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HAZARD AND RISK MAPPING OF TSUNAMI DISASTER USING HLOSS METHOD CASE STUDY: IDANO GAWO DISTRICT

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Abstract. Idano Gawo District in Nias Regency has geographical characteristics that make it vulnerable to tsunamis. The history of earthquakes in the Nias Islands, particularly the megathrust earthquake in 2005, highlights this vulnerability. This earthquake was triggered by the major Aceh earthquake on December 26, 2004, and resulted in a tsunami that reached heights of 2-3 meters, impacting several coastal areas in the Nias Islands. Consequently, effective disaster mitigation strategies are necessary. Mapping tsunami hazards and risks is essential for effective mitigation planning, as it helps identify areas at risk and vulnerable to tsunamis based on a scenario involving a height of 16 meters. This study employs the hloss and cost distance methods for mapping. The tsunami hazard and risk levels, with a focus on the 16-meter height scenario, are analyzed using ArcGIS software. Data processing for the tsunami disaster hazard and risk is conducted using Microsoft Excel. Specifically, Bozihona Village is identified as a high-risk area, encompassing a total area of 3.76 km² with a corresponding tsunami risk area of 3.77 km².

Keywords: *Bozihona Village, Idano Gawo District, Hloss method, Mapping, Tsunami risk.*
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INTRODUCTION

Nias is a district located in North Sumatra Province, Indonesia. It sits to the west of Sumatra Island and borders the Indian Ocean, making it a strategically important area. Nias Regency covers approximately 5,121 km² and includes a mix of both small and large islands. The region's diverse topography and geomorphological features, which include hills and coastal areas, make Nias prone to natural disasters. This vulnerability necessitates special attention for disaster risk management, particularly regarding tsunamis and earthquakes. One notable area is Idano Gawo District, which has geographical characteristics that increase its susceptibility to tsunamis.

A tsunami is a series of ocean waves that travel across deep sea, characterized by a wavelength of approximately 100 km and a height of several tens of centimeters [1].

Earthquakes often occur in the ocean, particularly in subduction zones, such as around Nias Island, which frequently experiences tremors stemming from megathrusts. To effectively address the impact of tsunamis, a proper management system that includes tsunami risk maps must be developed. According to the provincial disaster risk index from 2015 to 2022, Nias Island has a relatively high disaster risk index [2]. The dip of the megathrust zone, which is around 13°, has been responsible for earthquakes in southeastern Sumatra [3]. A significant event occurred in the Nias Islands in 2005, where a megathrust earthquake released energy that disturbed the balance following the major Aceh earthquake on December 26, 2004. This earthquake triggered a tsunami that reached heights of 2-3 meters, impacting several coastal areas in the Nias Islands and highlighting the need for effective disaster mitigation [4]. Tsunami hazard and risk mapping is a critical component for effective planning and mitigation efforts.

Disaster mitigation refers to actions taken to reduce the risk of disasters through physical development, public awareness, and enhancing the community's ability to manage disaster threats. According to Government Regulation of the Republic of Indonesia Number 1 of 2008 concerning the Implementation of Disaster Management, one key component is non-structural mitigation. This involves efforts to minimize the impact of disasters by empowering communities and providing essential knowledge through methods such as hazard and tsunami risk mapping, specifically using the Hloss method [5]. Disaster risk encompasses the potential consequences faced by an area over time, including injuries, illness, death, life-threatening situations, displacement, loss of safety and comfort, property damage, and destruction. Analyzing the risk of a tsunami disaster involves combining the hazard value with the vulnerability value. This analysis is performed by multiplying the results of the hazard assessment with those of the vulnerability assessment, ultimately producing a risk map. The resulting risk value is then used to prepare and explain the risk map [1].

RESEARCH METHOD

The data used in this study are secondary data in the form of Google Maps satellite imagery obtained through the SAS Planet application and DEMNAS data with a resolution of 0.27 arc seconds. The study area is located in Nias Regency, at coordinates 0 ° 53'1.5 '' - 1 ° 17'16.6 '' N and 97 ° 29'0.7 '' - 97 ° 58'29 '' E. The research method used is the hloss and cost distance method to map the level of tsunami hazard and risk with a wave height scenario of 16 meters based on the Papadopoulos scale. Data processing was carried out using ArcGIS software to create tsunami risk and hazard maps, and Microsoft Excel for processing related data [6].

Table 1. Tsunami Intensity Scale

Intensity Scale	Tsunami Height (m)	Tsunami Intensity
I – V	<1.0	0
VI	2. 0	1
VII – VIII	4. 0	2
IX – X	8. 0	3
XI	16. 0	4
XII	32. 0	5

Equation Berryman used to model the decrease in tsunami wave height using the hloss method in modeling tsunami hazard inundation, the formula used is as follows:

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

Where, H_{loss} isthe value of water decline when entering the land, n is the value of the land use roughness coefficient, S is the slope or (slope), and$H_0$is the height of the tsunami from the coastline.

The Crunch Model is a conceptual framework that posits disasters as the outcome of a hazard calculation process [8]. The model's equation is expressed as follows

$$R = H\, x\, V \qquad (2)$$

where, R is the risk value, H is the hazard value, and V is the vulnerability value.

Land use accuracy assessments are employed to evaluate the precision of land use classifications. These assessments involve calculating producer accuracy, user accuracy, and overall accuracy, as outlined by Jaya [9]. The formulas for these metrics are as follows

$$overall\ accuracy = \frac{\sum_{i=1}^{n} x_{ii}}{N} \times 100\% \qquad (3)$$

$$Kappa\ accuracy = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} x_i + x_{+i}}{N^2 - \sum_{i=1}^{r} x_i + x_{+i}} \times 100\% (4)$$

where, N is the number of pixels in the sample,$x_i$is the number of pixels in the i-th row, is the number of pixels in the i-th column, is the diagonal value of the contingency matrix of the i-th row and i-th column $x_{+i}x_{ii}$

RESULT AND DISCUSSION

Slope gradient is a parameter used in calculating the hloss value in Equation 1. DEMNAS data with a resolution of 0.27 Arc-Second is processed into slope gradient data which is classified into 5 classes as follows [10].

Table 2. Slope Gradient Classification

Slope Class	Slope	Information
1	0 – 8 %	Flat
2	8 – 15 %	Sloping
3	15 – 25%	A bit steep
4	25 – 45%	Steep
5	45% or more	Very steep

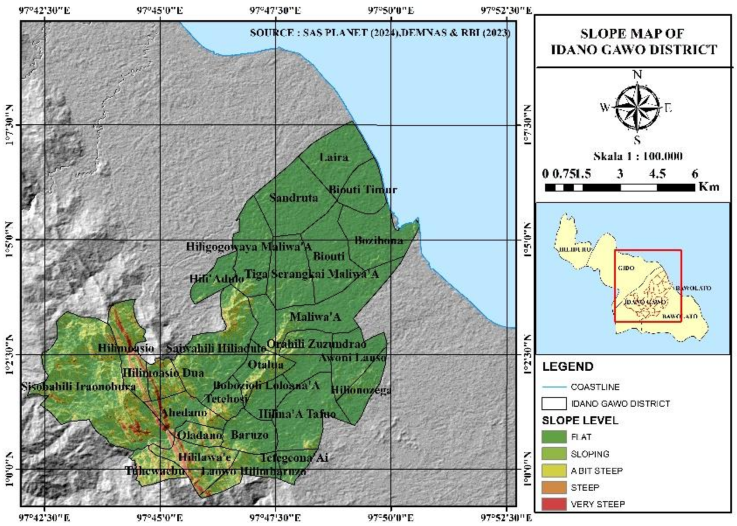

Figure 1. Slope Gradient Map

Based on the results of the DEMNAS data analysis and classification, the results of the slope map of Idano Gawo District are obtained in Figure 1. Based on Figure 1, the results show that the coastal area has a flat slope with a slope of (0 - 3.8%). So it can be said that Idano Gawo District has a flat slope, meaning that if the slope is flat it will have a dangerous impact on tsunami disasters [11].

Land cover map is a parameter used to input surface roughness coefficient value data in tsunami modeling with a tsunami height scenario of 16 meters. Land cover map is processed using maximum likelihood classification from image data Google Maps Satellite, and tested the level of accuracy of land use using Equations 3 and 4. Based on these equations, the results of the land use accuracy test were as follows.

Table 3. Land Use Accuracy Test Results

OID	*Class Value*	forest	field	settlement	bush	total	*u-accuracy*	*kappa*
0	Forest	63	0	1	2	66	0.954545	0
1	Field	0	7	1	0	8	0.875	0
2	Settlement	0	0	1	0	1	1	0
3	Bush	0	0	0	5	5	1	0
4	Total	63	7	3	7	80	0	0
5	*p accuracy*	1	1	0.333333	0. 71429	0	0.95	0
6	*kappa*	0	0	0	0	0	0	0. 85102

In Table 3, the accuracy results are obtained, namely the valuep accuracyworth 95% and the kappa value is 85% so that the results maximum likelihood classification can be categorized as very good and can be used in land use analysis.[12].

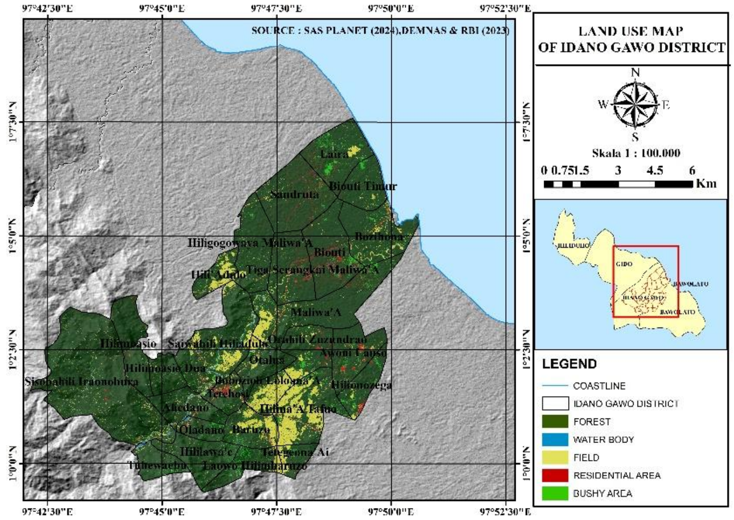

Figure 2. Land Use Map

Based on the results of the maximum likelihood classification analysis, the map results in Figure 2 show land use in Idano Gawo District. Dark green is a forest area, blue is a water body, yellow is a field, red is a settlement and light green is a bush. Sisobahili Iraonohura Village in Idano Gawo District has an area in the forest with an area of approximately 15.81 km^2, Village Saiwahili Hili'Adulo is a village located on a body of water with an area of approximately 0.24km^2, Bobozioli Loloana'A Village has an area located on a field with an area of approximately 1.2km^2, Biouti Village, which is a village that has a residential area with an area of approximately 0.41km^2, and Village Hiligafoa is a village that has a bushy area with an area of approximately 0.44km^2 .Based on the land use map, we can determine the danger and risk of tsunamis, by entering the roughness coefficient value to model tsunami inundation with a tsunami height scenario of 16 meters [13].

Table 4. Roughness Coefficient Value

Type of Land Use	Coefficient of Roughness
Shrubs	0.040
Forest	0.070
Settlement	0.045
Ricefield	0.020
Plantation	0.035
Field	0.030
Building/Construction	0.050
Water Body	0.007

Based on the results of the land use analysis obtained in Figure 2 and entering the roughness coefficient values in Table 4, a roughness coefficient value map is obtained as shown in Figure 3.

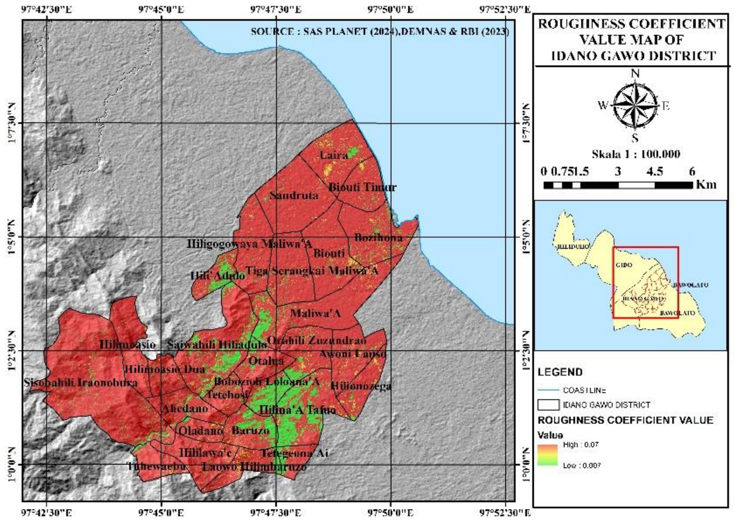

Figure 3. Land Use Roughness Coefficient Value Map

Figure 3 shows that the lowest roughness coefficient value is 0.007 in green (Water Body) and the highest value is 0.07 in red (Forest). The results of the roughness coefficient value map are the basis for vulnerability to tsunami hazard and risk mapping with a 16 m height scenario in the DistrictIdano Gawo, if the roughness coefficient value is large then the impact of the tsunami will not be large and vice versa [14].

The tsunami hazard map is obtained from the calculation results using Equation 1 and data processing into fuzzy membership to determine safe, moderate, and high areas against tsunamis with a height of 16 meters. Based on this processing, the map shown in Figure 4 is obtained.

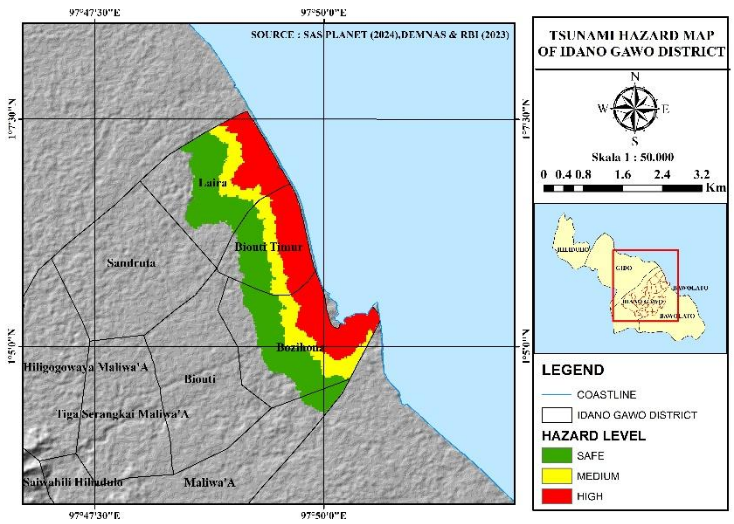

Figure 4. Tsunami Hazard Map of Idano Gawo District

Figure 4 maps the extent of tsunami inundation with a tsunami height scenario of 16 meters which makes the area a tsunami hazard area where the red area is an area with a very high level of danger, the yellow area is an area with a moderate level of danger, and the green area is an area with a safe level of danger. Based on the results in Figure 4, the analysis results are obtained in Table 5.

Table 5. Tsunami Hazard Map Analysis Results with 16 Meter Height Scenario

Name Village	Safe (0 – 5 m)	Currently (5 – 10 m)	Tall (10 - 15.9 m)	Total Area (km^2)	Level Danger
East Biouti	0.85	0.54	1.16	2.55	Currently
Bozihona	1.59	0.82	1.35	3.76	Tall
Laira	1.51	0.58	1.11	3.20	Tall
Maliwa'A	0.29	0.00	0.00	0.29	Safe
Total	4.24	1.94	3.62	9.80	

Table 5 shows the results of the analysis of the area of tsunami inundation with a 16-meter height scenario in Idano Gawo District of 9.80 km^2 which is classified into 3 categories: safe area (0 - 5m), medium area (5 - 10m), and high area (10 -15. 9m). Bozihona District is categorized as a high-hazard area with a total inundation area of 3.76 km^2 which is influenced by the distance from the coastline, flat slope and roughness index in the area.[15].

Based on the results of hazard data processing by multiplying the vulnerability using Equation 2, the results of the tsunami risk map with a height scenario of 16 m are obtained. In Figure 6.

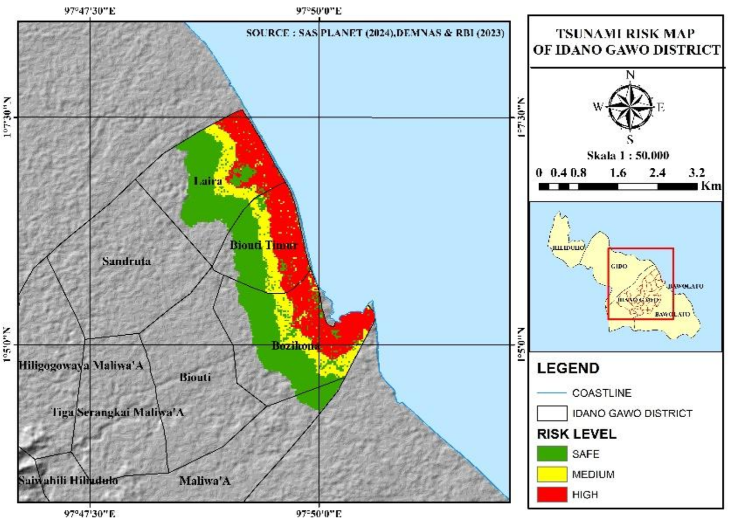

Figure5. Tsunami Risk Map for Idano Gawo District

Figure 5 maps the area of tsunami inundation with a 16 meter height scenario which makes the area a tsunami risk area based on the roughness coefficient value factor of land use in the District Idano Gawo. The red area has a very high level of danger, the yellow area has a moderate level of danger, and the green area has a safe level of danger. Based on the results in Figure 5, the analysis results are obtained in Table 6.

Table 6. Tsunami Hazard Map Analysis Results with 16 Meter Height Scenario

Name Village	Safe (0 – 5 m)	Currently (5 – 10 m)	Tall (10 - 15.9 m)	Total Area (km^2)	Level Risk
East Biouti	0.97	0.49	1.10	2.55	Currently

Bozihona	1.83	0.72	1.22	3.77	Tall
Laira	1.70	0.53	0.96	3.19	Tall
Maliwa'A	0.29	0.00	0.00	0.29	Safe
TOTAL	4.79	1.73	3.28	9.80	

Table 6shows the results of the tsunami inundation area risk analysis with a 16-meter height scenario in Idano Gawo District of 9.80 km^2 which is classified into 3 categories: Safe area (0 - 5m), medium area (5 - 10m), and high area (10 - 15.9m). Bozihona District is categorized as a high-hazard area with a total inundation area of 3.77 km^2 which is influenced by the tsunami hazard and the roughness coefficient index. A low roughness coefficient value has a smooth surface so that it is easily hit by tsunami waves. [16]

CONCLUSION

The results of the mapping of the level of danger and risk of a tsunami with a height of 16 m inIdano Gawo Districtnamely the VillageBozihona has a high level of danger with a total inundation area of 3.76 km^2 and a high level of tsunami risk with a total area of 3.77 km^2. Tsunami hazard map and tsunami risk map obtained results of areas with gentle slopes and roughness coefficient values of land use into tsunami hazard areas with a tsunami height scenario of 16 m so that it becomes a factor for the area to be in the danger zone, so that people in the area are advised to evacuate themselves to a safer place.

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