: 2004 Aceh Tsunami and 2011 Tōhoku Tsunami). *International Journal of Multidisciplinary Approach Research and Science*, *1*(03), 288–301. https://doi.org/10.59653/ijmars.v1i03.165

Latue, P. C., & Rakuasa, H. (2023). Spatial Analysis of Landscape Suitability of Ambon City for Settlement Using Geographic Information System. *Jurnal Riset Multidisiplin Dan Inovasi Teknologi*, *1*(02), 59–69. https://doi.org/10.59653/jimat.v1i02.218

Latue, T., Latue, P. C., Rakuasa, H., Somae, G., & Muin, A. (2023). Mapping of Landslide Prone Areas in Huamual Sub-District, Seram Bangian Barat Regency, Indonesia. *Jurnal Riset Multidisiplin Dan Inovasi Teknologi*, *1*(02), 84–93. https://doi.org/10.59653/jimat.v1i02.239

Lestari, D. A., Fitriasari, N. S., Ahmad, T. E., Rais, A., & Azhari, D. R. (2021). Spatial Analysis on Tsunami Predictions in Pandeglang Regency. *Forum Geografi*, *35*(1). https://doi.org/10.23917/forgeo.v35i1.12367

Lestari, D. A., Susiloningtyas, D., & Supriatna, S. (2020). Spatial Dynamics Model of Land Availability and Population Growth Prediction in Bengkulu City. *Indonesian Journal of Geography*, *52*(3), 427. https://doi.org/10.22146/ijg.44591

Manakane, S. E., Latue, P. C., & Rakuasa, H. (2023). Integrating Geospatial Technology in Learning: An Innovation to Improve Understanding of Geography Concepts. *Sinergi International Journal of Education*, *1*(2), 60–74. https://doi.org/10.61194/education.v1i2.70

Murjaya, J., Karnawati, D., Supriyanto, Yuliatmoko, R. S., Hardy, T., Rohadi, S., & Rahman, A. (2021). Mechanical responses and earthquake activities on tectonic setting of Banda block (case study: Ambon earthquake occurred on September 26, 2019). *AIP Conference Proceedings*, *2331*, 030001. https://doi.org/10.1063/5.0041775

Pakniany, Y., Tiwery, W. Y., & Rakuasa, H. (2022). Mitigasi Bencana Gempa Bumi Berbasis Kearifan Lokal di Desa Nuwewang Kecamatan Pulau Letti Kabupaten Maluku Barat Daya. *Dialektika: Jurnal Pemikiran Islam Dan Ilmu Sosial*, *15*(1), 1–7.

Philia Christi Latue, H. R. (2022). Dinamika Spasial Wilayah Rawan Tsunami di Kecamatan Nusaniwe, Kota Ambon, Provinsi Maluku. *Jurnal Geosains Dan Remote Sensing (JGRS)*, *3*(2), 77–87. https://doi.org/10.23960/jgrs.2022.v3i2.98

Rakuasa, H., & Lasaiba, M. (2023). Pemetaan Kondisi Fisik Wilayah Sebagai Upaya Dalam Mitigasi Bencana Tsunami di Kecamatan Moa Lakor, Kabupaten Maluku Barat Daya, Provinsi Maluku. *Geoforum*, *2*(12), 13–21.

Rakuasa, H., & Mehdila, M. C. (2023). Penerapan Pendidikan Mitigasi Bencana Gempa Bumi untuk Siswa dan Guru di SD Negeri 1 Poka, Kota Ambon, Provinsi Maluku. *Jurnal Pengabdian Masyarakat Indonesia*, *3*(3), 441–446. https://doi.org/10.52436/1.jpmi.1138

Rakuasa, H., Supriatna, S., Karsidi, A., Rifai, A., Tambunan, M. ., & Poniman K, A. (2022). Spatial Dynamics Model of Earthquake Prone Area in Ambon City. *IOP Conference Series: Earth and Environmental Science*, *1039*(1), 012057. https://doi.org/10.1088/1755-1315/1039/1/012057

Ramadhan, M. F., Handayani, H. H., & Nurwatik. (2021). Analysis of Tsunami Disaster Risk Level Using Grid-Based Method (Case Study: Coastal South Beach Blitar). *IOP Conference Series: Earth and Environmental Science*, *731*(1), 012033. https://doi.org/10.1088/1755-1315/731/1/012033

Röbke, B. R., & Vött, A. (2017). The tsunami phenomenon. *Progress in Oceanography*, *159*, 296–322. https://doi.org/10.1016/j.pocean.2017.09.003

Septory, J. S. I., Latue, P. C., & Rakuasa, H. (2023). Model Dinamika Spasial Perubahan Tutupan Lahan dan Daya Dukung Lahan Permukiman Kota Ambon Tahun 2031. *GEOGRAPHIA : Jurnal Pendidikan Dan Penelitian Geografi*, *4*(1), 51–62. https://doi.org/10.53682/gjppg.v4i1.5801

Sihasale, D. A., Latue, P. C., & Rakuasa, H. (2023). Spatial Analysis of Built-Up Land Suitability in Ternate Island. *Jurnal Riset Multidisiplin Dan Inovasi Teknologi*, *1*(02), 70–83. https://doi.org/10.59653/jimat.v1i02.219

Solov′ev, S. L. (1974). *Catalogue of Tsunamis on the Western Shore of the Pacific Ocean*. Institute of Oceanic Sciences.

Sugandhi, N., Supriatna, Kusratmoko, E., & Rakuasa, H. (2023). Spatial modelling of tsunami hazards and their exposure to settlements in Ambon City. *IOP Conference Series: Earth and Environmental Science*, *1173*(1), 012013. https://doi.org/10.1088/1755-1315/1173/1/012013

Susan E Manakane, Philia Christi Latue, Glendy Somae, H. R. (2023). The Role of Geography Research in Supporting Sustainable Development in Ambon City, Indonesia: A Review. *Sinergi International Journal of Economics*, *1*(2), 64–75. https://doi.org/10.61194/economics.v1i2.67

Susiloningtyas, D., Lestari, D. A., & Supriatna, S. (2020). Pemodelan Spasial Peak Ground Acceleration dan Prediksi Luas Genangan Tsunami di Kota Bengkulu. *Majalah Geografi Indonesia*, *34*(2), 166. https://doi.org/10.22146/mgi.44168

Syamsidik, Rasyif, T. M., & Kato, S. (2015). Development of accurate tsunami estimated times of arrival for tsunami-prone cities in Aceh, Indonesia. *International Journal of Disaster Risk Reduction*, *14*, 403–410. https://doi.org/10.1016/j.ijdrr.2015.09.006

Theochrasia Latue & Philia Christi Latue. (2023). Analisis Spasial Prediksi Bahaya Tsunami di Kecamatan Salahutu Pulau Ambon. *Buana Jurnal Geografi, Ekologi Dan Kebencanaan*, *1*(1), 21–30.

Ward, S. N. (2020). *Tsunami* (pp. 1–21). https://doi.org/10.1007/978-3-030-10475-7_22-1