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Earthquake Risk Analysis as a Disaster Mitigation-Based Spatial Planning Strategy in the National Tourism Strategic Area of Kolorai Village, Morotai Island

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ABSTRACT

Kolorai Village is a National Strategic Tourism Area (KSPN) influenced by complex tectonic activity. The low community resilience to earthquake disasters in Kolorai Village means that the government must refrain from using disaster risk factors as a reference in developing disaster mitigation-based tourism areas. This research aims to analyse the risk of earthquake disasters in the tourism area of Kolorai Village. Problem-solving in this research uses the survey method and descriptive analysis with a quantitative approach. Primary data or field data in the form of vulnerability and capacity data are obtained using the help of checklist instruments, questionnaires, and interviews. The earthquake disaster risk analysis results in Kolorai Village have a score of 3. They are included in the high category with a percentage of hazard factors of 43%, 28% vulnerability, and 29% capacity. The value of earthquake disaster risk is produced as a map that illustrates the elements of earthquake disaster risk in the Kolorai Village Tourism Area. So that it can be used for spatial planning, it needs to be integrated with disaster risk reduction.

Keywords: Earthquake, Mitigation, Disaster risk, Tourism

ABSTRAK

Desa Kolorai merupakan Kawasan Strategis Pariwisata Nasional (KSPN) yang dipengaruhi oleh aktivitas tektonik yang kompleks. Rendahnya ketahanan masyarakat terhadap bencana gempabumi di Desa Kolorai membuat pemerintah harus menahan diri untuk tidak menggunakan faktor risiko bencana sebagai acuan dalam mengembangkan kawasan pariwisata berbasis mitigasi bencana. Penelitian ini bertujuan untuk menganalisis risiko bencana gempabumi di kawasan pariwisata Desa Kolorai. Pemecahan masalah dalam penelitian ini menggunakan metode survei dan analisis deskriptif dengan pendekatan kuantitatif. Data primer atau data lapangan berupa data kerentanan dan kapasitas diperoleh dengan menggunakan bantuan instrumen checklist, kuesioner, dan wawancara. Hasil analisis risiko bencana gempabumi di Desa Kolorai memiliki nilai 3. Termasuk dalam kategori tinggi dengan persentase faktor bahaya 43%, kerentanan 28%, dan kapasitas 29%. Nilai risiko bencana gempabumi tersebut dihasilkan dalam bentuk peta yang menggambarkan unsur-unsur risiko bencana gempabumi di Kawasan Wisata Desa Kolorai. Agar dapat digunakan untuk perencanaan tata ruang, maka perlu diintegrasikan dengan pengurangan risiko bencana.

Kata kunci: Gempabumi, Mitigasi, Risiko bencana, Pariwisata

INTRODUCTION

Morotai Island is an island that has a geological setting with small faults and tectonic activity from major and minor plates that produce subduction zones. The subduction zone is formed from the Pacific, Philippine, Sangihe, and Maluku Sea plate meeting (Cardwell & Isacks, 1978; Hamilton, 1979; Katili, 1978; Sukamto et al., 1981), which causes earthquakes. Based on Indonesia's disaster risk index data in 2022 (Adi et al., 2023), it was identified that Morotai Island has a very high earthquake disaster risk index. Geographically, the government centre of Morotai Island is located in the coastal area and land topography, so it has a considerable impact on the occurrence of earthquakes. This is because earthquakes are the main trigger for other disasters, such as tsunamis. Morotai Island is one of the areas designated as a National Tourism Strategic Area (KSPN) and a priority destination with historical and marine tourism attractions with a carrying capacity different from other areas (Astuti & Noor, 2016).

Morotai Island has small islands with a high potential for earthquake disasters, one of which is Kolorai Village. Kolorai Village is often visited by tourists, with beach tourism, fishing, diving, and snorkelling as its main attractions. Protection of tourist visitors and residents from future earthquake disasters is necessary because it will be very significant to the impact of catastrophic events on potential losses, damage, and casualties (Chou & Chiu, 2021). Although there were no casualties, it is crucial for regional stability in the growth of tourism potential, especially in tourist villages located in earthquake-prone areas.

The potential for many casualties, complex disaster conditions, the absence of information and data on disaster risk, and one's attitude in dealing with disasters are factors in the low level of community resilience to a disaster (November & Leanza, 2015). As a result, the government cannot use disaster risk factors as a reference in developing disaster mitigation-based tourism areas. The impact and risk of earthquake disasters can be reduced by maximizing efforts to increase knowledge and understanding for the community and strengthening community capacity for disaster preparedness in optimizing tourism villages.

The results of field identification show that disaster mitigation needs to be considered in the spatial conditions in Kolorai Village. Some of the causes are that disaster mitigation plans have yet to be incorporated into the spatial layout of tourist destinations. In addition, the local community needs to be more understanding and prepared to deal with earthquake disasters. So, it is necessary to carry out a strategy in disaster mitigation-based tourism development by paying attention to aspects of earthquake disaster risk assessment, especially in Kolorai Village. Disaster mitigation is an effort to reduce the impact or risk of disasters through physical development, awareness, and capacity building in the face of disaster hazards (*Https://Bnpb.Go.Id/Potensi-Ancaman-Bencana,n.d.)*.

The high risk of catastrophe makes the government obliged to be aware and immediately investigate strategic priority areas with high-hazard threats. Disaster risk is the possibility of a loss in a particular area caused by a combination of hazards or threats or hazards (bet), vulnerability, and site capacity(United States Agency for International Development, 2009). An earthquake disaster risk analysis is important because it can provide a comprehensive picture of the existing level of risk. From this analysis, mitigation measures that can be applied to reduce or prevent the impact of losses and casualties, as well as disaster mitigation-based spatial planning as an effort to protect the tourism potential in Kolorai Village, can be identified.

Earthquake disaster risk research has been carried out (Amelia et al., 2020) in the South Morotai Tourism Area by obtaining an earthquake disaster risk value for the South Morotai District with a high disaster risk level risk. However, earthquake disasters in the National Tourism Strategic Area (KSPN), especially the Kolorai Tourism Village, still need to be done. Thus, a comprehensive study related to earthquake disaster risk analysis in Kolorai Village is needed in the context of disaster mitigation-based spatial planning to protect tourism potential in the area. The novelty of this research lies in the KSPN, which is a priority for the central government in terms of disaster-based tourism development, especially earthquake disasters.

This research aims to determine the level of earthquake risk in Kolorai Village as a material for disaster mitigation-based tourism development. Problem-solving in this research uses a quantitative descriptive method approach with Geographical Information System (GIS) analysis. The data components used in this research are hazard, *vulnerability*, and capacity. Primary data or field data in the form of vulnerability data and capacity data are obtained with the help of *checklist* instruments, questionnaires, and interviews. The selection of the number of respondent samples was used using the *Purposive Sampling* method and calculated using the *Slovin* calculation. The secondary data required in the research is hazard data in the research area in the form of earthquake hazard maps. The data is then processed using the scoring method and the creation of earthquake disaster risk maps assisted by the *QuantumGIS* program. The analysis of earthquake disaster risk data refers to the Regulation of BNPB No. 2 of 2012 (BNPB, 2012).

It is expected that disaster mitigation-based spatial planning strategies can be carried out such as strengthening early warning systems, improving disaster-resilient infrastructure, spatial arrangements that prioritize safety aspects, and increasing the capacity of communities and regional management institutions in dealing with earthquake disasters.

METHODOLOGY

This research uses a survey method and descriptive analysis with a quantitative approach. The data needed in this research are hazard, vulnerability, and capacity. This research is divided into three stages, namely the pre-research stage, the research stage, and the final stage. The pre-research set included field observations to obtain preliminary information on the condition of the research area, determine the number of samples and design questionnaires and checklists. The research stage was carried out to get primary data with the help of questionnaires during field surveys to the community, checklist data on building type identification, and interviews. Respondent data collection was carried out using the Purposive Sampling method and calculated with the Slovin calculation as follows:

$$n = \frac{N}{1+N(e)^2} \tag{1}$$

Where n is the sample size or number of respondents, N is the population size, and e is the percentage of allowance for the accuracy of sampling errors that can still be tolerated. Secondary data was obtained from hazard maps, maps of the Regional Spatial Plan, geological maps, Indonesian earthquake maps, sub-district profile data from the Central Statistics Agency (BPS), and DEM SRTM images. The hazard map was used as initial information to conduct field surveys.

The final stage of the research consisted of data processing and analysis. Data processing was carried out using the scoring method, and disaster risk maps were created with the help of the QuantumGIS program. Data analysis techniques in disaster risk assessment, especially earthquakes, refer to Perka BNPB No. 2/2012 (BNPB, 2012) based on hazard, vulnerability, and capacity components. The disaster risk analysis uses the following formula approach:

$$R \approx H * \frac{V}{C} \tag{2}$$

Where R is disaster risk, h is a hazard: the frequency (likelihood) a particular disaster is likely to occur with a certain intensity in a specific location. V is vulnerability: the expected loss (impact) in a particular area if a specific disaster occurs with a certain power. C is the capacity available in the area to recover from the disaster.

The identification of hazard analysis was obtained from the North Maluku Earthquake Hazard Map map prepared by Ningrum et al. From the hazard map, the value of ground motion acceleration (PGA) can be seen, and then hazard classification is carried out according to the values in Table 1.

Table 1. Field value for hazard classification

PGA Value	Class	Value	Weight (%)	Score
< 0.26	Low	1		0.333333
0.26 – 0.70	Medium	2	100	0.666667
> 0.70	High	3		1.000000

Source: Regulation of the head of the national disaster management agency number 02 year 2012

Vulnerability analysis is divided into social, economic, and physical vulnerability. The sources of information used came from the Regional Spatial Plan map (road network and public facilities), geological map, Indonesian Earth Map (land use), and sub-district profile data from BPS. The indicators for social vulnerability are population density, sex ratio, poverty ratio, the ratio of disabled people, and age group ratio. The economic vulnerability indicators are the productive land area in rupiah (rice fields, plantations, agricultural land, and ponds) and the gross regional domestic product moreover, physical vulnerability indicators are used in building checklist data shown in Table 2 and Table 3.

Table 2. Social vulnerability index conversion parameters and equations

Parameter	Weight (%)	Kelas			Score
		Low	Medium	High	
Population density	60	< 500 population/km^2	500-100 population/km^2	> 1000 population/km^2	Class/maximum class score
Sex Ratio	40	< 20%	20 – 40 %	> 40 %	

Source: Regulation of the head of the national disaster management agency number 02 year 2012 (modification)

Table 3. Economic Vulnerability Index Conversion Parameters and Equations

Parameter	Weight (%)	Kelas			Score
		Low	Medium	High	
Productive land	60	< 50 million	50 - 200 million	> 200 million	Class/maximum class score
PDRB	40	< 100 million	100 – 300 million	> 300 million	

Source: Regulation of the head of the National Disaster Management Agency Number 02 Year 2012

Capacity analysis is obtained from the level of preparedness of local communities based on indicators of knowledge and experience and attitudes and actions. The needles used are listed in the questionnaire, which will be analyzed by scoring. Disaster risk analysis assessed and mapped the components of hazard, vulnerability, and capacity. The value of disaster risk is obtained by using the scoring method for each element and then overlaying the hazard, vulnerability, and capacity values. The scoring results are then classified using three interval classes of risk levels: high, medium, and low.

RESULTS AND DISCUSSION

Overview of Kolorai Village, South Morotai

The activity of the active Maluku Sea plate strongly influences Kolorai Village. It has an area with a high risk of seismic disasters, but this village is a trendy tourist destination. Therefore, it is necessary to conduct a disaster risk assessment, especially related to earthquake disasters in Kolorai Village. The topographic condition of Kolorai Village is in the form of land with a geographical location on the coast with an area of 4.96 km2 and a population of 565 people. Based on data on earthquake events, at least nine events have occurred in Kolorai Village (BPS Kabupaten Pulau Morotai, 2022). Kolorai Village, commonly called Kolorai Island, is one of the tourism products on Morotai Island, a Government Strategic Priority Tourism Destination (Major Project) stipulated in the 2020-2024 National Medium-Term Development Plan. In addition, based on Government Regulation 26 of 2008 concerning the Determination of National Strategic Areas, Morotai Island is designated as one of the National Strategic Areas. This is intended to accelerate the economic development of Morotai Island.

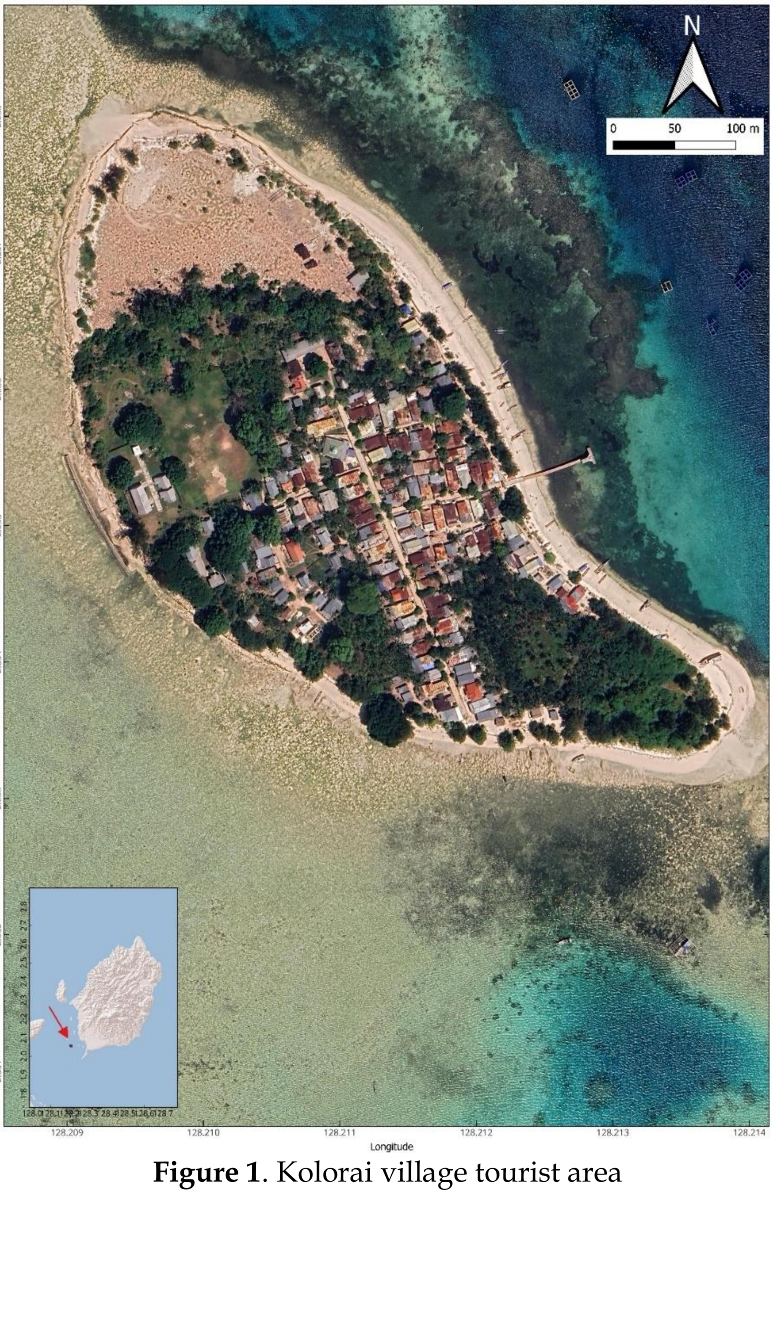

Figure 1. Kolorai village tourist area

Tourism villages are particularly vulnerable to disasters, especially earthquakes, and can be severely affected. Tourism industry revenue plays an essential role in the economy of tourist destinations. Disasters such as earthquakes can cause a drastic drop in the number of tourists. The local economy is directly affected, especially for workers and businesses that depend on tourism. Recognizing that disaster risk management is essential to managing sustainable tourism areas is critical. Spatial design and development in tourist villages should consider disaster risk factors and initiatives to reduce the impact of disasters. The goal is to reduce disaster losses to people, the economy, and the environment by building a safer and more disaster-resistant physical environment. As seen in Figure 2, Kolorai Village is the target of the spatial pattern on Morotai Island.

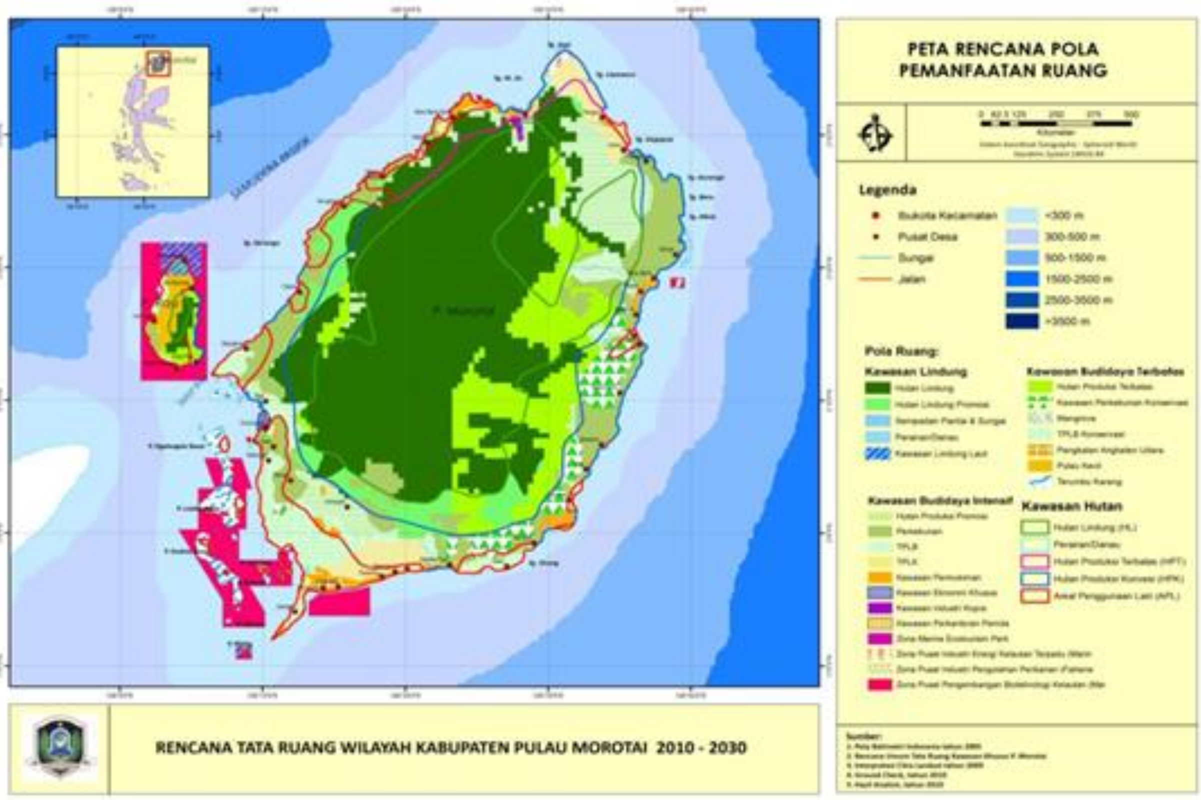

Figure 2. Map of spatial utilisation pattern plan

Earthquake Hazard

The potential earthquake hazard on Morotai Island is high (BNPB, 2015), as seen from the distribution of seismicity, as shown in Figure 3. The process of assessing the vulnerability of an area or location to earthquakes and their possible impacts is known as earthquake hazard analysis. The data needed for the hazard analysis is the North Maluku Earthquake Hazard Map created by (Ningrum et al., 2020).

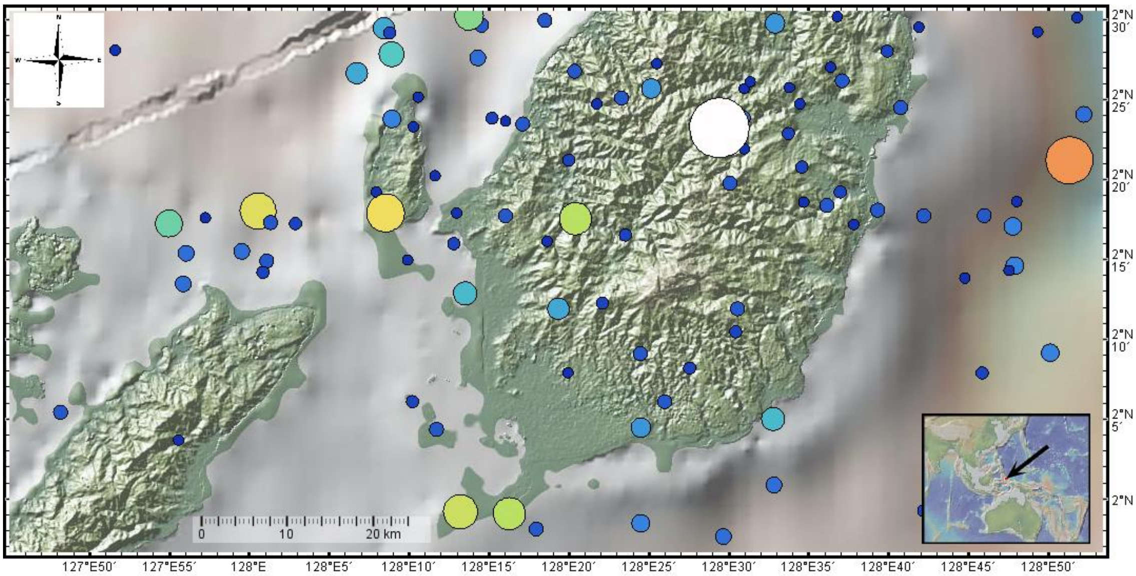

Figure 3. Seismicity map of morotai island (GeoMapApp, 2021).

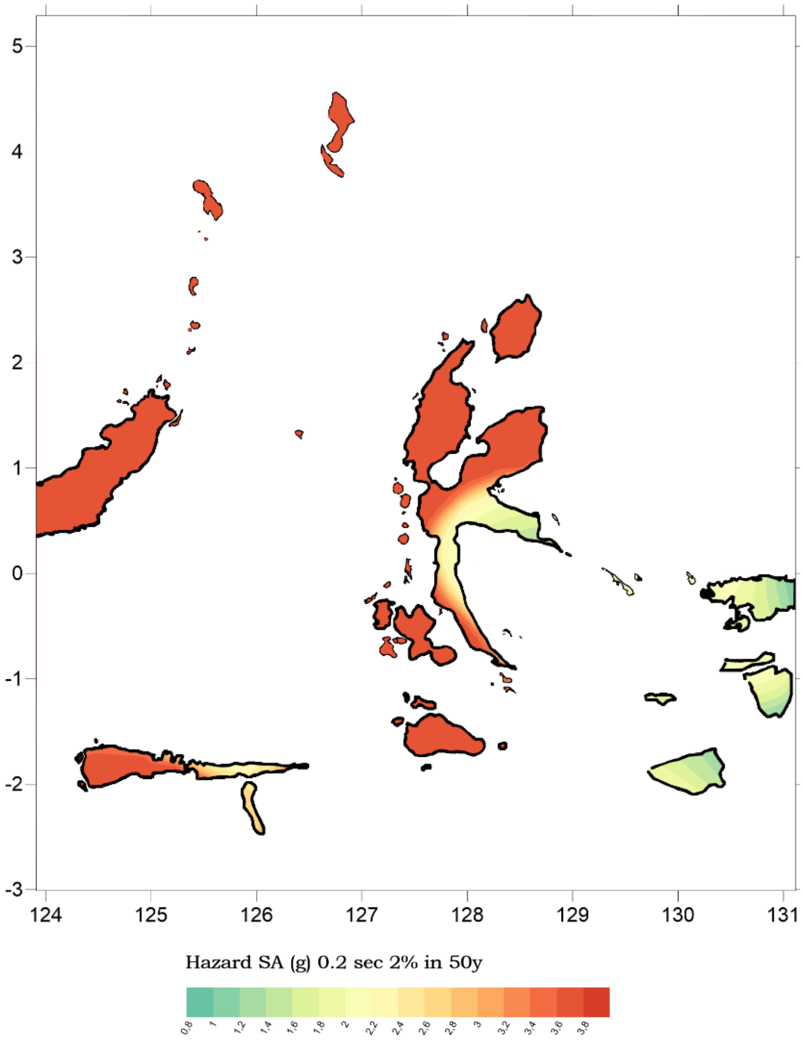

Figure 4. Earthquake hazard map of north maluku (Ningrum et al., 2020)

Kolorai Village has a relatively high potential earthquake hazard, as seen from the earthquake hazard map for Morotai Island that has been carried out by (Ningrum et al., 2020) and shown in Figure 4. The Peak Ground Acceleration (PGA) value for Morotai Island is the highest at 3.8 gal. Kolorai Village scored three and is included in the high category based on the PGA value obtained.

Earthquake Vulnerability

Vulnerability is a condition in which a group or community cannot handle the negative impacts of a risk (Rif'an & Tyawati, 2020). Because vulnerability is dynamic and changes in response to changes in community norms and environmental factors, vulnerability assessments must be conducted (Mardiatno et al., 2012). The assessment of earthquake vulnerability in Kolorai Village is limited to social vulnerability (population data in the form of population, area, and population density), physical vulnerability, and economic vulnerability.

According to South Morotai data in figures by BPS in 2021, Kolorai Village has a population of 565 people. There are 307 men and 258 women, and a sex ratio of 119.0. From this data, the social vulnerability index is 48.3, with a score of 1.5. It is included in the medium class. Physical vulnerability refers to the possibility of physical hazards to people and buildings (Westen et al., 2011). The measurement of physical vulnerability uses checklist data in the field on buildings in Kolorai Village, and then we give a weighted score. The score obtained for the physical vulnerability of buildings in Kolorai Village is an average of 2 or 96% and is included in the medium category and can be seen in Figure 5. The economic vulnerability used is the type of work, number of workers, and average income. The result of economic vulnerability in Kolorai Village in the form of a score is a score of 2 and is included in the medium category. An average score of 2 was obtained and included in the medium category for the total vulnerability value.

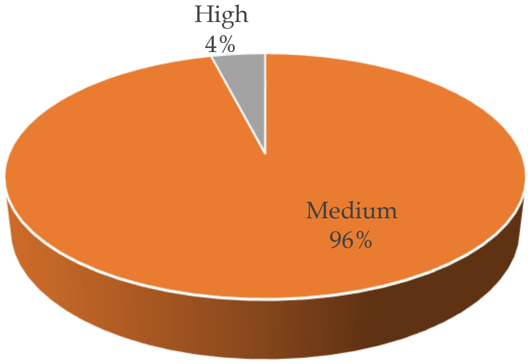

Figure 5. Diagram of percentage of physical vulnerability of kolorai village, south morotai

Community Capacity for Earthquake Disasters

Capacity is the ability of regions and communities to take action to reduce the level of threat and the level of loss caused by disasters (Perka BNPB No. 02 of 2012). The ability of communities, organizations, and systems to handle and overcome various situations, emergencies, or disasters using their resources is known as capacity (Rif'an & Tyawati, 2020). Community capacity towards earthquake disasters consists of assessing preparedness with indicators of knowledge, experience, attitudes, and actions. The results of the analysis of community capacity towards earthquake disasters in Kolorai Village have an average score of 0.53 and are included in the moderate category. Data on community capacity based on the indicators used can be seen in Figure 6. It shows that the knowledge and experience indicator is 44%, and the attitude and action indicator is 56%.

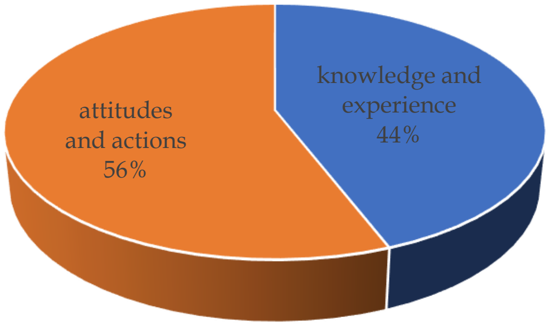

Figure 6. Diagram of percentage of community capacity based on indicators

Earthquake Disaster Risk

A way to illustrate the potential adverse impacts that can result from a potential disaster is a disaster risk assessment. A disaster risk assessment should identify the hazard, vulnerability, and capacity factors that makeup disaster risk (BNPB Regulation No. 2/2012). A disaster risk map represents the level of risk faced by an earthquake disaster. Hazard, vulnerability, and capacity factors are displayed in the disaster risk map in spatial form. The results of the analysis of earthquake disaster risk in Kolorai Village is with a score of 3 and is included in the high category. A percentage of hazard factors of 43%, vulnerability of 28%, and capacity of 29% can be seen in Figure 7.

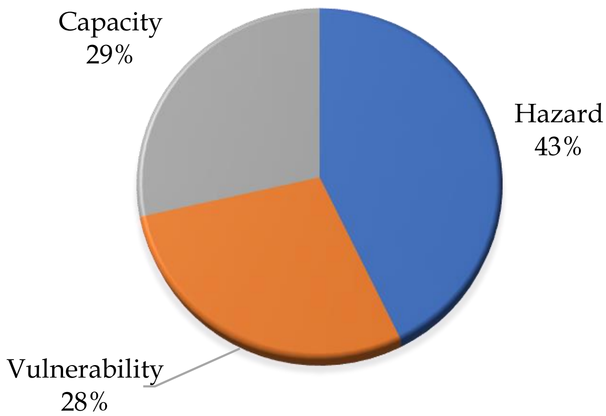

Figure 7. Percentage diagram of hazard, vulnerability and capacity of kolorai village

The percentage results obtained can be displayed in Figure 8 as an earthquake disaster risk map in Kolorai Village. The average earthquake disaster risk score for Kolorai Village is high, at 3. The zoning regulations for the Kolorai Village Tourism Area have not considered earthquake disaster risk. Figure 8 illustrates how the elements of earthquake disaster risk in the Kolorai

Village Tourism Area can be used to create more appropriate zoning regulations. Therefore, spatial planning needs to be integrated with disaster risk reduction.

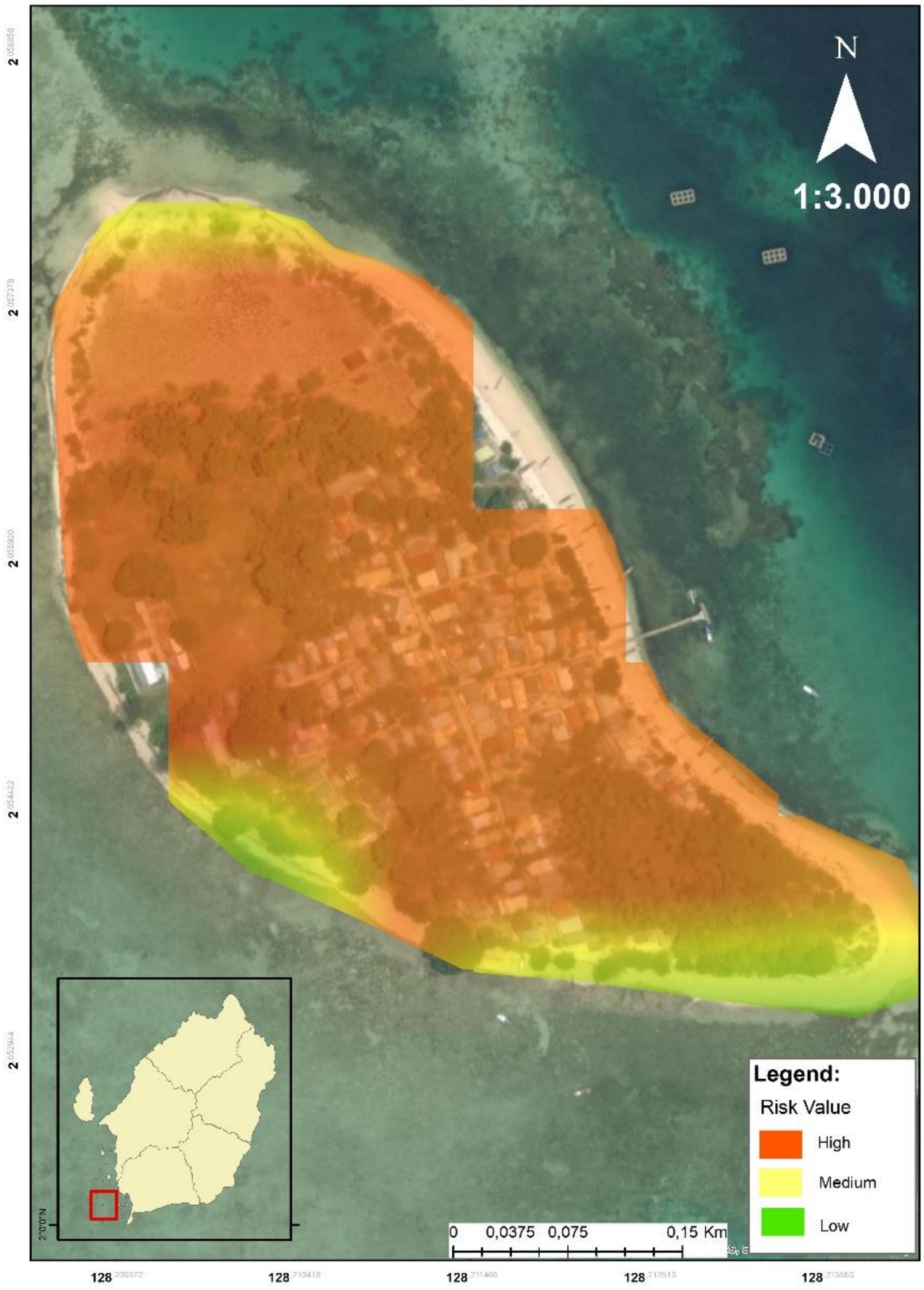

Figure 8: Map of earthquake disaster risk map at kolorai village

CONCLUSION

Based on data analysis, it can be concluded that the level of earthquake disaster risk in Kolorai Village, Morotai Island, is a "high" risk level with a score of 3, with a percentage of hazard factors of 43%, vulnerability of 28%, and capacity of 29%. In particular, this earthquake-prone area is located at a radius of less than 1 kilometer from the coastline, with the riskiest areas located on the coast around tourism centers, such as resort centers and docks. Analysis of the spatial suitability of tourism areas based on the level of earthquake risk shows that tourism development must consider aspects of the disaster, especially earthquakes, as a dominant factor. Based on the results of this study, suggestions can include increasing community preparedness capacity through regular socialization, training, and disaster simulations and optimizing the spatial arrangement of tourism areas by paying attention to disaster mitigation aspects.

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