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[Research Article]

Spatial Analysis of Landslide Prone Areas in Tidore Island, Indonesia

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Abstract

The topographic condition of Tidore Island, where 50% of the area is on a steep slope, makes Tidore Island prone to landslides during the rainy season. This research aims to spatially identify landslide prone areas in Tidore Island using slope morphology method. SMORPH method is conducted by identifying and classifying potential landslide areas based on slope shape and slope angle matrix. The result of this study shows that high landslide potential area is 2,569.42 ha, medium potential area is 3,296.99 ha, low potential area is 4,778.46 ha, and very low potential area is 1,126.55 ha. Among the sub-districts in Tidore Island, North Tidore has the largest presentation area of 892.48 ha. It can be concluded that areas with steep slopes and convex or concave slope shapes have higher landslide potential. The findings of this research are expected to help local government in future spatial planning efforts for landslide mitigation.

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Abstrak

Kondisi topografi Pulau Tidore yang 50% wilayahnya berada pada kemiringan lereng yang curam, menyebabkan Pulau Tidore rawan longsor pada saat musim hujan. Penelitian ini bertujuan untuk mengidentifikasi secara spasial daerah rawan longsor di Pulau Tidore dengan menggunakan metode morfologi lereng. Metode SMORPH dilakukan dengan mengidentifikasi dan mengklasifikasikan daerah yang berpotensi longsor berdasarkan matriks bentuk lereng dan sudut lereng. Hasil dari penelitian ini menunjukkan bahwa daerah yang berpotensi longsor tinggi seluas 2.569,42 ha, daerah yang berpotensi sedang seluas 3.296,99 ha, daerah yang berpotensi rendah seluas 4.778,46 ha, dan daerah yang berpotensi sangat rendah seluas 1.126,55 ha. Di antara kecamatan-kecamatan yang ada di Pulau Tidore, Tidore Utara memiliki luas presentasi terbesar yaitu 892,48 ha. Dapat disimpulkan bahwa daerah dengan lereng yang curam dan bentuk lereng yang cembung atau cekung memiliki potensi longsor yang lebih tinggi. Temuan penelitian ini diharapkan dapat membantu pemerintah daerah dalam upaya perencanaan tata ruang di masa depan untuk mitigasi bencana longsor.

INTRODUCTION

According to data from the Indonesian Disaster Prone Index (Indeks Risiko Bencana Indonesia/IRBI), Tidore Island is known for its high potential for landslides in the North Maluku region (BNPB, 2022). Particularly during the rainy season, landslides frequently occur on the island. These natural disasters, which typically happen in mountainous or steep areas, are often triggered by heavy rainfall or earthquakes (Khalil et al., 2020; Somae et al., 2022). Tidore Island boasts a diverse topography, characterized by steep slopes and easily erodible soil. Such landslides can result in significant loss of life, damage to property and infrastructure, and have a lasting impact on the local economy (Comert et al., 2019; Safriani & Wibowo, 2022).

In order to prevent and reduce the risk of landslides, it is crucial to conduct a spatial analysis to identify areas prone to landslides on Tidore Island. Spatial analysis is a method used to study and map the spatial patterns and relationships of geographical phenomena (Ristya et al., 2019; Susetyo et al., 2022; Sugandhi et al., 2023). Geographic Information System is a very important tool to identify spatially and temporally potential landslide areas in Ambon City (Bhunia & Shit, 2022; Van Phong et al., 2022). One of the simplest and most accurate GIS methods to identify potential landslide areas is the slope morphology or SMORPH method (Ramdhoni et al., 2020). According to previous researchers, the SMORPH method is quite good and simple to help identify landslide potential in an area that only uses slope shape and slope slope variables obtained from Digital Elevation Model (DEM) data processing (Ramdhoni et al., 2020; Mufidawati et al., 2021)

In this study, the Slope Morphology method is employed for spatial analysis to identify potential landslide areas based on elevation data, such as slope inclination and slope shape. By conducting this analysis, local government and relevant organizations can develop effective strategies to mitigate the risks (Rakuasa et al., 2022; Muin & Rakuasa, 2023). These measures may include appropriate land-use regulations, implementation of soil conservation practices, monitoring rainfall, establishing early warning systems, and constructing infrastructure that can withstand landslides (Rahim et al., 2018; Firdaus, 2022; Pakniany et al., 2023).

Based on the background mentioned above, the objective of this study is to identify the areas on Tidore Island that are prone to landslides, using spatial analysis. The research findings are expected to provide a solid foundation for making informed decisions in order to prevent and minimize the impact of landslide disasters on the island. Ultimately, the aim is to ensure the safety and sustainability of the community on Tidore Island in the face of natural hazards.

METHOD

This research was conducted on Tidore Island, located in the North Maluku Province. The Slope Morphology (SMORPH) method was used to identify areas on Tidore Island that are prone to landslides, based on the variables of slope inclination and slope shape.

Slope Morphology method is a geospatial analysis method used to understand and identify the shape and characteristics of slopes or topography of an area (Sugandhi et al., 2023). The main objective of this method is to identify areas with potential risk of landslide based on the shape and slope. In the Slope Morphology method, topographic data or DEM data is used to map and analyze the slope morphology in the studied area (Saraswati et al., 2019)

The study utilized administrative boundary data of sub-districts and digital elevation data obtained from the Geospatial Information Agency. The data processing involved converting the DEM into slope inclination and slope shape using ArcGIS 10.8 software. The slope inclination was classified into six categories: 0-8%, 8-15%, 15-25%, 25-45%, 46-65%, and >65%, while the slope shape was classified into three categories: Concave, Flat, and Convex. The results of analyzing the slope inclination and slope shape data were then combined to determine the classes of landslide potential based on the SMORPH matrix presented in Table 1.

Table 1. SMORPH Matrix

Slope Shape	Slope Angel					
	0-8%	8-15%	15-25%	25-45%	46-65%	>65%
Concave	Very Low	Low	Low	Low	Low	Medium
Flat	Very Low	Low	Low	Low	Medium	High
Convex	Very Low	Low	Medium	High	High	High

Source: Ramdhoni et al. 2020; Somae et al. 2022

RESULT AND DISCUSSION

Slope Inclination

Slope inclination has a significant influence on landslide hazards (Triwahyuni et al., 2017; Susetyo et al., 2022). Steep slopes pose a higher risk of landslides due to the increased vulnerability of soil or rock stability on those slopes (Ristya et al., 2019; Asmare, 2022). Steep slope gradients impose greater load on the soil or rock. When this load exceeds the soil or rock's strength limit, it results in soil movement and potential landslides. The steeper the slope, the greater the pressure exerted on the soil or rock, thus increasing the likelihood of landslides (Permadi et al., 2019). According to Figure 1, slope inclination on Tidore Island is mainly represented by slopes ranging from 25-45%, covering an area of 3,210.06 hectares or 27.44%. This is followed by slopes with an inclination of 15-25%, which occupy an area of 2,586.92 hectares or 22.11%. Slopes with an inclination of 8-15% cover 2,043.24 hectares or 17.46% of the land. Slopes ranging from 45-65% account for 1,799.60 hectares or 15.38%. Areas with slopes of 0-8% cover 1,126.55 hectares or 9.63%, while slopes exceeding 65% make up 932.92 hectares or 7.97% of the total area.

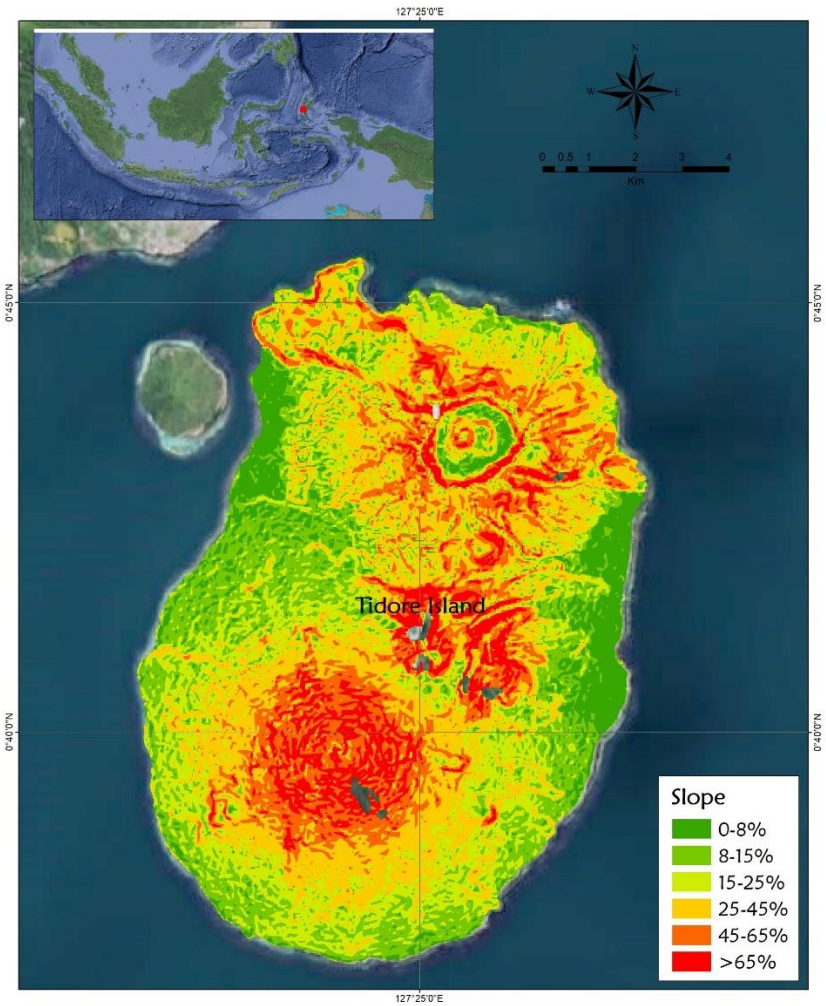

Figure 1. Slope Inclination

Slope Shape

The shape of slopes is a crucial factor that influences slope stability and the potential for landslides on Tidore Island. Slope shape refers to the visual appearance of a slope in a given sequence (Ramdhoni et al., 2020). Typically, a slope consists of different sections, including the summit, convex areas, concave areas, and footslope (Triwahyuni et al., 2017). he summit area is the highest point prone to erosion, while the middle part of the slope, which can be either convex or concave, often experiences significant surface runoff erosion. The footslope area is where sediment deposition occurs (Harist et al., 2018). On Tidore Island, the slopes exhibit different shapes, including convex slopes covering an area of 1,673.96 hectares, flat slopes covering 8,370.03 hectares (71.38% of the total area), and concave land shapes covering 1,682.35 hectares (14.35% of the total area). The spatial distribution of slope shapes can be observed in Figure 2.

Landslide Potential Areas

The combination of slope shape and slope inclination results in the identification of potential landslide areas. Using the SMORPH method, landslide potential is categorized into four classes: very low, low, medium, and high. The research findings reveal that 21.83% of the study area is classified as having a high landslide potential, covering an area of 2,569.42 hectares. Areas with a medium landslide potential account for 28.01% of the area, totaling 3,296.99 hectares. Regions with a low landslide potential cover 40.59% of the area, spanning 4,778.46 hectares. Lastly, areas with a very low landslide potential encompass 9.57% of the total area, equivalent to 1,126.55 hectares within the study area.

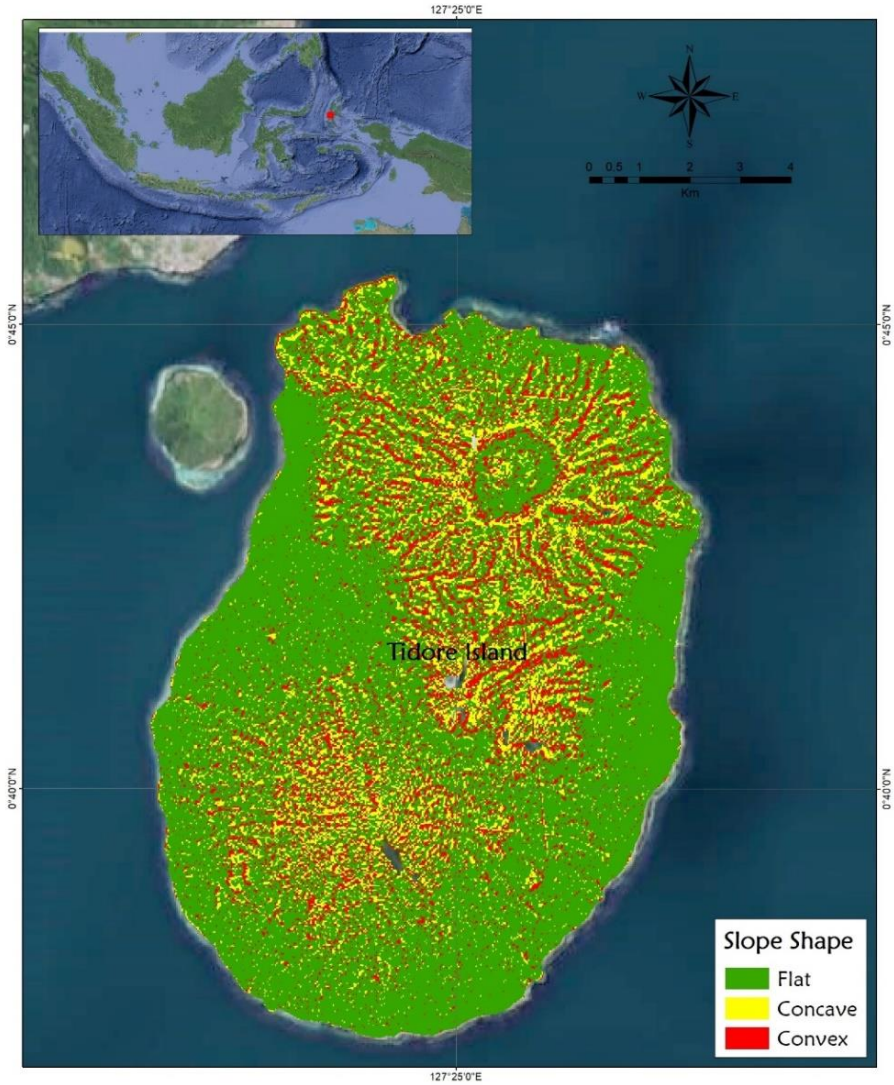

Figure 2. Slope Shape

Table 2. Potential Landslide Areas by Sub-district

Landslide Potential Class	Sub-district (ha)			
	Tidore	Tidore Selatan	Tidore Timur	Tidore Utara
Non Potential	282.51	62.32	276.47	505.26
Low Potential	951.93	1.047.34	876.46	1.902.73
Moderate Potential	608.99	592.08	1.020.73	1.075.20
High Potential	476.10	365.35	835.49	892.48

Based on Table 2 and Figure 2, it is evident that Tidore Utara Sub-district has the highest percentage of land area compared to other sub-districts on Tidore Island in each landslide potential category. Tidore Utara Sub-district is predominantly characterized by a low landslide potential class, covering an area of 1,902.73 hectares. Tidore Timur Sub-district is mostly classified as a moderate landslide potential class, spanning an area of 1,020.73 hectares. Similarly, Tidore Selatan Sub-district and Tidore Sub-district are mainly characterized by a moderate landslide potential class, covering areas of 1,047.34 hectares and 951.93 hectares, respectively.

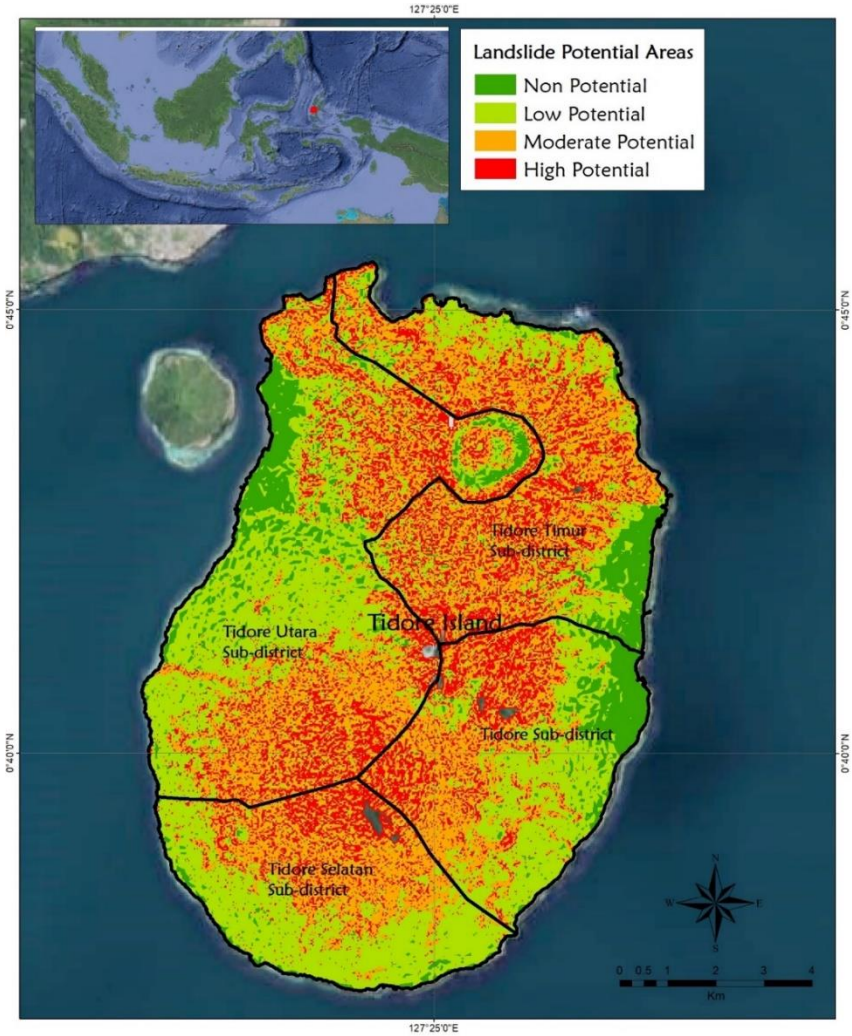

Figure 3. Landslide Prone Areas on Tidore Island

In simpler terms, the spatial analysis using the SMORPH method shows a direct relationship with the characteristics of the research location. Areas with steep slopes and concave or convex slope shapes are highly prone to landslides. This finding aligns with previous studies, which have demonstrated that steep slopes accompanied by concave or convex slope shapes increase the likelihood of landslides in those areas. On the other hand,

areas with smaller slope gradients and relatively flat slopes have a lower landslide potential (Harist et al., 2018; Rakuasa & Rifai, 2021; Rakuasa et al., 2022; Somae et al., 2022)

The findings of this research contribute to a better understanding of landslide-prone areas on Tidore Island. Through spatial analysis and geographic data, the study successfully generates clear maps highlighting high-risk regions. This information holds significant value for regional development planning, infrastructure location decisions, and disaster mitigation strategies (Fan et al., 2019; Sarkar & Dorji, 2019) Ultimately, the research outcomes provide a solid foundation for effective disaster risk reduction planning on Tidore Island. By identifying landslide-prone areas and analyzing the influencing factors, the study aids in the identification of practical strategies and actions to minimize the risks (Latue et al., 2023). For instance, recommendations may include implementing proper slope management, enhancing drainage systems, selecting suitable building materials, and regulating land use practices accordingly (Manakane et al., 2023).

The weakness of using the SMORPH method in this study is that it only relies on topographic data from the shape of the slope (concave, planar, or convex) and its gradient. It is expected that future researchers can add other variables such as land use, rainfall, soil type and others or can combine this method with other methods to get better results.

The findings of this study hold great potential to increase awareness among the local community and government about the risks of landslides on Tidore Island. By making the research results accessible to the public, educational initiatives can be undertaken to inform people about the dangers of landslides and the necessary preventive measures. Furthermore, this information can serve as a valuable guide for the government and relevant organizations in implementing more effective policies and mitigation programs. In this way, the study can make a significant contribution to the management of landslide risks, community protection, and sustainable development on Tidore Island.

CONCLUSION

Tidore Utara Sub-district stands out among other sub-districts on Tidore Island as having the highest percentage of land area prone to landslides across various categories. Tidore Island features a diverse landscape with different slope shapes and gradients, and landslides primarily occur on concave and convex slopes. The terrain is characterized by hills and mountains with steep slopes. The findings from the SMORPH method clearly indicate that steeper slopes accompanied by concave or convex shapes increase the likelihood of landslides in those specific regions. These research results are expected to provide valuable assistance to the local government in their future efforts to mitigate landslide disasters and to guide them in spatial planning that prioritizes disaster mitigation measures.

REFERENCES

Asmare, D. (2022). Landslide hazard zonation and evaluation around Debre Markos town, NW Ethiopia—a GIS-based bivariate statistical approach. *Scientific African*, *15*, e01129. https://doi.org/10.1016/j.sciaf.2022.e01129.

Bhunia, G. S., & Shit, P. K. (2022). *Geospatial Technology for Multi-hazard Risk Assessment*, 1–18. https://doi.org/10.1007/978-3-030-75197-5_1.

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

Comert, R., Avdan, U., Gorum, T., & Nefeslioglu, H. A. (2019). Mapping of shallow landslides with object-based image analysis from unmanned aerial vehicle data. *Engineering Geology*, 260 (July), 105264. https://doi.org/10.1016/j.enggeo.2019.105264.

Fan, R. L., Zhang, L. M., & Shen, P. (2019). Evaluating volume of coseismic landslide clusters by flow direction-based partitioning. *Engineering Geology*, 260 (March), 105238. https://doi.org/10.1016/j.enggeo.2019.105238.

Firdaus, H. S. (2022). Pengaruh Perubahan Curah Hujan dan Perubahan Tutupan Lahan terhadap Bencana Longsor berdasarkan Analisis Spasial. *Jurnal Riset Perencanaan Wilayah Dan Kota*, *1*(2), 159–166. https://doi.org/10.29313/jrpwk.v1i2.480.

Harist, M. C., Afif, H. A., Putri, D. N., & Shidiq, I. P. A. (2018). GIS modelling based on slope and morphology for landslide

potential area in Wonosobo, Central Java. *MATEC Web of Conferences*, 229, 03004. https://doi.org/10.1051/matecconf/201822903004.

Khalil, S., Baja, B., Azikin, S. H., & Alimuddin, A. (2020). Typology of Spatial Based Landslide Disaster Control in Parepare City South Sulawesi. *International Journal of Advanced Research in Engineering and Technology*, 11(10), 123–138. https://doi.org/10.34218/IJARET.11.10.2020.012.

Latue, P. C., Sihasale, D. A., & Rakuasa, H. (2023). Pemetaan Daerah Potensi Longsor di Kecamatan Leihitu Barat, Kabupaten Maluku Tengah, Menggunakan Metode Slope Morphology (SMORPH). *INSOLOGI: Jurnal Sains dan Teknologi*, *2*(3), 486–495. https://doi.org/10.55123/insologi.v2i3.1912.

Manakane, S. E., Latue, P. C., & Rakuasa, H. (2023). Identifikasi Daerah Rawan Longsor Di DAS Wai Batu Gajah, Kota Ambon Menggunakan Metode Slope Morphology Dan Indeks Storie. *Gudang Jurnal Multidisiplin Ilmu*, 1(1), 29–36.

Mufidawati, H., Damayanti, A., & Supriatna. (2021). Vegetative conservation for landslide mitigation in bungaya sub-district, gowa regency, south sulawesi province. *IOP Conference Series: Earth and Environmental Science*, *683*(1), 012064. https://doi.org/10.1088/1755-1315/683/1/012064.

Muin, A., & Rakuasa, H. (2023). Spatial Analysis of Landslide Potential Using Modification of the Storie In-dex Method in the Wae Batu Gajah Watershed, Ambon City, Indonesia. *International Journal of Scientific Multidisciplinary Research*, *1*(3), 107–116. https://doi.org/10.55927/ijsmr.v1i3.3625.

Pakniany, Y., Latue, P. C., & Rakuasa, H. (2023). Pemetaan Daerah Rawan Longsor di Kecamatan Damer, Kabupaten Maluku Barat Daya, Provinsi Maluku. *Jurnal Altifani Penelitian Dan Pengabdian Kepada Masyarakat*, *3*(2), 235–242. https://doi.org/10.25008/altifani.v3i2.367.

Permadi, M. G., Jamaludin, Parjono., & Sapsal, M. T. (2019). Implementation of the SMORPH method for mapping the susceptibility area of landslide in Bogor City. *IOP Conference Series: Earth and Environmental Science*, 343(1), 12195. https://doi.org/10.1088/1755-1315/343/1/012195.

Rahim, I., Ali, S. M., & Aslam, M. (2018). GIS Based Landslide Susceptibility Mapping With Application of Analytical Hierarchy Process in District Ghizer, Gligit Baltistan Pakistan. *Geoscience and Environment Protection*, 6(5), 34–49.

Rakuasa, H., Supriatna, S., Tambunan., M,P., Salakory, M., & Pinoa, W, S. (2022). Analisis Spasial Daerah Potensi Rawan Longsor di Kota Ambon Dengan Menggunakan Metode SMORPH. *Jurnal Tanah dan Sumberdaya Lahan*, 9(2), 213–221. https://doi.org/10.21776/ub.jtsl.2022.009.2.2.

Rakuasa, H., & Rifai, A. (2021). Pemetaan Kerentanan Bencana Tanah Longsor Berbasis Sistem Informasi Geografis Di Kota Ambon. In BIG (Ed.), *Prosiding Seminar Nasional Geomatika* (pp. 327–336). BIG & MAPIN. http://dx.doi.org/10.24895/SNG.2020.0-0.1148.

Ramdhoni, F., Damayanti, A., & Indra, T. L. (2020). Smorph application for landslide identification in Kebumen Regency. *IOP Conference Series: Earth and Environmental Science*, 451(1), 012013. https://doi.org/10.1088/1755-1315/451/1/012013.

Ristya, Y., Supriatna., & Sobirin. (2019). Spatial pattern of landslide potensial area by SMORPH, INDEX STORIE and SINMAP method In Pelabuhanratu and surrounding area, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 338(1), 12033. https://doi.org/10.1088/1755-1315/338/1/012033.

Safriani, E. W., & Wibowo, Y. A. (2022). Preparedness and Adaptive Capacity of Students for Landslide Disasters in Karangkobar, Central Java, Indonesia. *KnE Social Sciences*. https://doi.org/10.18502/kss.v7i5.10536.

Saraswati, R., Harist, M. C., Putri, D. N., Afif, H. A., Wibowo, A., & Ash-Shidiq, I. P. (2019). Risk level of landslide disaster in Wonosobo. *IOP Conference Series: Earth and Environmental Science*, 311(1),

12025. https://doi.org/10.1088/1755-1315/311/1/012025.

Sarkar, R., & Dorji, K. (2019). Determination of the Probabilities of Landslide Events—A Case Study of Bhutan. *Hydrology*, *6*(2), 52. https://doi.org/10.3390/hydrology6020052.

Somae, G., Supriatna, S., Manessa, M. D. M., & Rakuasa, H. (2022). SMORPH Application for Analysis of Landslide Prone Areas in Sirimau District, Ambon City. *Social, Humanities, and Educational Studies (SHES): Conference Series*, 5(4), 11. https://doi.org/10.20961/shes.v5i4.68936.

Sugandhi, N., Supriatna, S., & Rakuasa, H. (2023). Identification of Landslide Prone Areas Using Slope Morphology Method in South Leitimur District, Ambon City. *Jambura Geoscience Review*, 5(1), 12–21. https://doi.org/https://doi.org/10.34312/jgeosrev.v5i1.14810.

Susetyo, J. A., Kurnianto, F. A., Nurdin, E. A., & Pangastuti, E. I. (2022). Landslide Disaster Mapping in Silo District, Jember Regency. *IOP Conference Series: Earth and Environmental Science*, 975(1), 12011. https://doi.org/10.1088/1755-1315/975/1/012011.

Triwahyuni, L., Sobirin, S., & Saraswati, R. (2017). Analisis Spasial Wilayah Potensi Longsor dengan Metode SINMAP dan SMORPH di Kabupaten Kulon Progo, Daerah Istimewa Yogyakarta. *Prosiding Industrial Research Workshop and National Seminar*, 69–76. https://doi.org/10.35313/irwns.v8i3.701.

Van Phong, T., Dam, N. D., Trinh, P. T., Van Dung, N., Hieu, N., Tran, C. Q., Van, T. D., Nguyen, Q. C., Prakash, I., & Pham, B. T. (2022). *GIS-Based Logistic Regression Application for Landslide Susceptibility Mapping in Son La Hydropower Reservoir Basin* (pp. 1841–1849). https://doi.org/10.1007/978-981-16-7160-9_186.