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Identification of Landslide Prone Areas Using Slope Morphology Method in South Leitimur District, Ambon City

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ABSTRACT

South Leitimur District is one of the districts in Ambon City where landslides often occur, and this disaster causes many losses. One of the mitigation efforts is mapping areas with the potential for landslides to determine their distribution and risks. This study aims to apply the slope morphology method to identify landslide-prone areas in South Leitimur Regency. This study uses a Digital Elevation Model (DEM) extracted into the shape of slopes and slopes and processed using ArcGIS 10.8 software. This study uses the slope morphology method or SMORPH to identify and classify areas with potential landslides based on the matrix between the slope's shape and angle. The results of the study were classified into four classes of landslide potential, namely very low potential with an area of 2,489, 53 ha, low with an area of 3,278, 22 ha, medium with an area of 672, 32 ha, and high with an area of 685, 67 ha. Hutumury Village is a village that has the largest landslide potential area in each class of landslide potential in the South Leitimur District; this is because this village is a village that has the most significant area compared to other villages. The village that has a low landslide potential is Ema Village. The results of this study also illustrate that the higher the slope with convex or concave slopes, the higher the potential for landslides. The results of this study are expected to help the government of South Leitimur Regency in efforts to mitigate landslides in the future.

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1. INTRODUCTION

Landslides are natural disasters usually occurring in mountainous areas (Safriani & Wibowo, 2022). Landslides are the movement of mass soil, rock, or material sliding down a slope (Triwahyuni et al., 2017). Landslide is the downslope movement of rock or soil or both that occurs on collapse surfaces, both rotational slides and planar (translational slides), where most of the material often moves as a coherent or semi-coherent mass (Afif et al., 2019). Zhou et al. (2022) argue that landslides are the movement of masses of soil, rock, or material that falls down a slope. Landslide disasters that often occur in Indonesia have caused severe environmental damage and claimed many lives (BNPB, 2021).

Landslide disasters can be caused by two factors, namely natural factors in the form of rainfall (Salunkhe et al., 2022), slope and soil conditions (Paronuzzi et al., 2022), and human factors (Skilodimou et al., 2018) in the form of land use that pays little attention to the physical condition of the area (Khalil et al., 2020). Apart from natural factors, landslides can also be caused by human activities that affect the landscape, such as agricultural activities, slope loading, and mining

(Persichillo et al., 2018; Nguyen et al., 2022). The danger of landslides in the South Leitimur District from time to time has increasingly threatened the lives of residents who live on mountain slopes (Aditian et al., 2018).

Based on the actual monthly disaster data and information for Ambon City in 2021, the floods and landslides that occurred in Ambon City on July 11, 2021, were caused by high-intensity rain and swift river flows which caused landslides and floods on Sunday, July 11, 2021, at 04.00 WIT. The floods and landslides hit nine villages, five sub-districts, and five sub-districts, including South Leitimur District. They recorded as many as 969 people were affected by the floods and landslides in Ambon City, 212 houses were threatened with landslides, 180 homes were flooded, 132 houses were damaged, moderately damaged, one church unit was affected by flooding, two educational facilities units affected and one sports facility affected (BPBD Kota Ambon, 2021).

Hazard and risk assessment for Ambon City using landslide inventory and geographic information system which divides Ambon City into four landslide hazard zones, namely very high (critical) zone with an area of 51.77 ha (14.46%), high (unstable) 168.72 ha (47.12%), moderately (unstable) with an area of 108.48 ha (30.30%), and low hazard zone (stable) with an area of 29.08 ha (8.12%) (Rakuasa et al., 2022). Rakuasa & Rifai (2021) also researched mapping landslide vulnerability based on geographic information systems in Ambon City. The results of their research divided Ambon City into three landslide vulnerability zones: low landslide zone, which has an area of ± 5,957.67 ha (17.81%). The moderate landslide zone has an area of ± 18,584.59 ha (17.81%), and the high landslide zone has an area of ± 8,900.11 ha (26.61%).

Identifying and mapping landslide-prone areas are essential in mitigating future landslide disasters (Hamida & Widyasamratri, 2019). The Geographic Information System is a tool that plays an essential role in identifying potential landslide areas spatially and temporally in Ambon City (Bhunia & Shit, 2022; Van Phong et al., 2022). One of the simplest and most accurate GIS methods for identifying potential landslide areas is the slope morphology or SMORPH method (Ramdhoni et al., 2020; Mufidawati et al., 2021). According to previous researchers, the SMORPH method is quite excellent and straightforward in helping identify the potential for landslides in an area that only uses slope shape and slope variables obtained from Digital Elevation Model (DEM) data processing (Ristya et al., 2019; Saraswati et al., 2019; Ramdhoni et al., 2020; Rakuasa et al., 2022; Somae et al., 2022). According to Wang et al. (2017), using the SMORPH method will provide a reasonably good representation of landslide potential compared to other methods, such as the Storie Index or Stability Index Mapping (SINMAP). In the SMORPH method, the variable shape of the slope and slope is used based on the Digital Elevation Model (DEM) so that this data can better analyze the potential for landslides (Rahim et al., 2018). Of the several other methods, the SMORPH method is suitable for implementing geographic information system-based rasters because it is computationally simple (Hoyt & William, 2008; Asmare, 2022).

The multiple research locations with various regional features from earlier studies show what is new in this research. The South Leitimur District in Ambon City, prone to landslides, was the region under study. This is the first research to look at landslide-prone locations in Ambon City utilizing the slope morphology or SMORPH approach. Therefore the results of this study can provide a spatial description of landslide-prone areas in South Leitimur District so that preventive steps can be taken to reduce risk, and the results of this study will be recommended to the government or stakeholders in the area in facilitating decision making policies and regulations related to spatial planning based on future disaster mitigation.

This research used the slope morphology or SMORPH method, which has a better accuracy rate than the Storie Index and SINMAP methods for identifying and classifying potential landslide areas based on a matrix between slope shape and slope angle (Harist et al., 2018; Mufidawati et al., 2021). Compared to the Transient Rainfall Infiltration and Grid-based Regional Slope Stability method or TRIGRS, the SMORPH method is straightforward to apply to identify potential landslide areas. In contrast to the TRIGRS method, which is entirely conditional where to predict ground motion, it must be influenced by the resolution of temporal rainfall variations, the resolution of geotechnical parameters spatially, and the resolution of digital elevation models (Sugianti et al., 2016). According to Triwahyuni et al. (2017), the SMORPH method has the advantage of very good accuracy compared to other methods.

Based on this background, it is necessary to carry out a disaster mitigation effort by identifying potential areas for landslides in Leitimur Selatan District, and it is hoped that this can be used to minimize the danger and losses from future landslide disasters. This study aims to identify areas prone to landslides using the Slope Morphology method.

2. METHOD

This type of research is quantitative descriptive using the Slope Morphology (SMORPH) method, which is a spatial analysis method with a Geographic Information System approach to predict the potential for landslide-prone areas in an area using parameters referring to geomorphological parameters in the form of slope shapes such as concave, planar or convex, and slope gradient (Shaw & Johnson, 1995; Ramdhoni et al., 2020). The choice of the SMORPH method for this research is because this method is straightforward to predict the potential for landslide-prone areas in South Leitimur District as well as the geographical and topographical conditions of South Leitimur District, which are hilly and mountainous and have varying slopes making this method very effective and efficient when applied.

The materials used in this research included administrative maps of South Leitimur District, scale 1:50,000 - BAPEKOT Ambon, Indonesian Topographical Map (RBI) of Ambon City, scale 1:50,000 - Geospatial Information Agency, National DEM data for Ambon City Sheets 2612-23 and Sheets 2612 -24 - Geospatial Information Agency. The DEMNAS data used in this study has a spatial resolution of 0.27 arc seconds or about 8 meters, using the EGM 2008 vertical datum, which is certainly much better when compared to using other DEM data such as the SRTM DEM which has a spatial resolution of 3 arc seconds or around 90 meters, DEM SRTM with a spatial resolution of 1 arc second or about 30 meters and, DEM ALOS-PALSAR with a resolution of 12.5 meters (Julzarika & Harintaka, 2019).

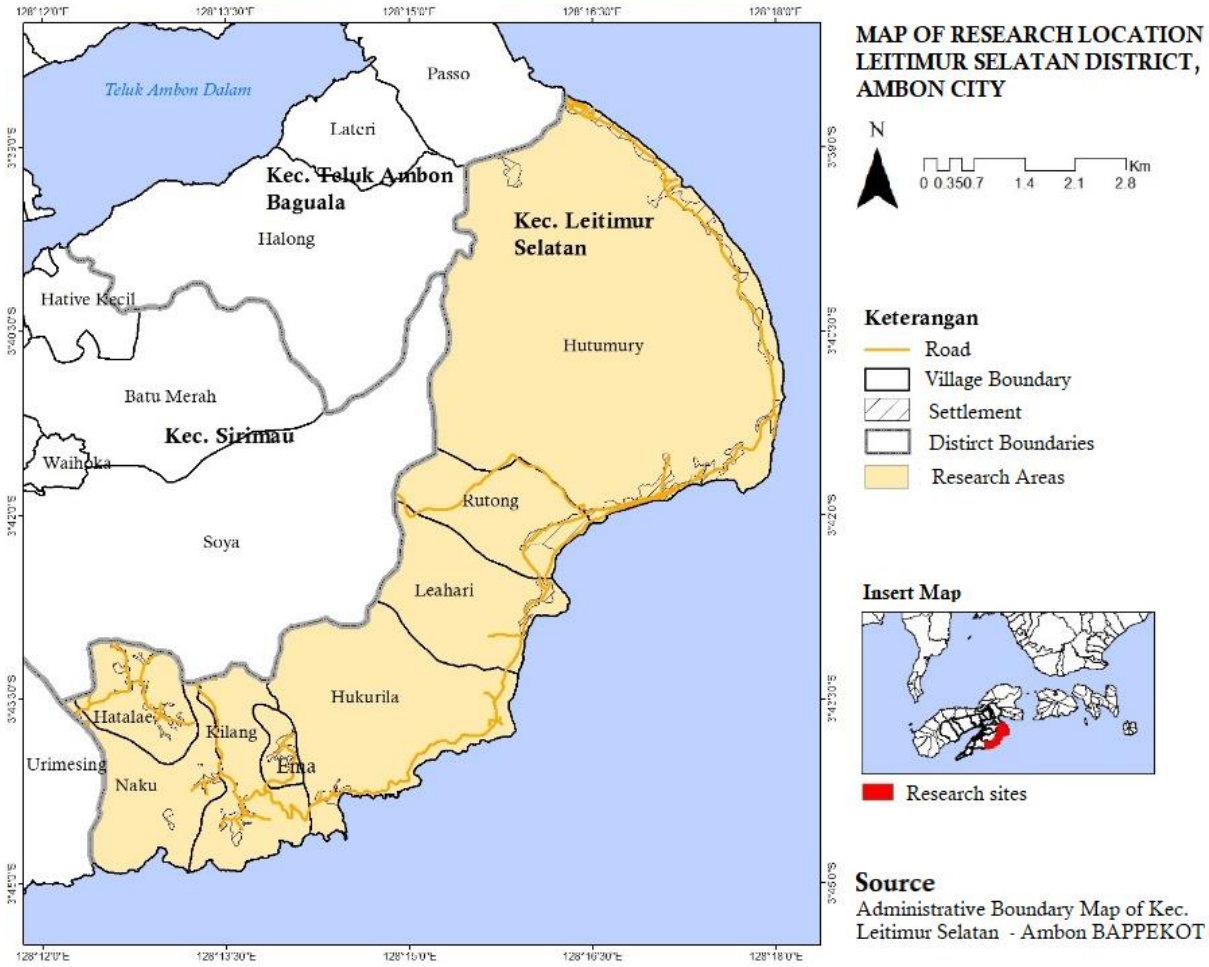

Figure 1. Research location

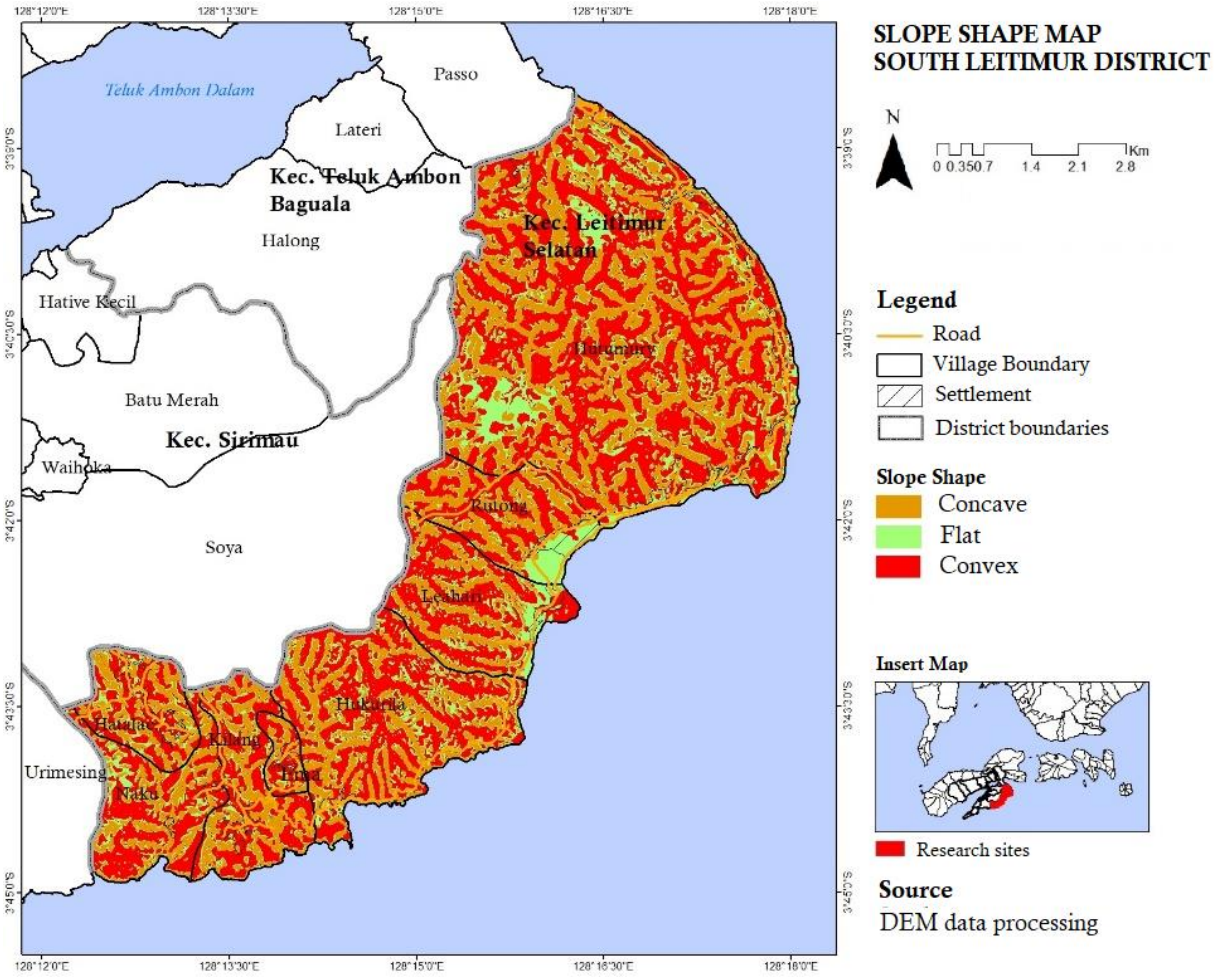

Figure 2. Slope shape map

The tool used for processing and analyzing data in this study is Microsoft Office software, ArcGIS 10.8. This research was conducted in South Leitimur District, Ambon City, Maluku Province. Administratively, South Leitimur District consists of 8 villages, including Ema Village, Hatalae Village, Hukurila Village, Hutumury Village, Leahari Village, Naku Village, Rutong Village, and Kilang Village. Spatial research locations can be seen in Figure 1.

The processing of data on potential landslide-prone areas uses Digital Elevation Model (DEM) data, which is extracted into the slope and the slope's shape. DEM data is processed using ArcGIS 10.8 software using tools in the form of slope to produce slope data (in %). The next step is to process the slope shape data. This processing uses tools in the form of curvature to create slope

Table 1. Slope and slope shape variable classification

Variable	Classification	Area (ha)	Percentage (%)
Slope	0 – 8%	1666,23	35,07
	8 – 15%	1218,13	25,64
	15 – 25%	947,93	19,95
	25 – 45%	704,80	14,83
	45 – 65%	166,18	3,50
	>65%	47,70	1,00
	Total	4750,98	100,00
Slope shape	Concave	1756,60	36,97
	Flat	649,44	13,67
	Convex	2344,93	49,36
	Total	4750,98	100

Source: Data Processing Results 2022

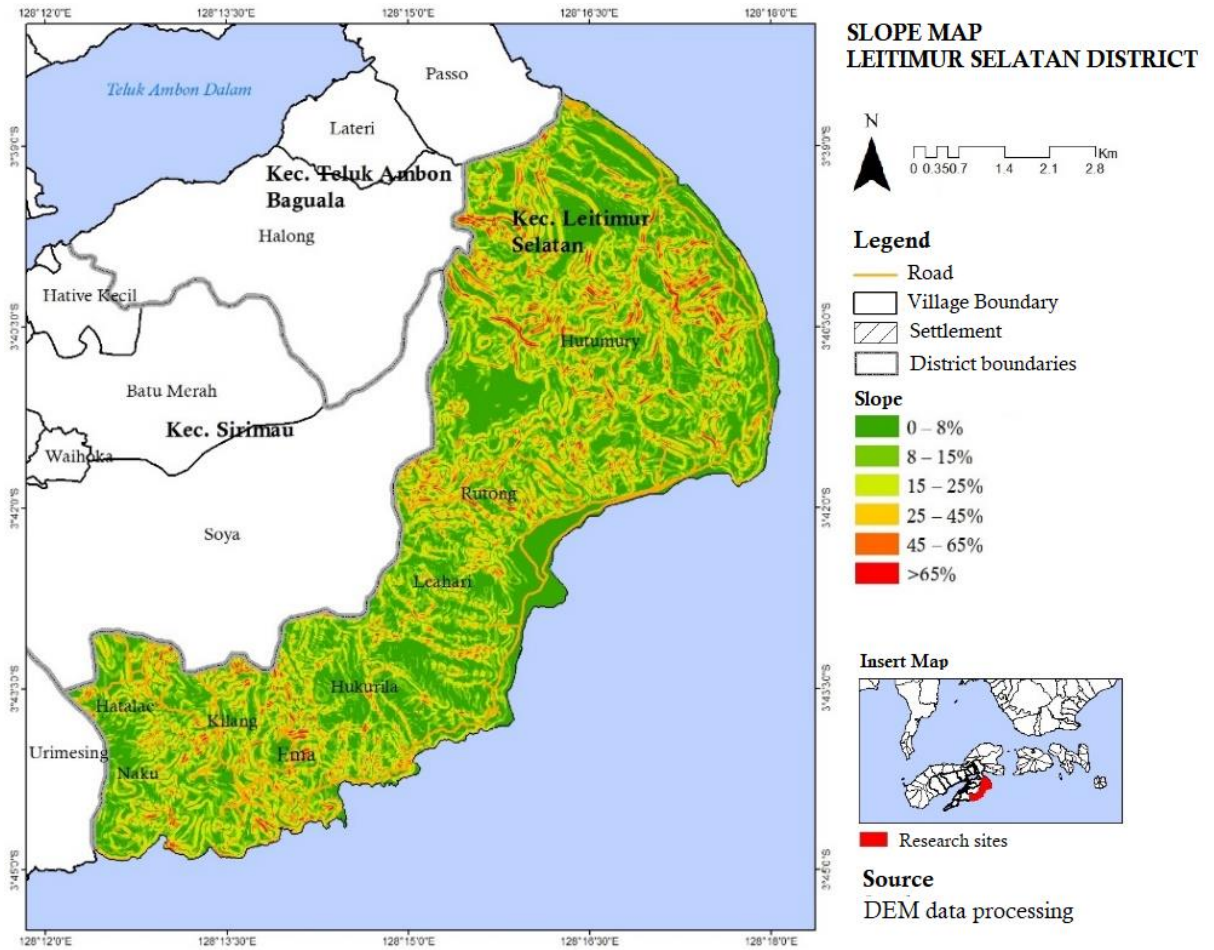

Figure 3. Slope map

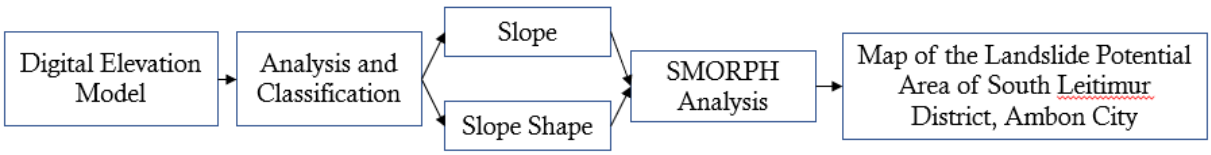

Figure 4. Workflow

shapes. The classification of slope and slope shape variables is based on the research of Ramdhoni et al. (2020). Spatially the variable classification of slope and shape of the slope can be seen in Figure 2, and tabularly can be seen in Table 1.

The slope shape at the research location can be seen in Figure 2, which is dominated by convex slopes with an area presentation of 49.36% or an area of 2344.93 ha. The shape of the concave slope has an area of 1756.60 ha or 36.97%, and a flat slope has an area of 649.44 ha or 13.67% of the total research area. Details can be seen in Table 1. Based on the processing of the slope variable, which can be seen In Figure 3, it is known that the 0-8% slope class dominates the study area with an area percentage of 35.07%, followed by the 8-15% slope class with an area percentage of 25.64% or an area of 1,218.13 ha and the slope class > 65% only has an area of 47.70 ha or only 1% of the total area of South Leitimur District, in full, can be seen in Table 1.

Table 2. SMORPH matrix

Slope shape	Slope angle (%)					
	0-8%	8-15%	15-25%	25-45%	45-65%	>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: Triwahyuni et al. (2017); Ramdhoni et al. (2020)

In more detail, the workflow of this research can be seen in Figure 4, where the results of data processing of the slope and slope shape will be overlaid to determine the class of landslide potential in the South Leitimur District. The landslide potential class is determined based on the SMORPH matrix developed by Shaw & Johnson (1995) and has been widely used by previous researchers Triwahyuni et al. (2017) and Ramdhoni et al. (2020). For more details, the SMORPH matrix can be seen in Table 2.

3. RESULT AND DISCUSSION

After the slope and slope shape data are overlaid based on Table 2 (SMORPH Matrix), analysis and classification of potential landslide areas in South Leitimur District are carried out into four classes, including very low, low, medium, and high. Spatially, the landslide potential area can be seen in Figure 5. Based on Figure 5 and Table 3, it is known that the distribution of landslide potential areas in Leitimur Selatan District is dominated by low landslide potential with an area of 3278.22 ha, followed by very low potential class with an area of 2489.53 ha, high landslide potential has an area of 685.67 ha and for areas and moderate landslide potential has an area of 672.32 ha. The village with the broadest area in the very low landslide potential class is Hutumury Village, with an area of 466.97 ha or 66.93%, and the village with the smallest area is Ema Village, with an area of 8.95 ha or 15.09%. In the low landslide potential class, the village with the most significant area is Hutumury Village, with an area of 2,173.36 ha or 66.30%, and vice versa Ema Village has an area of 30.39 or 0.93%. For the medium landslide potential class, Hutumury Village has the widest area, 444.42 ha or 66.10%, whereas Ema Village only has an area of 7.37 ha or 1.10%. For the high landslide potential class, Hutumury Village has an area of 466.97 ha or 68.10%, followed by Hukurila Village, which has an area of 56.60 ha or 8.25%, and Ema Village only has an area of 7.08 ha or 1.03%.

The results of observations at the study site show that the landslides are spatially in areas with high landslide potential and are very close to residential areas, which are topographically under the slopes of a mountain. The landslide that occurred in South Leitimur District also caused damage to public infrastructure such as roads which spatially can be seen that the roads are located on the

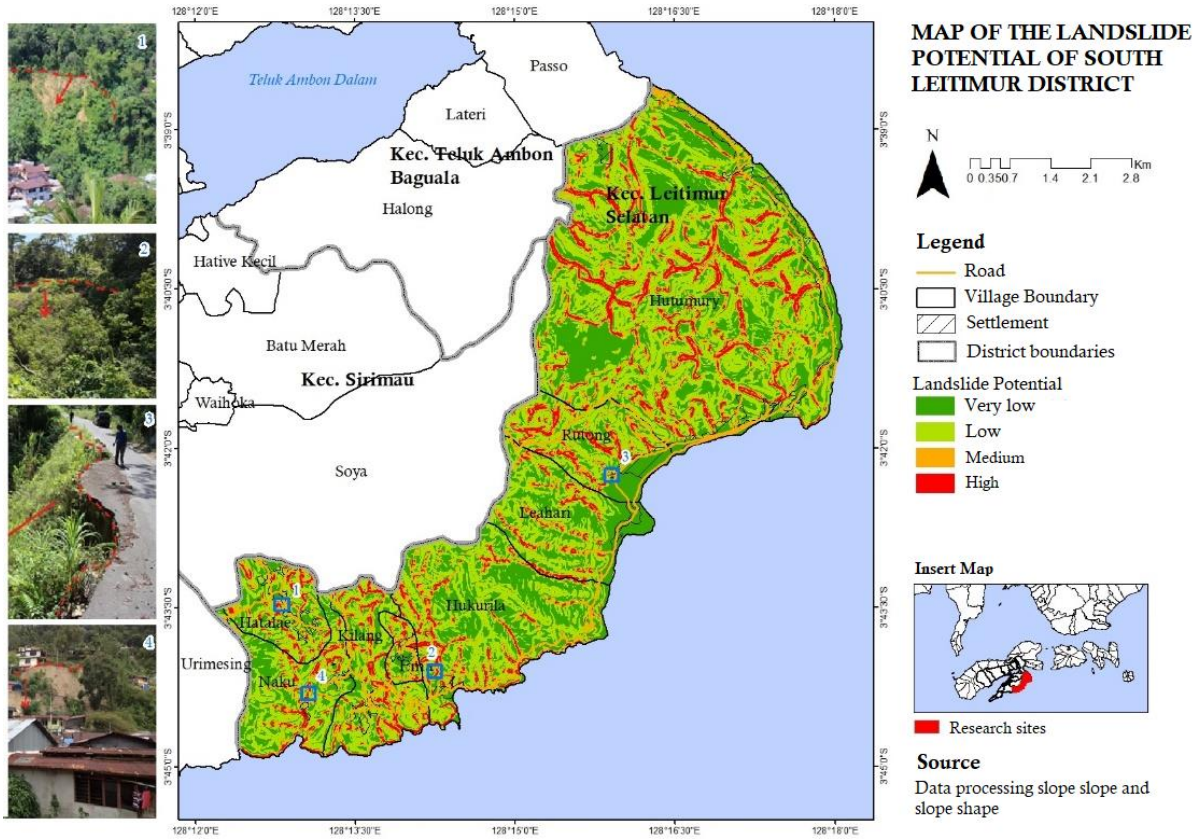

Figure 5. Landslide potential map of South Leitimur District

Table 3. Landslide potential area per village in South Leitimur District

Village	Landslide potential class area of SMORPH							
	Very Low		Low		Medium		High	
	ha	%	ha	%	ha	%	ha	%
Ema	15,09	0,64	30,39	0,93	7,37	1,10	7,08	1,03
Hatalae	67,50	2,71	111,51	3,40	24,05	3,58	21,30	3,11
Hukurila	277,26	11,14	332,09	10,13	64,31	9,56	56,60	8,25
Hutumury	1666,23	66,93	2173,36	66,30	444,42	66,10	466,97	68,10
Leahari	170,73	6,86	163,56	4,99	31,97	4,75	25,68	3,74
Naku	110,80	4,45	162,64	4,96	30,11	4,48	28,58	4,17
Rutong	105,37	4,23	147,25	4,49	34,97	5,20	37,61	5,48
Kilang	75,77	3,04	157,42	4,80	35,13	5,23	41,87	6,11
Total	2489,53	100	3.278,22	100	672,32	100	685,67	100

outskirts of steep slopes and have the potential for landslides to occur at any time. The landslide that occurred in South Leitimur District impacted road access in the area, thereby disrupting the accessibility of residents around the landslide incident. In Figure 5, see the former avalanches that hit residents' houses, the actual conditions/findings in the field, and potential areas for landslides in South Leitimur District.

In simple terms, it can be concluded that the results of the spatial analysis using the SMORPH method are directly proportional to the conditions of the research location, where areas with steep slopes and concave and convex slopes have the potential for landslides to occur; the opinion of Rakuasa and Rifai supports this, in his research in Ambon City where the steep slope accompanied by the formation of convex or concave slopes will cause a higher potential for landslides in the area but vice versa if the slope is smaller. The slope shape is relatively flat in the area, the smaller the potential for landslides.

Hutumury Village is a village that has the widest area in South Leitimur District and has a diverse topography. This village has the widest area in each class of potential landslides in the South Leitimur District. The villages in South Leitimur District are generally located in mountainous regions which are in very low and low class. Based on Figure 5 and Table 3, many landslides are found in areas with concave and convex slopes, flat slopes with the least number of landslides compared to flat and concave shapes. The central part of the slope, which is convex or concave, can result in relatively large erosion by surface runoff, thereby increasing the potential for higher landslides (Ramdhoni et al., 2020)

Based on the Ambon City disaster risk assessment documents for 2017-2021, it is explained that South Leitimur District is one of the sub-districts with a high level of landslide risk in Ambon City. The area's topography is hilly and mountainous, with steep slopes (BNPB, 2021). The study's results clearly explain the identification of the distribution of potential landslides in the South Leitimur District using the SMORPH method, which detects the distribution of potential landslides based on the slope and slope shape. The SMORPH method will provide a fairly good representation of landslide potential compared to other methods, such as the Storie Index or Stability Index Mapping (SINMAP). In the SMORPH method, the variable of slope shape and the slope is used, which is based on the Digital Elevation Model (DEM) so that this data can analyze the potential for landslides per pixel (Triwahyuni et al., 2017), while the Storie Index method is a semiquantitative method for rating (rating) soil based on general soil characteristics to determine land use potential and soil productivity capacity (Ramdhoni et al., 2020)

4. CONCLUSION

The application of the SMORPH method to identify the distribution of potential landslides in South Leitimur District is classified into four levels of landslide potential: very low, low, medium, and high. Areas with high landslide potential dominate the northern and southern parts of the South Leitimur District. In this area, most of the landslides occur as concave and convex slopes. Hutumury Village is a village that has the largest landslide potential area in each class of landslide potential in the South Leitimur District. This is because this village is a village that has the largest

site compared to other villages; on the other hand, the village that has a very low potential for landslides is Ema Village. The use of the SMORPH method in this study provides a relatively good representation of results in identifying potential landslides compared to other methods, such as the Storie Index or Stability Index Mapping (SINMAP). The application of the SMORPH method in this study illustrates that a higher slope accompanied by a convex or concave slope shape will lead to a higher potential for landslides in the area. The research results are expected to help the Ambon City government and related agencies, especially the Leitimur Selatan District government, in future landslide disaster mitigation efforts and disaster mitigation-based spatial planning efforts. The results of this study are expected to be useful and become a reference for researchers who conduct similar research in the future. It is hoped that the SMORPH method can be integrated with other methods, such as the Storie Index, SINMAP, or the TRIGRS method, and additional parameters to analyze potential landslide areas more accurately in the future.

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