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Extreme Waves and Coastal Erosion Hazards, Communities Risk Perception and Social Vulnerability: Analysis of Two Villages in East Nusa Tenggara (NTT)

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ABSTRACT

This study aims to examine risk perception and social vulnerability of two coastal communities in NTT namely Borokanda and Mautapaga. A quantitative method was applied to achieve the aim of this study. A primary dataset was collected through a structured questionnaire, which was responded to by a total of 110 households in these coastal communities. The differences between the coastal communities of Borokanda and Mautapaga, in social vulnerability and risk perception was analysed statistically using the Mann-Whitney U test. The results show that the coastal communities of Borokanda and Mautapaga have been identified to be significantly different in ethnicity, disaster experience, and disaster knowledge inherited from older generations. However, such indicators do not impact the differences between these coastal communities on social vulnerability and risk perception. A high score of social vulnerability index by the coastal communities of Borokanda and Mautapaga has been identified as the root cause of the low level of risk perception..

Keywords: Extreme Waves; Coastal Erosion; Risk Perception; Social Vulnerability

1. INTRODUCTION

People in high-risk areas of disasters always consider the options that significantly contribute to risk reduction and also consider lives and livelihood safety by adopting coping strategies for these hazards in the form of capability, expertise, knowledge, and technology that have all been encultured to their customs and traditions [1]–[3]. Their perception of the hazards may be beneficial in reducing their level of vulnerability, or conversely, disadvantageous due to generating their tolerance regarding hazards.

As an archipelagic country with the second-longest coastline in the world, Indonesia becomes is more vulnerable to coastal hazards than most countries. Indonesia Disaster Data Information/*Data Informasi Bencana Indonesia* (*DIBI*) and The National Disaster Management Agency/*Badan Nasional Penganggulangan Bencana* (*BNPB*) reported that since 2000 there had been 294 incidents of disaster caused by extreme waves and coastal erosion totalling about 1.3% of the total natural disaster occurred in Indonesia [4]. By 2015, these coastal disasters had occurred in almost all parts of Indonesia, with a total economic loss of about 80 trillion Indonesian Rupiah, and 5 million people suffered from these disasters [5].

Communities who occupy coastal areas in Indonesia, including Borokanda and Mautapaga, which are located in the coastal area of Ende Regency, must prepare for potential hazards that may threaten their lives. The villages of Borokanda and Mautapaga are located on the southern coast of Ende Regency, which is physically vulnerable to extreme waves and coastal erosion hazards due to their geographical position. Every year, inhabitants of Borokanda

and Mautapaga village are threatened by these hazards, which consequently leads to coastal erosion hazards. Those inhabitants identify the hazards as the southeast wind's take effect.

However, socio-economic conditions and the impact of hazards on the coastal communities in these two villages are different. The people in Borokanda are bound by ethnicity, while the Mautapaga community is heterogeneous and from diverse social backgrounds. Coastal communities in these two villages may be similarly vulnerable to physical impacts, but they have differences in impacts and socioeconomics conditions, which may reflect their perception of what and their social vulnerability towards extreme waves and coastal erosion hazards.

This study will examine the social vulnerability and risk perception of communities in two villages in Indonesia— namely, Borokanda and Mautapaga, and whether that perception contributes beneficially or result in disadvantages to locals in coping with extreme waves and coastal erosion hazards.

2. METODOLOGY

A. Study Areas

Borokanda and Mautapaga villages are located in the low-lying areas of Ende Regency, East Nusa Tenggara Province, Indonesia (Fig 1 and 2). Two communities that occupy the low-laying areas of these villages—namely Dusun (village hamlet) Baraiwena and Mautapaga Bawah were selected as study areas. These village hamlets are situated in the southern part of the Ende Regency with an altitude of about 0 – 18 meters above sea level [6], [7]. By their geographical position, these areas may be exposed to potential natural disasters such as extreme waves, coastal erosion and tsunamis.

Fig 1. Image of Borokanda village [35]

Fig 2. Image of Mautapaga village [36]

Regarding extreme waves disaster, Borokanda experienced the worst event in 2014. The disaster was reported to have affected 32 people and threatened 37 houses of this coastal community [4]. The report also presents the mitigation strategies that were conducted by the local government to cope with extreme waves and coastal hazards, including building coastal protection using sandbags and constructing a 100-metre of coastal protection gabions [4], [5].

The community in Mautapaga village had not reported experiences with extreme waves and coastal erosion hazards until May 2018. These hazards destroyed structured barriers as well as three residential houses, and one person was reported missing due to these disasters [8]. Furthermore, coastal erosion that concurrently happened with extreme waves also threatened three houses in this area. Relocation of the families was suggested by the head of the village. However, due to financial inability, the affected families refused to

relocate [8]. Even though this disaster impacted people and the environment as well as bringing economic losses, it was not recorded on the BNPB disaster database.

B. Indicator Selection

The indicators for this study were selected based on the literature review and adjusted to the conditions of the two study areas. The indicators used in this study are illustrated in Table 1 and Table 2.

Table 1. Selected indicators for determining risk perception

Indicators	Description	Explanation of Indicators	References
Risk knowledge	The understanding of exposed communities regarding the risk that may threaten their life	Percentage of people who agreed that coastal areas are the riskiest place on earth and vulnerable to natural disasters; Percentage of people who agreed that coastal communities are potentially impacted by such disaster, such socioeconomic condition affected the vulnerability of coastal communities; Percentage of people that disagree that disaster risk is measured by economic loss, environmental disruption and the number casualties; Percentage of people who agree that social capital affects to develop disaster awareness.	[9]
Disaster knowledge	The understanding of exposed communities regarding extreme waves and coastal erosion hazards according to literature.	Percentage of people who agree that wind and moon gravity are drivers of extreme waves; Percentage of people who agree that coastal erosion occurs concurrently to extreme waves; Percentage of people who agree that the sea-level rise may exacerbate the impact of extreme waves and coastal erosion	[9]

Table 2. Selected indicators for determining social vulnerability

Indicators	Description of Indicators	References
Occupation	Percentage of households where the head of families reports that the source of family income is not earned from permanent occupations	[10]–[13]
Income diversity	Percentage of households where the head of families reports that they only have one source of income	([14]–[18]
House ownership	Percentage of households where rent houses	[13], [15], [18]–[22]
Quality of houses	Percentage of households without permanent houses	[15], [18], [21], [22]
Residential status	Percentage of households where are not residents of the village	[15], [20], [23]
Family size	Percentage of households where are consisted of more than five people in a house	[14], [17], [20], [21], [24]–[26]
Vulnerable age group	Percentage of households where are consisted of children aged under five years old and elderly above 65 years old	([12], [17], [24], [26]–[28]
Life insurance	Percentage of households without having life insurance	[13], [15], [18]
House insurance	Percentage of households without having house insurance	[13], [15], [18]
Communication media	Percentage of households without owning mobile phones	([11], [17], [24]
Transportation	Percentage of households without owning vehicles	[11], [17], [24]

C. Data Collection

The study was conducted to obtain quantitative data required to determine the social vulnerability and risk perception in the two communities in the study areas. This included collecting primary and secondary data. Secondary data were obtained to complement and compare primary data sources. These sources included comprehensive literature reviews from related sources such as books, journals, articles, and reports from the Bureau of Statistics Indonesia, the ?, and the administration office in the villages.

In this study, primary data was obtained through a questionnaire that focused on households. In order to achieve the objectives of the study, questions were constructed, including some about demographics and socio-economic factors, risk perception and social vulnerability factors.

The sample was selected through random sampling technique, and a total of 110 households was nominated to complete the surveys. The sample size was determined by using Slovin formula:

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

where, N = total population, n = number of sample, and e = desired error tolerance.

A total of 33 questions were asked, using a structured questionnaire model. This model was selected due to the ease in responding to questions, which considered the educational background of respondents in study areas. The surveys were conducted in June 2018 and were assisted by three enumerators to collect the data.

D. Data Analysis

The social vulnerability index (SVI) was determined by calculating the surveyed data of the 11 indicators using formulation:

$$\text{SVI} = \frac{\sum_{i=1}^{n} Index_{SV}}{n}$$

The index was calculated using the formulation developed by Hahn *et al.* (2009) and was scaled from 0 (least vulnerable) to 0.5 (most vulnerable). Standardisation of the value of each indicator was conducted by using the equation developed by the UNDP to calculate the Human Development Index [10] as is described in the following equation.

$$Dimension\ Index = \frac{Actual\ Value - Minimum\ Value}{Maximum\ Value - Minimum\ Value}$$

Each indicator was measured by its frequency and determined by percentage. Thus, the minimum and maximum values were set to 0 and 100%, respectively. Similarly, indicators of risk perception were also determined by its frequency and described in percentages.

Even though the comparison provided by descriptive analysis may present the differences in social characteristics, social vulnerability, and risk perception of the two coastal communities of Borokanda and Mautapaga, the Mann-Whitney U test was applied to confirm the differences in statistical approach.

3. Result And Discussion

A. Demographic Description

It has been shown in this study that the coastal communities of Borokanda and Mautapaga villages have significant differences in ethnicity, disaster knowledge inherited from past generations and disaster experiences (Table 4). Borokanda was identified as consisting of a single ethnic group (Ende), while Mautapaga is heterogeneous due to the variety of residents' ethnicity. Moreover, all the coastal communities in Borokanda have experienced extreme waves and coastal erosion hazards, while in Mautapaga, only 17.3% of respondents have experienced similar hazards. Moreover, 76.4% of respondents in Borokanda are reported to have inherited disaster knowledge from their ancestors, while only 15.4% of respondents in Mautapaga have inherited such knowledge from their ancestors (Table 3).

Table 3. Characteristics of respondents in study areas

Variables	Frequency of response	
	Borokanda	Mautapaga
Etnicity		
Endenese	100	28.8
Lionese	0	30.8
Others	0	40.4
Disaster experience	100	17.3
Disaster knowledge inherited from older generations	76.4	15.4

Table 4. Analysis of the difference in ethnicity, disaster experience and disaster knowledge between coastal communities of Borokanda and Mautapaga Using The Mann-Whitney U test

Measurement	Value
Mann-Whitney U	00.000
Wilcoxon W	6.000
Z	-1.993
p-Value	0.046

Note. p-value < 0.05, which is defined as significant differences

All of the people in the coastal communities of Borokanda were identified as Endenese living in a patrilinear community, who descended from one patrilineally related group of communities [11]. Inhabitants of Borokanda have lived in this area over generations, and through an adaptation process, they have preserved the sustainability of their village, as well as their ethnicity, including their coping process with natural disasters. These coping strategies have been passed down over generations through local knowledge. This knowledge is often bound up with specific locations and has been tested over time [12].

B. *Social Vulnerability*

Regarding social vulnerability, both coastal communities have been identified as highly vulnerable communities. Moreover, this result also presents a slightly different score on the social vulnerability index between the coastal communities of Borokanda and Mautapaga (Table 5). The social vulnerability index of the Borokanda coastal community is 0.491, and it is slightly higher than the index of the Mautapaga coastal communities (0.448).

Table 5. Social vulnerability index of respondents in the study areas

Component Vulnerability	SVI	
	Borokanda	Mautapaga
Occupation	0.655	0.442
Income diversity	0.400	0.558
House ownership	0.018	0.173
Quality of houses	0.200	0.404
Residential status	0.018	0.135
Family size	0.636	0.365
Vulnerable age group	0.800	0.962
Life insurance	0.909	0.519
House insurance	1.00	0.923
Communicative media	0.109	0.096
Transportation	0.655	0.346
Total Social Vulnerability Index	**0.491**	**0.448**

The Mann-Whitney U test revealed no significant difference in the social vulnerability index between the coastal communities of Borokanda and Mautapaga. The results of this test are presented in Table 6.

Table 6. Analysis of the differences in social vulnerability index between the coastal communities of Borokanda and Mautapaga

Measurement	Value
Mann-Whitney U	56.000
Wilcoxon W	122.000
Z	-0.296
p-Value	0.767

Note. p-value > 0.05, which is defined as no differences.

This circumstance is likely to affect their risk perception. The socially vulnerable populations are likely to less worry about potential loss due to the small number of valuable assets [13].

C. *Risk Perception*

Respondents in the coastal communities of Borokanda and Mautapaga villages were asked about their perceptions regarding extreme waves, coastal erosion disasters, and about their risk knowledge.

In response to questions regarding risk knowledge, more respondents in Borokanda agreed to the statement about potential risk in coastal areas as well as to the vulnerability of coastal areas towards natural disasters (89.1% and 83.6%, respectively), than those surveyed in Mautapaga (44.2% and 55.8%, respectively). Conversely, only a small percentage of respondents in Borokanda agreed that natural hazards might impact coastal communities, that their socioeconomic condition may exacerbate their vulnerability, and that they measured the risk by economic losses and environmental destruction (23.6%, 23.6% and 36.5%, respectively). In Mautapaga, these percentages are lower than those for the same questions (32.3%, 50% and 40.4%, respectively). Moreover, over half of those surveyed in Borokanda and Mautapaga were reported as agreeing that disaster knowledge inherited from older generations is beneficial for disaster awareness.

Another section of the questionnaire required the respondents to express their agreement or disagreement regarding extreme waves and coastal erosion hazards. The results show that 80% of those who were interviewed in Borokanda agreed that winds are the drivers of the disaster. The percentage response to this question is higher than for Mautapaga. However, more respondents in Mautapaga agreed that moon gravity impacts on wave hight and coastal erosion is a

consequence of extreme waves disasters than those surveyed in Borokanda the percentage of respondents from the former who agreed with the question (51.9%) was higher than that from tle later (48.1%). Moreover, about 69% of respondents in both coastal communities agreed on the impacts of sea-level rise, which potentially exacerbates the disaster. The results are summarised in Table 7.

Table 7. Summary of risk perception of the respondents in the study areas

Description of Criteria	Frequency of response	
	Borokanda	Mautapaga
Risk knowledge		
Coastal areas are the riskiest place on earth	89.1	44.2
Coastal areas are vulnerable to natural disasters	83.6	55.8
Coastal communities are potentially impacted by such disasters	23.6	32.7
The socioeconomic condition affected the vulnerability of coastal communities	23.6	50.0
Economic loss, environmental disruption and the number of casualties are attributed as the risk of a disaster	63.5	59.6
Indigenous knowledge affects to develop disaster awareness and preparedness	54.5	50.0
Disaster knowledge		
Extreme waves are triggered by winds	80.0	50.0
The moon gravity also has impacts to wave height	45.5	51.9
coastal erosion occurs concurrently to extreme waves	34.5	48.1
The sea-level rise exacerbates the impact of extreme waves and coastal erosion	69.1	69.2

Overall, the results of the Mann-Whitney U test determined no significant differences in social vulnerability and risk perception between the coastal communities in Borokanda and Mautapaga (Table 8).

Table 8. Analysis of the difference in risk perception between the coastal communities of Borokanda and Mautapaga

Measurement	Value
Mann-Whitney U	40.000
Wilcoxon W	95.000
Z	-0.757
p-Value	0.449

Note. p-value > 0.05, which is defined as no differences.

These results also indicate that even though these coastal communities showed significant differences in ethnicity, experience in disasters and disaster knowledge inherited from past generations (Table 4), they do not demonstrate any differences in risk perception or impact on social vulnerability.

This finding does not support the previous research conducted by Blolong and Bosschaart, Kuiper, van der Schee, & Schoonenboom (2013), which demonstrated the significance of indigenous knowledge in shaping risk perception and strengthening people's confidence to cope with disasters. This somewhat contradictory result may be due to the assuredness of this coastal community belief, which helps them to cope with coastal disasters as has been demonstrated by previous generations [14]. Trust in their local knowledge contributes to reducing their anxiety. However, in this regard, the coastal community of Borokanda is likely to trust their local knowledge. This behaviour may be triggered by the accuracy of the information that has been demonstrated by inhabitants in this coastal area. This circumstance has proved that vulnerable populations with limited adaptation strategies, particularly those developed by local governments, could cope with disasters due to knowledge inherited from older generations.

The effect of disaster experience also did not show a significant difference in risk perception and social vulnerability of the coastal communities of Borokanda and Mautapaga. In this regards, a probable explanation is that residents of Borokanda tolerate the risk and consider themselves to be safe due to the minimum significant consequences caused by disasters. Casualties have not been reported to have occurred during extreme waves and coastal erosion disasters in Borokanda—only environmental damage and some structural destruction such as damage to houses and roads.

This risk tolerance and trust of the local knowledge contribute to reducing worries. Coastal communities in Borokanda and Mautapaga may

assume that they are safe enough due to disaster experiences and disaster knowledge inherited from older generations. This belief may generate their negligence to develop adaptive capacities.

4. Conclusions

The most prominent finding to emerge from this study is that ethnicity, disaster experience, and disaster knowledge, inherited from past generations, do not affect the differences, between the coastal communities of Borokanda and Mautapaga, in social vulnerability and risk perception due to risk tolerance, trust to local knowledge and financial limitation.

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