

IDENTIFICATION OF POTENTIAL LANDSLIDE AREAS IN NUSANIWE SUB-DISTRICT USING SLOPE MORPHOLOGY METHOD

Philia Christi Latue¹, Heinrich Rakuasa²

¹Universitas Pattimura

²National Research Tomsk State University, Russian Federation

heinrichrakuasa01@gmail.com²

Received: 30-06-2024

Revised: 18-07-2024

Approved: 28-07-2024

ABSTRACT

This study aims to identify landslide-prone areas in Nusaniwe District using the Slope Morphology Method (SMORPH), which is based on slope and slope shape analysis. The research method uses the Slope Morphology Method (SMORPH) to assess landslide potential in Nusaniwe District. The analysis was carried out by mapping the slope gradient and slope shape in the area to determine areas at high risk of landslides. Topographic and geological data were collected and analyzed to identify factors that contribute to landslide risk. The results of the analysis show that complex geological and topographic conditions in Nusaniwe District increase the risk of landslides. Areas with high slope gradients and steep slope shapes are identified as the most landslide-prone areas. This assessment revealed a significant relationship between slope gradient, slope shape, and landslide potential in the area. The conclusion is that the analysis of slope and slope shape using the Slope Morphology Method (SMORPH) is effective in identifying landslide-prone areas in Nusaniwe District. To reduce landslide risk, interdisciplinary collaboration, community education, and development of effective mitigation strategies are needed. These findings provide a basis for planning and implementing landslide prevention measures in areas with similar conditions.

Keywords: *Landslide, Nusaniwe, Slope Morphology*

INTRODUCTION

Landslides are one of the most serious natural disasters and can cause huge losses both in terms of human lives and significant environmental damage (Marzuki, 2022). In Indonesia, including in areas such as Maluku, landslides are not only a threat to daily life but also have extensive economic impacts (Rakuasa, 2022). Nusaniwe sub-district, located in the eastern part of Ambon City, is known to have complex geographical conditions with the presence of various soil types and diverse topography (Heinrich, 2022). This condition makes the area one of the most vulnerable to landslides (Rakuasa, et. al 2022). In addition, human activities such as infrastructure development and land use change also contribute to the increased risk of landslides (G. Somae, 2022). With a diverse topography, including slopes and unstable soil types, this area frequently experiences landslide events that can threaten the safety of residents as well as surrounding infrastructure (P. C. Latue., 2023). Therefore, it is important to identify potential landslide areas with appropriate methods to minimize the risk of such disasters.

In 2023, the National Disaster Management Agency (BNPB) noted that 121 houses and one school collapsed due to landslides that hit Nusaniwe Subdistrict, Ambon City, Maluku Province, this occurred after high-intensity rain accompanied by unstable soil structures in the surrounding area . The BNPB Operations Control Center (Pusdalops) noted that this event affected 35 families or 495 people in Latuhalat Village in Nusaniwe District. From the visual report, it can be seen that the landslide location is on

a fairly sloping area. Therefore, the landslide had an impact on residents' houses which suffered damage to the roof with mild to severe categories. This study was conducted in response to the need for more accurate and detailed information on potential landslide areas in Nusaniwe Sub-district. This information is crucial for the planning and implementation of effective landslide mitigation strategies (H. Rakuasa, 2023). With the identification of landslide potential areas, the government and community can take proactive measures to reduce the risk and impact of landslides.

One of the methods used in the identification of landslide potential is the Slope Morphology method (H. Latue, 2023). This method utilizes slope morphology to identify areas prone to landslides. The Slope Morphology method is based on the understanding of the relationship between slope morphology and the tendency of landslides (M. C. Harist, 2018). The Slope Morphology Method (SMORPH) is a relatively new approach in landslide analysis. It combines topographic data and slope morphology to detect areas most prone to landslides (H. Manakane, 2023). Slope Morphology (SMORPH) method is a spatial analysis method that uses Geographic Information System (GIS) approach to predict potential landslide prone areas based on geomorphological parameters such as slope shape (concave, planar, or convex) and slope slope (H. Sugandhi, 2023).

This method is considered effective and efficient in identifying potential landslide-prone areas in areas that have diverse geographical and topographical conditions, such as mountainous and hilly areas. SMORPH uses shape and slope variables based on Digital Elevation Model (DEM) data to better analyze landslide potential compared to other methods such as Storie Index or Stability Index Mapping (SINMAP) (Y. Ristya, et al 2019). This method provides a relatively good representation in identifying landslide potential compared to other methods. SMORPH provides a deeper understanding of how physical and geological factors affect landslide potential, which cannot always be detected through traditional methods (M. G. Permadi, 2019).

Although the Slope Morphology method is effective in identifying potential landslide areas, there are several challenges that need to be addressed. These include the complexity of local geologic and topographic conditions, as well as the limited data available for slope morphology analysis (R. Triwahyuni, L., 2017) This research aims to increase public awareness about landslide risk and the importance of mitigation. Community education on how to identify potential landslide areas and steps that can be taken to reduce the risk is an integral part of landslide mitigation efforts. In a global context, this study is also relevant as it helps in further understanding of landslide dynamics in tropical and humid climates, which are common conditions in Indonesia. This knowledge can be used to develop more effective mitigation strategies in other regions facing similar challenges. This research highlights the importance of collaboration between different disciplines, including geography, geology and civil engineering, in addressing landslide issues. This multidisciplinary approach is essential to produce a comprehensive and sustainable solution. Overall, the Identification of Landslide Potential Areas in Nusaniwe Sub-district using Slope Morphology Method is a significant contribution to the field of natural disaster research, particularly landslides, in Indonesia. This study shows that with the right approach and advanced technology, we can reduce the risk of landslides and better prepare the community to face such disasters.

RESEARCH METHODS

This research was conducted in Nusaniwe Sub-district, Ambon City, Maluku Province, Indonesia. This study used sub-district administrative boundary data obtained from the Ambon City Government Agency and National DEM data of Ambon City obtained from the Geospatial Information Agency. This research uses Sentinel 2 imagery to analyze built-up land in Nusaniwe Sub-district in 2024. This research uses the slope morphology or SMORPH method. The slope morphology method or SMORPH is a method of identifying landslide-prone areas that focuses on analyzing slope morphology [5]. SMORPH uses input parameters such as slope morphology and other factors to identify potential areas prone to landslides (Abdul Mui, 2023)

Table 1.
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

This research uses Arc GIS 10.8 software to analyze landslide potential in Nusaniwe Sub-district, Ambon City. National DEM data of Ambon City was then processed to produce slope data and slope shape data. The slope shape classification is classified into 3 forms namely concave slope shape with value <-0.1 , flat slope shape with value $-0.1 - 0.01$, and convex slope shape with value >0.01 . The slope is classified into 6 classes namely 0-8%, 8-15%, 15-25%, 25-45%, 45-65% and $>65\%$. The data of slope shape and slope slope were overlaid by referring to the SMORPH Matrix in table 1. The landslide potential area of Nusaniwe Sub-district was then overlaid with built-up land to obtain the built-up area affected by landslide. More details of the work can be seen in Figure 1.

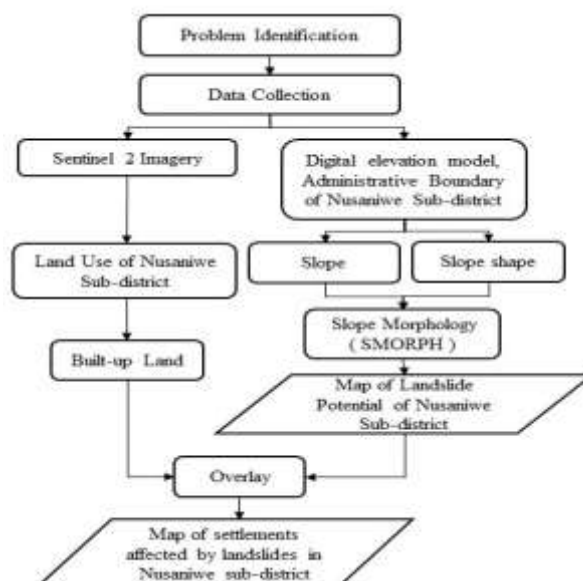


Figure 1. Workflow

RESULTS AND DISCUSSION

Slope

Slope slope is the angle between a flat plane (e.g., ground or surface) and a vertical line (F. Ramdhoni, 2020) It is measured in degrees and is used to describe how steep a slope is. A greater slope indicates that the slope is steeper, while a lower slope indicates that the slope is more gentle (N. Wang, 2017). The slope in Nusaniwe sub-district is classified into 6 classes consisting of 0-8% covering 12,531.76 ha or 38.49%, 8-15% slope covering 7,446.03 ha or 22.87%, 15-25% slope covering 5. 775.97 ha or 17.74%, slope 25-45% or 4,678.52 ha or 14.37%, slope 45-6% covering 1,427.58 ha or 4.38%, slope >65% covering 701, 76 ha or 2.16%. The relationship between slope and landslide potential is very close. Steep slope becomes one of the main factors of landslide, supported by the earth's gravity. Areas with slope more than 15% are considered prone to landslides (Hoyt, Et., al. 2008). Landslides often occur in places with steep slopes, such as mountains or hills, although some areas are covered by vegetation. Other factors affecting landslides besides slope and vegetation are the presence of impermeable layers or sliding planes, as well as differences in soil texture that can affect the speed and intensity of landslides.

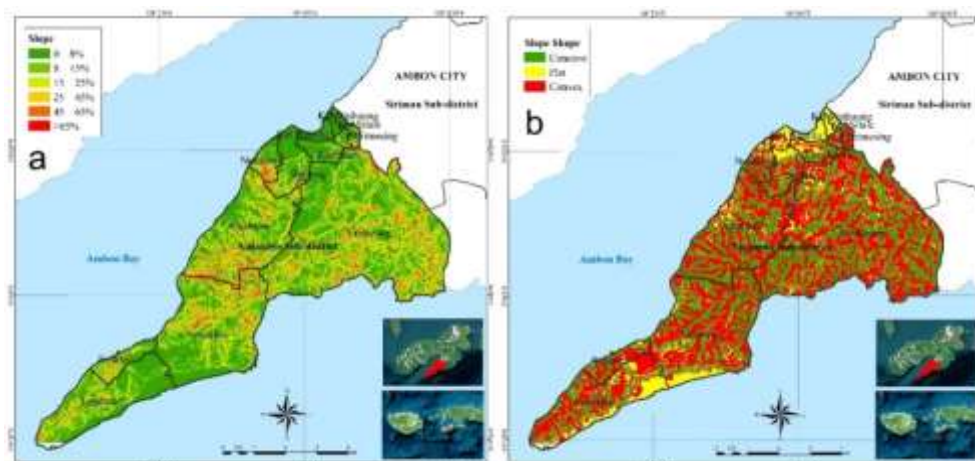


Figure 2. a. Slope Map, b. Slope Shape Map

Slope Shape

Slope shape is a physical characteristic of the earth's surface that shows the extent to which an area or region has a slope or steepness. This slope shape can consist of convex slope shape, flat slope shape, concave slope shape, depending on the geological process and surrounding environmental conditions. The results of the analysis of the slope shape of Nusaniwe sub-district show that the concave slope shape has an area of 11,224.61 ha or 34.47%, flat slope shape has an area of 5,698.37 ha or 17.50% and convex slope shape of 15,640.53 or 48.03%. Steep or convex slope shapes and high slopes increase the potential for landslides (H. R. Ferol Huwae, 2023). This is because a high slope can accelerate the flow of water and soil material, which in turn can cause landslides. In addition, the depth of the soil slide plane is also an important factor. Deeper slip planes can store more water and materials, which if given additional loads (such as from heavy rainfall), can cause landslides (H. Pakniany, 2023). More details of the slope shape map can be seen in Figure 2b.

Landslide Potential Areas

Landslide potential areas are areas that have certain physical and geological characteristics that make them susceptible to landslide events. Landslides occur when slope-forming material moves down or off the slope, which is a significant displacement of material and can be hazardous to life and property in the vicinity. The landslide potential class in Nusaniwe Sub-district is then classified into 5 classes consisting of very low class with an area of 1,867.12 ha or 39.86%, low landslide potential class has an area of 1,975.79 ha or 42.18%, medium landslide potential class has an area of 431.58 ha or 9.21%, high landslide potential class has an area of 409.51 ha or 8.74% of the total area of Nusaniwe sub-district.

The results of the analysis of landslide potential areas in Nusaniwe Sub-district were then overlaid with settlement distribution data to predict the distribution and extent of affected settlements. Landslide-affected settlements refer to residential areas or locations that are located in areas that have a high level of landslide vulnerability. This means that the area is located in a zone that has geological and topographical characteristics that make it vulnerable to landslide events. In the very low landslide potential class, settlements predicted to be affected by landslides cover an area of 746.90 ha or 70.93%. Low class is 230.63 ha or 21.90%, medium class is 51.65 ha or 4.90% and high class has a high area of 23.83 ha or 2.26%.

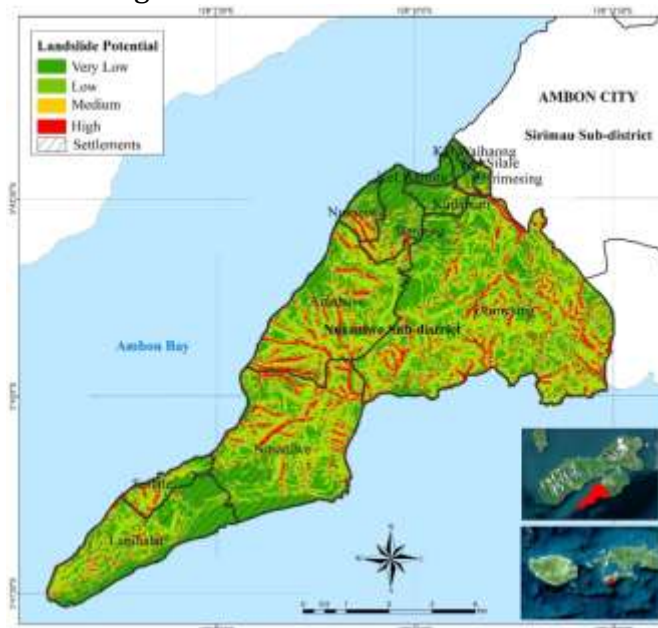


Figure 3. Map of landslide potential of Nusaniwe sub-district

Slope slope and slope shape have a close relationship with landslide potential in areas such as Nusaniwe Sub-district. High slopes and steep or unstable slope shapes tend to increase the risk of landslides. Strong gravity on slope-forming materials can cause displacement of these materials down or off the slope, which is the main characteristic of landslides. In addition, unstable or excessively steep slope shapes can affect soil stability, making it more prone to landslides, especially after intensive rainfall or climate change. In Nusaniwe sub-district, specific geological and topographical conditions can affect the distribution and frequency of landslides. Areas

with high slopes and steep or unstable slope shapes tend to be landslide hotspots. Therefore, a good understanding of the relationship between slope and slope shape with landslide potential is essential for disaster planning and mitigation in this area.

Based on the results of this research, it is necessary to mitigate landslides in Nusaniwe Sub-district which involves a series of actions designed to reduce the risk and impact of landslides. Based on information from the sources provided, some important steps that can be taken include:

- 1) **Risk Assessment and Inventory:** The first step is to conduct a risk assessment and inventory of potential landslide areas. This involves identifying areas with high slopes, steep or unstable slope forms, and soil types prone to landslides. Knowledge of the distribution and frequency of landslides in Nusaniwe Sub-district, as mentioned in the source, is essential to determine which areas require mitigation interventions.
- 2) **Infrastructure Development and Environmentally Friendly Development:** Avoiding development in areas with landslide potential and promoting environmentally friendly development is essential. This includes avoiding development on steep slopes and ensuring that existing infrastructure is safe and does not exacerbate landslide potential.
- 3) **Water and Erosion Management:** Managing water and reducing soil erosion are key in reducing landslide risk. This can involve applying techniques such as terracing, planting ground cover trees, and efficient irrigation systems to reduce excessive water flow and reduce erosion.
- 4) **Community Education and Awareness:** Raising public awareness about landslide risks and ways to reduce them is essential. This can involve education campaigns, training, and community dialog to ensure that all community members understand the risks and the actions they can take to reduce the risks.
- 5) **Development of Early Warning Systems:** Developing and strengthening early warning systems for early detection of potential landslides is essential. This could involve the use of technology and geospatial data to detect changes that may signal landslide risk and allow sufficient time for intervention.

Through a combination of risk assessment, development of environmentally friendly infrastructure, water and erosion management, community education and awareness, and development of an early warning system, Nusaniwe sub-district can reduce the risk and impact of landslides.

CONCLUSION

Based on the research results of Identification of Potential Landslide Areas in Nusaniwe Sub-district using Slope Morphology Method, it can be concluded that an in-depth understanding of the relationship between slope slope and slope shape with landslide potential is crucial for natural disaster mitigation. This research makes a significant contribution in the effort to reduce landslide risk in the region by identifying vulnerable areas, as well as highlighting the importance of community education, environmentally friendly infrastructure development, and interdisciplinary collaboration in dealing with landslide challenges in tropical and humid climates such as Indonesia.

REFERENCES

- M. Marzuki and H. R. Gayo, 'Local Wisdom of Gayonese in Landslide Hazard Mitigation', in *Proceedings of the 2nd International Conference on Social Science, Political Science, and Humanities (ICoSPOLHUM 2021)*, Atlantis Press, 2022, pp. 75–79. doi: <https://doi.org/10.2991/assehr.k.220302.012>.
- A. Rakuasa, H., Rifai, 'Pemetaan Kerentanan Bencana Tanah Longsor Berbasis Sistem Informasi Geografis di Kota Ambon', in *Seminar Nasional Geomatika Tahun 2021*, Badan Informasi Geospasial, 2021, pp. 327–336. doi: 10.24895/SNG.2020.0-0.1148.
- G. S. Heinrich Rakuasa, 'Analisis Spasial Kesesuaian dan Evaluasi Lahan Permukiman di Kota Ambon', *J. Sains Inf. Geogr. (J SIG)*, vol. 5, no. 1, pp. 1–9, 2022, doi: DOI: <http://dx.doi.org/10.31314/j%20sig.v5i1.1432>.
- S. Rakuasa, H., Supriatna, S., Tambunan., M,P., Salakory, M., Pinoa, W, 'Analisis Spasial Daerah Potensi Rawan Longsor di Kota Ambon Dengan Menggunakan Metode SMORPH', *J. Tanah dan Sumberd. Lahan*, vol. 9, no. 2, pp. 213–221, 2022, doi: 10.21776/ub.jtjstl.2022.009.2.2.
- G. Somae, S. Supriatna, M. D. M. Manessa, and H. Rakuasa, 'SMORPH Application for Analysis of Landslide Prone Areas in Sirimau District, Ambon City', *Soc. Humanit. Educ. Stud. Conf. Ser.*, vol. 5, no. 4, p. 11, Dec. 2022, doi: 10.20961/shes.v5i4.68936.
- P. C. Latue and H. Rakuasa, 'Spatial Analysis of Landscape Suitability of Ambon City for Settlement Using Geographic Information System', *J. Ris. Multidisiplin dan Inov. Teknol.*, vol. 1, no. 02, pp. 59–69, Sep. 2023, doi: 10.59653/jimat.v1i02.218.
- BNPB, *Indeks Resiko Bencana Indonesia*. Jakarta: Badan Nasional Penanggulangan Bencana, 2023.
- H. Rakuasa and P. C. Latue, 'Role of Geography Education in Raising Environmental Awareness: A Literature Review', *J. Educ. Method Learn. Strateg.*, vol. 2, no. 01, pp. 1–7, Oct. 2023, doi: 10.59653/jemls.v2i01.293.
- H. Latue, P. C., Sihasale, D. A., & Rakuasa, 'Pemetaan Daerah Potensi Longsor di Kecamatan Leihitu Barat, Kabupaten Maluku Tengah, Menggunakan Metode Slope Morphology (SMORPH)', *INSOLOGI J. Sains Dan Teknol.*, vol. 2, no. 3, pp. 486–495, 2023, doi: <https://doi.org/10.55123/insologi.v2i3.1912>.
- M. C. Harist, H. A. Afif, D. N. Putri, and I. P. A. Shidiq, 'GIS modelling based on slope and morphology for landslide potential area in Wonosobo, Central Java', *MATEC Web Conf.*, vol. 229, p. 03004, Nov. 2018, doi: 10.1051/matecconf/201822903004.
- H. Manakane, S. E., Latue, P. C., & Rakuasa, 'Identifikasi Daerah Rawan Longsor Di DAS Wai Batu Gajah, Kota Ambon Menggunakan Metode Slope Morphology Dan Indeks Storie', *Gudang J. Multidisiplin Ilmu*, vol. 1, no. 1, pp. 29–36, 2023.
- H. Sugandhi, N., Supriatna, S., & Rakuasa, 'Identification of Landslide Prone Areas Using Slope Morphology Method in South Leitimur District, Ambon City.', *Jambura Geosci. Rev.*, vol. 5, no. 1, pp. 12–21, 2023, doi: <https://doi.org/10.34312/jgeosrev.v5i1.14810>.
- Y. Ristya, Supriatna, and Sobirin, 'Spatial pattern of landslide potensial area by {SMORPH}, {INDEX} {STORIE} and {SINMAP} method In Pelabuhanratu and surrounding area, Indonesia', *{IOP} Conf. Ser. Earth Environ. Sci.*, vol. 338, no. 1, p. 12033, Nov. 2019, doi: 10.1088/1755-1315/338/1/012033.
- M. G. Permadi, Jamaludin, Parjono, and M. T. Sapsal, 'Implementation of the {SMORPH}

- method for mapping the susceptibility area of landslide in Bogor City', *{IOP} Conf. Ser. Earth Environ. Sci.*, vol. 343, no. 1, p. 12195, Oct. 2019, doi: 10.1088/1755-1315/343/1/012195.
- R. Triwahyuni, L., Sobirin dan Saraswati, 'Potensi, Analisis Spasial Wilayah Progo, Longsor dengan Metode SINMAP dan SMORPH di Kabupaten Kulon Daerah Istimewa Yogyakarta', in *Industrial Research Workshop and National Seminar*, 2017, pp. 69 – 76.
- Abdul Muin and Heinrich Rakuasa, 'Spatial Analysis of Landslide Potential Using Modification of the Storie In-dex Method in the Wae Batu Gajah Watershed, Ambon City, Indonesia', *Int. J. Sci. Multidiscip. Res.*, vol. 1, no. 3, pp. 107–116, Apr. 2023, doi: 10.55927/ijsmr.v1i3.3625.
- F. Ramdhoni, A. Damayanti, and T. L. Indra, 'Smorph application for landslide identification in Kebumen Regency', *IOP Conf. Ser. Earth Environ. Sci.*, vol. 451, no. 1, p. 012013, Mar. 2020, doi: 10.1088/1755-1315/451/1/012013.
- N. Wang, G. Xu, P., Wang, C., N., & Jiang, 'Appllication of a GIS-based slope unit method fo landslide susceptibility mapping along the Longzi River, Southeastern Tibetan Plateau, China', *Int. J. Geo-Information*, vol. 6, no. 6, p. 172, 2017.
- Hoyt and William C. H., *Slope Stability Modelling and Landslide Hazard in Freshwater Creek and Ryan Slough Humboldt County*. California: Pacific Watershed Associates, 2008.
- Katherine Lowe, 'Landslides: Slope stability, triggers, failure dynamics, and morphology', *geoengineer.org*, 2015. <https://www.geoengineer.org/education/web-class-projects/cee-544-soil-site-improve-winter-2015/assignments/landslide-physics-and-earthquakes> (accessed Jun. 29, 2021).
- H. R. Ferol Huwae, Daniel Anthoni Sihasale, Reindino Letedara, Philia C Latue, 'Analisis Spasial Daerah Potensi Longsor Di Desa Allang, Pulau Ambon Berdasarkan Slope Morphology', *Larisa Penelit. Multidisiplin*, vol. 1, no. 1, pp. 43–49, 2023.
- E. W. Safriani and Y. A. Wibowo, 'Preparedness and Adaptive Capacity of Students for Landslide Disasters in Karangobar, Central Java, Indonesia', *KnE Soc. Sci.*, Mar. 2022, doi: 10.18502/kss.v7i5.10536.
- H. Pakniany, Y., Latue, P. C., & Rakuasa, 'Pemetaan Daerah Rawan Longsor di Kecamatan Damer, Kabupaten Maluku Barat Daya, Provinsi Maluku', *J. Altifani Penelit. dan Pengabd. Kpd. Masy.*, vol. 3, no. 2, pp. 235–242, 2023, doi: <https://doi.org/10.25008/altifani.v3i2.367>.