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Assessments of physical, social, and economic vulnerability in Tarakan due to climate change

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ABSTRAK

Perubahan iklim menjadi salah satu fenomena yang memengaruhi kondisi masyarakat pesisir dari aspek fisik, sosial, maupun ekonominya. Sebagai masyarakat yang tinggal di daerah pesisir, tentu mereka tergolong sebagai masyarakat rentan karena berada di wilayah rawan bencana. Penelitian ini bertujuan untuk mengkaji klasifikasi kerentanan fisik, sosial, dan ekonomi, serta kapasitas masyarakat pesisir akibat perubahan iklim di Kota Tarakan dan mengukur hubungan kerentanan fisik, sosial, dan ekonomi terhadap kapasitas masyarakat dari adanya bencana akibat perubahan iklim di Kota Tarakan. Data yang digunakan adalah kualitatif dan kuantitatif dengan pendekatan deskriptif menggunakan metode skala Likert, skala Guttman, dan skala penilaian, serta uji korelasi Spearman Rank. Hasil dari penelitian menyatakan bahwa tingkat kerentanan fisik masyarakat pesisir Kota Tarakan adalah tinggi pada angka 80%, dan kerentanan sosial ekonomi masyarakat pesisir Kota Tarakan adalah sedang pada angka berturut-turut 52% dan 52%. Sementara untuk tingkat kapasitas masyarakat yaitu tinggi pada angka 69%. Untuk tingkat hubungan kerentanan fisik, sosial, dan ekonomi terhadap kapasitas masyarakat yaitu sangat lemah.

ABSTRACT

Climate change is one of the phenomena that affects the condition of coastal communities in their physical, social, and economic aspects. Communities in a coastal area are considered vulnerable because they live in a disaster-prone area. This study aims to examine the classification of physical, social, and economic vulnerability as well as the capacity of coastal communities due to climate change in Tarakan City and to measure the relationship

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between physical, social, and economic vulnerability and community capacity from disasters due to climate change in Tarakan City. The data used are qualitative and quantitative, with a descriptive approach using the Likert scale method, the Guttman scale, the rating scale, and the Spearman rank correlation test. The results demonstrate that the level of physical vulnerability of the coastal community in Tarakan City was high at 80%, and the socioeconomic vulnerability of the coastal community in Tarakan City was medium at 52% and 52%, respectively. Meanwhile, the level of community capacity is high at 69%. The level of relationship between physical, social, and economic vulnerability and community capacity is very weak.

INTRODUCTION

Marine and coastal areas possess a significant amount of potential for regional development. Coastal areas have various renewable and non-renewable natural resources. The annual global contribution of coastal and marine biodiversity stands at $ 28 trillion, while up to ± 3 billion of the world's population depend on the sea and beaches for their livelihood (Asian Development Bank Institute, 2022). In addition to the previously mentioned functions, the ocean contributes to the regulation of carbon dioxide emissions and ecosystem temperature, the provision and production of clean water and oxygen, the determination of weather and rainfall patterns, the preservation of underwater cultural heritage and relationships with local communities, the provision of food and other natural resources, and most significantly, it harbors abundant marine life and biodiversity (United Nations Environment Programme, 2021). Nevertheless, plastic pollution is presently causing ongoing harm to coastal waters via the consumption, attachment, and absorption of toxic bioaccumulative substances into plastic; between 75 and 199 million tonnes of plastic are estimated to be in the ocean (United Nations Environment Programme, 2021; Handayani *et al*., 2019). Furthermore, as much as 80% of waste is generated either directly or indirectly by land-based economic activities, such as rivers, wastewater systems, or direct discharge into the ocean (Handayani *et al*., 2019; Korshenko *et al*., 2020).

Oceans are intrinsically linked to biodiversity and the enrichment of marine life and ecosystems. As a result, marine and coastal areas are very vulnerable to various environmental and anthropogenic phenomena (Food and Agriculture Organization, 2020; Lincoln *et al*., 2022). From the impacts of climate change to plastic pollution and overfishing, many unprecedented threats are looming over our oceans linked to anthropogenic activities. This shows that the anthropogenic use, production, and disposal of plastic must be changed so that the oceans can produce sustainable results (Basconi *et al.*, 2023; Pakalniete *et al*., 2017).

As suggested by Lincoln *et al*. (2022), climate change and marine debris threaten marine ecosystems and services. Coastal degradation and waste impose financial burdens not only on society but also on governments. Coastal communities

bear a substantial responsibility and burden in the form of damage rehabilitation and waste disposal costs. Further studies have established that waste presents a hazard to both human health and ecosystem integrity (Landrigan *et al*., 2020; Wibowo *et al*., 2019).

Climate change is a global issue affecting archipelagic countries, including Indonesia. With a land area of 6.23 million km^2 and 17,504 islands, Indonesia, the largest archipelagic nation globally, is particularly susceptible to potential disasters resulting from climate change. Coastal regions are particularly vulnerable to such impacts (Cai *et al*., 2021; Handayani *et al*., 2019). However, it is worth noting that coasts and coastal urban areas boast a population exceeding 20,000 people. This growth trend persists due to the easy access of residents to natural areas, beaches, rivers, and the sea, as well as to employment opportunities, services, and housing (Maryuningsih, 2014; Pratiwi, 2023). The exponential expansion of coastal cities gives rise to environmental problems, which eventually result in disasters within those cities. These disasters manifest as floods, increases in sea level, land subsidence, and seawater infiltration into land areas (*rob)* (Andari *et al*., 2023).

Community vulnerability is closely related to poverty levels and lack of adaptive capacity. Several findings indicate that community vulnerability to climate change varies across regions, even within the same country (Bele *et al*., 2014; Thomas *et al*., 2019). The level of vulnerability is influenced by climate conditions and exposure, community sensitivity, and adaptive capacity (Jurgilevich *et al*., 2017).

Physical, social, and economic vulnerability factors are largely determined by the development context, which substantially affects information access, household income, education, and exposure to environmental hazards in the workplace and home, as well as infrastructure and service quality and quantity (Hapsoro & Buchori, 2015). Prior studies have established that the vulnerability of coastal areas to climate change is attributable to sea level rise. Due to this vulnerability, these areas are prone to tidal flooding, erosion-induced sedimentation, and land area reduction due to subsidence. In addition, the adverse consequences of tidal wave-induced damage to coastal ecosystems disrupt maritime transportation and even lead to the destruction or complete loss of local tourist destinations. Furthermore, the consequences can adversely affect the livelihoods of local inhabitants, such as damage to seaweed foundations (Asiyah *et al*., 2015; Yuliastini *et al*., 2023).

North Kalimantan, one of the provinces comprising the archipelago, is situated along several coastal sites in cities and districts, further enhancing those areas' vulnerability to the effects of climate change. Tarakan City, situated along the coast of North Kalimantan, is confronted with a significant threat imposed by climate change on the social, economic, and physical aspects of life, including infrastructure. This phenomenon necessitates analyzing disaster risk management to anticipate vulnerabilities that may be revealed by climate change (Pilli-Sihvola *et al*., 2018; Roy

et al., 2023). A reason for this urgency is that Tarakan, the most populous city in North Kalimantan Province and one of Indonesia's most strategically located coastal regions, attracts a significant number of productive inhabitants. Based on data from the 2020 population census for North Kalimantan Province, Tarakan City has the most populous distribution in North Kalimantan Province; it is home to 242,786 individuals, or 34.59% of the province's total population (Badan Pusat Statistik, 2021). With a geographical area of only 0.33% of the area of North Kalimantan and the smallest area of the other regions in North Kalimantan, Tarakan City has a notably high population density (968.05 per km^2). This is one of the contributing factors to the greater vulnerability of coastal areas to disasters, including those caused by climate change (Krigel *et al*., 2023; Mainali & Pricope, 2017).

Based on the explanation regarding the degradation of coastal areas due to climate change on ecological, social, and economic systems, it is very important to provide input for policies and practices related to managing these risks. However, research on this risky issue is still lacking. Research on the vulnerability of coastal communities is an important area of research, considering that coastal areas are vulnerable to various threats, such as natural disasters, climate change, and environmental degradation. However, the literature still has several gaps that need to be addressed.

One of the most prominent gaps is the lack of comprehensive studies. Research on the vulnerability of coastal communities typically focuses on one or two aspects of vulnerability, such as economic or environmental aspects. In fact, numerous factors affect the vulnerability of coastal communities. Therefore, it is necessary to carry out a comprehensive study covering all vulnerability aspects, namely socio-cultural, economic, environmental, and institutional. Apart from that, ongoing studies are also critical. Research on the vulnerability of coastal communities should be performed on an ongoing basis because the vulnerability of coastal communities, along with changes in environmental and socioeconomic conditions, can fluctuate over time. Therefore, ongoing studies are critical to monitor changes in the vulnerability of coastal communities and to develop appropriate mitigation strategies.

The study seeks to comprehensively and rigorously identify problems pertaining to the physical infrastructure and social and economic factors of coastal communities in Tarakan City. This study has three objectives. First, we analyze the level of physical, social, and economic vulnerability due to climate change in the coastal area of Tarakan City. Second, this study assesses the capacity of the Tarakan City coastal community to withstand climate change-induced disasters. Third, we investigate the relationship between economic, social, and physical vulnerability and the capacity of the community in Tarakan City's coastal region to withstand climate change-induced disasters. The research serves as a benchmark for the local government in improving the welfare of the coastal communities of Tarakan City.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

Vulnerability

Vulnerability is a state of decreased resilience due to external influences that pose threats to life, livelihoods, natural resources, settlements, infrastructure, economic productivity, and well-being (Hapsoro & Buchori, 2015; Tasri *et al*., 2021). Vulnerability is the inability of individuals or community groups to mitigate the impact of a hazard (Eghdami *et al*., 2023; Rijanta *et al*., 2014).

This study classifies vulnerability into the following three categories: physical, economic, and social (Widyantoro & Usman, 2021). Physical vulnerability reflects the vulnerability of infrastructure, economic vulnerability is associated with community welfare, and social vulnerability is related to relations between communities.

Physical vulnerability pertains to regions or areas prone to disasters, where identifying such areas or places (place vulnerability) is of utmost importance. Vulnerability denotes regions or areas susceptible to being struck by disaster threats; settlement in such areas would exacerbate the area's vulnerability (Bevacqua *et al*., 2018). Broadly speaking, physical vulnerability concerns residential infrastructure in hazard-threatened or disaster-prone areas. Several indicators affect this vulnerability, including the percentage of infrastructure area, infrastructure density, percentage of emergency construction, electricity network, road length ratio, telecommunication network, local water company network, and so on (Badan Penanggulangan Bencana Daerah Kota Tarakan, 2017). Several studies have demonstrated that houses closer to the shore exhibit higher vulnerability levels (Angus & Hansom, 2021).

Economic vulnerability refers to a country’s susceptibility to the adverse effects of a financial crisis (Raduszynski & Numada, 2023). Economic vulnerability is a selected variable based on economic activities within a given area, enabling the population to meet their fundamental daily necessities. Economic vulnerability is obtained by calculating the percentage of impoverished households, which is determined by the number of poor households divided by the number of heads of households and the percentage of workers in the vulnerable sector, namely the primary sector (Adnyani & Sugiharti, 2019).

Social vulnerability is calculated based on population density, growth rate, and the proportion of individuals falling within the vulnerable age group (0–5 and > 60 years old). Interval calculations will be used to determine the value of each parameter, resulting in three distinct scores, with greater values indicating a greater area's vulnerability classification. Every evaluated parameter must undergo the scoring accumulation phase to derive a final classification level of social vulnerability for each research location at a later time.

Community Capacity

Capacity is described as the ability" a combination of all existing strengths in

a community, social group, or organizational group that can reduce the impact of the risk of a disaster." The community's role and accountability significantly affect the prevention and mitigation of climate-related disasters regarding participation and causation (Ehsan *et al*., 2022).

Vulnerability refers to a condition or nature of individuals or societies that renders them incapable of confronting dangers or threats. Capacity is defined as the resources, methods, and strengths possessed by a community that enables it to defend and prepare, prevent, overcome, reduce, and quickly recover from disasters (Badan Nasional Penanggulangan Bencana, 2013).

Capacity refers to all the strengths, attributes, and resources available within a community, organization, or society to manage and reduce disaster risks and strengthen resilience (United Nations Office for Disaster Risk Reduction, 2017). This research explores the notion of capacity as encompassing the knowledge, attitudes, and adaptations that an individual or group possesses to protect and prepare for disasters and prevent, overcome, or recover from their detrimental effects. Distinction is made in community capacity according to mitigation capability, specifically understanding of coastal disasters.

Mitigation refers to a planned and executed effort or course of action to reduce the extent of damage and adverse effects caused by a disaster. Mitigation is an initial measure implemented to establish a foundation for reducing disaster risks and losses. These losses may manifest as property damage or human casualties and should not be regarded as the last resort to address such incidents. Complete awareness of the characteristics of the dangers encountered is an essential and preliminary measure in executing mitigation strategies. Each country or region faces a unique set of dangers. Some countries are considered earthquake zones, while others are prone to hurricanes or floods. The impact of hazards and the extent of the resulting harms are contingent upon the regional circumstances, encompassing the community, structures, resources, and infrastructure. Understanding the inherent dangers encountered entails being aware of 1) The potential categories of hazards that may transpire and the scale of the hazards that will materialize. 2) The causes of disasters 3) Activities that are susceptible to causing hazards 4) The ramifications that arise from resilience hazards.

RESEARCH METHODS

This research seeks to determine the physical, social, and economic vulnerability and community capacity due to climate change. We carried out the study in the coastal area of Tarakan City, including Amal Beach Sub-District, Karanganyar Pantai Sub-District, Mambirdan Sub-District (Tanjung Pasir), Selumit Pantai Sub-District, Lingkas Ujung Sub-District, and Juata Laut Sub-District. Data were obtained by directly distributing 150 questionnaires to respondents and conducting direct interviews. Respondents in this study were individuals (households) living in the

coastal area of Tarakan City.

We utilized both primary and secondary data. Field activities, in-depth interviews, and structured interviews provided the primary data, whereas secondary sources and prior research provided the secondary data. The sampling method was selected to acquire a representative sample: non-probability sampling (non-random sampling) and probability sampling (random sampling). We employed a random sampling technique known as area sampling to select respondents for structured interviews from study areas in coastal regions most impacted by coastal erosion, specifically those close to the sea.

The study measures the degree of community vulnerability to coastal disasters. The vulnerability study incorporates four distinct variables: physical, social, economic, and community capacity variables, which pertain to the community's understanding of disasters. Table 1 presents the parameters pertaining to community capacity and susceptibility of communities in the coastal metropolis of Tarakan to climate change. The variables and components of vulnerability utilized in this study along the coastal region of Tarakan City were formulated in accordance with the variable risk of climate change-induced disasters (Choirunisa & Giyarsih, 2016; Khan *et al*., 2022).

Table 1
Community Vulnerability and Capacity Parameters

Objective	Factor	Variable/Element	Description of Vulnerability Parameters
Vulnerability	Physique (Akhmadi *et al*., 2012; Angus & Hansom, 2021);	Distance from the Coastline	Houses nearer to the coasts are more vulnerable.
		House Type	Non-permanent houses (not yet complete with stones) are more vulnerable than permanent houses (full of stones).
	Social (Eghdami *et al*., 2023)	Gender	Female individuals are more vulnerable than male ones.
		Age	Children and elderly people are more vulnerable.
		Education	More educated individuals are less vulnerable.
		Disabilities	Disabled individuals are more vulnerable.
	Economy (Akhmadi *et al*., 2012; Maurischa *et al*., 2023)	Work	Employed individuals are less vulnerable.
		Income	Individuals earning income above the district or city minimum wage are less vulnerable.
		Number of low-income families	Communities with a higher proportion of low-income families are more vulnerable.
		Economic Facility	Communities with a higher proportion of low-income families are more vulnerable.
Community Capacity	Knowledge of disaster (Khan *et al*., 2022)	Knowledge of Coastal Disasters	Those with a better understanding of coastal disasters are less vulnerable.
		Knowledge of the Impact of Coastal Disasters	Those with a greater understanding of the impact of coastal disasters are less vulnerable.
		Knowledge of Coastal Disaster Management	Those with a greater understanding of coastal disaster management are less vulnerable.

Objective	Factor	Variable/Element	Description of Vulnerability Parameters
		Knowledge about returning sources of income due to coastal disasters	Those with a greater understanding of returning sources of income due to coastal disasters are less vulnerable.

Analysis of Physical, Social, and Economic Vulnerability

We analyzed the level of physical, social, and economic vulnerability to climate change-induced disasters in the coastal area of Tarakan City. Table 2 presents the vulnerability category of each indicator.

Table 2
Vulnerable Category on Physical, Social, and Economic Vulnerability Indicators

Vulnerability Indicator	Vulnerability Category of Each Variable		
	Low	Medium	High
	1	2	3
Distance from the Coastline	> 500 m	200 m – 500 m	< 200 m
House Type	Stone	Half stone	Plank
Gender (Female)	< 33%	33% - 66%	> 66%
Age (Elderly)	< 33%	33% - 66%	> 66%
Education	Graduated from senior high school, vocational, or college	Graduated from elementary or junior high school	Did not graduate from elementary school or did not go to school
Disabilities	0	1-2	> 2
Family members	1-3	4-6	> 6
Resident Status	Original	Migrant	
Job status	Work	Job seekers or retired	Doesn't work
Income	> IDR 5,000,000	IDR 2,500,000 - IDR 5,000,000	< IDR 2,500,000
Economic Facility	Car, land, house, or more than two treasures	Motorcycle	0 or Bicycle
Social assistance	>1	KIP/BLT/ PKH/KIS	0

Source: BPBD Kota Tarakan (2017); Setyaningrum & Giyarsih (2012)

Table 2 presents the vulnerable category on physical, social, and economic vulnerability indicators in accordance with Law No. 39 of 1999 concerning Human Rights. The elderly, infants, the poor, pregnant women, and disabled people are all classified as members of the vulnerable group. In contrast, the Indonesian Human Rights National Action Plan (RAN) for 2015–2019 delineates the following vulnerable populations: individuals with disabilities, the elderly, the impoverished, women, children, refugees, indigenous peoples, and migrant laborers. As per the provisions outlined in Paragraph 2 of Law Number 24 of 2007 on Disaster Management, the vulnerable populations mentioned in paragraph (1) comprise the following: infants, toddlers, and children; pregnant or nursing mothers; disabled individuals; and the elderly.

Community Capacity Analysis

The degree of community capacity is classified into three levels: low, medium, and high. Therefore, starting from a value of one hundred percent, it is divided into the following three intervals:

Table 3
Community Capacity Category Interval Classification

Interval	Category
0 – 33%	Low
34 – 66%	Medium
67 – 100%	High

Source: Sugiyono (2013)

The employed data analysis comprises an explanation of the Likert, Guttman, and rating scales, which have been categorized according to individuals' awareness of coastal disasters resulting from climate change.

Community Vulnerability and Capacity Relations

To measure the correlation between the level of physical, social, and economic vulnerability and community capacity from climate change that triggers disasters, this study uses the Spearman rank correlation test analysis.

$$rho = 1 - \frac{6 \sum d^2}{n\,(n^2-1)} \quad \text{..... 1}$$

where:
Rho : Spearman Rank correlation coefficient
d^2 : squared ranking
n : the amount of data or samples

ANALYSIS AND DISCUSSION

Level of physical, social, and economic vulnerability

The following are the attributes of each physical vulnerability variable based on the research findings:

Table 4
Characteristics of Respondents Based on Physical Vulnerability

Variable	Vulnerability Criteria	Respondents	Percentage
Distance from the Coastline	< 200 m	128	85%
	200 m – 500 m	16	11%
	> 500 m	6	4%
House Type	Plank	52	35%
	Half Stone	47	31%
	Full Stone	51	34%

Source: processed primary data, 2022

Table 4 demonstrates that out of the 150 respondents in the study, variables pertaining to distance from the coastline exhibited the highest prevalence of vulnerability factors: those with a distance of 200 m attracted 128 respondents (85%) of the total population; those falling within the range of 200 m–500 m attracted 16

respondents (11%), and those exceeding 500 m attracted as few as six respondents (4%). Regarding the vulnerability factor, the number of respondents for each house type is nearly identical: 52 for plank houses (35%), 47 for half-stone houses (31%), and 51 for full-stone houses (34%). The predominant house type along the coast of Tarakan City is the plank type, accounting for up to 35% of the entire sample of respondents.

Table 5
Characteristics of Respondents Based on Social Vulnerability

Variable	Vulnerability Criteria	Respondents	Percentage
Gender	Male	62	41%
	Female	88	59%
Age	< 50 years	122	81%
	> 50 years	28	19%
Education	Did not graduate from elementary school or did not go to school	27	18%
	Graduated from elementary or junior high school	26	17%
	Graduated from senior high school, vocational or college	97	65%
Disabilities	0	0	0
	1-2	0	
	>2	0	
Family members	1-3	49	33%
	4-6	87	58%
	>6	14	9%
Resident Status	Indigenous	88	59%
	Migrant	62	41%

Source: processed primary data, 2022

The findings of the study indicate that among the 150 participants, 88 (59%) identified as female, 122 (81%) were at least 50 years old, and 97 (65%) had completed high school, vocational high school, or university. Regarding educational attainment, 97 (65%) of the respondents had completed such programs. Regarding family members, 87 (58%) of the respondents belonged to households with four to six members living in one house. Indigenous people comprised the majority of respondents (88 or 59%) for population status variables in Tarakan City, while the disability variable had no respondents.

The following are the attributes of each economic vulnerability variable based on the research findings:

Table 6
Characteristics of Respondents Based on Economic Vulnerability

Variable	Vulnerability Criteria	Respondents	Percentage
Job status	Work	60	40%
	Job seekers or retired	14	9%
	Doesn't work	76	51%
Income	> IDR 5,000,000	10	7%
	IDR 2,500,000 - IDR 5,000,000	23	15%
	< IDR 2,500,000	117	78%
Economic Facility	0 or Bicycle	15	10%

Variable	Vulnerability Criteria	Respondents	Percentage
	Motorcycle	98	65%
	Car, land, house, or more than two treasures	37	25%
Social assistance	0	16	11%
	KIS/ KIP/BLT/PKH	75	50%
	>1	59	39%

Source: processed primary data, 2022

From the sample of 150 participants in the study, Table 6 reveals that non-working status dominated the employment status variable, with 76 respondents (51%) having income less than IDR 2,500,000 dominated the income criterion with 117 respondents (78%), the economic means variable was dominated by the criterion of only having a motorbike with a total of 98 respondents (65%), and the social assistance variable was dominated by the criteria of respondents who had KIS assistance (Healthy Indonesia Card) or KIP (Smart Indonesia Card) or BLT (Direct Cash Assistance) or PKH (Family Hope Program) with a total population of 75 respondents (50%).

Community Capacity

The level of community capacity arguably affects the level of disaster vulnerability in coastal areas. The research results illustrate the following characteristics of each community capacity variable:

Table 7
Characteristics of Respondents Based on Community Capacity

Community Capacity	Capacity Criteria	Respondents	Percentage	Information
Knowledge of Coastal Disasters	Feeling climate change	127	85%	The population is dominated by residents who know or can provide information regarding disasters on the coast.
	Feel the disaster	140	93%	
	Located in a disaster-prone area	113	75%	
	The Disaster That Arises	150	100%	
	Disaster Event Intensity	148	99%	
Knowledge of the Impact of Coastal Disasters	Risks to the Environment	148	99%	The population is dominated by residents who know or can provide information on questions regarding the impact of disasters on the coast.
	Issued Funds	148	99%	
	Felt Impact	150	100%	
	Loss Estimation	150	100%	
Knowledge of Coastal Disaster Management	Trusted institution for disaster mitigation	150	100%	The population is dominated by residents who do not have facilities for preparing for post-disaster handling. Even though the
	Disaster Response Outreach	69	46%	
	Community Group	10	7%	
	Government Programs	43	29%	

Community Capacity	Capacity Criteria	Respondents	Percentage	Information
				institutions trusted for disaster mitigation exist within the community, the level of public trust is dominated by low choice.
Knowledge about returning sources of income due to coastal disasters.	Post-Disaster Assistance Jobs other than the coast How to return a source of income Discussion on strengthening the economy, technology, and poverty alleviation	25 33 61 8	17% 22% 41% 5%	The population is dominated by residents who are considered to have difficulty returning to their source of income after the disaster on the coast because they do not have facilities.

Source: processed primary data, 2022

Analysis of the Classification of Physical, Social, and Economic Vulnerability Levels

The physical, social, and economic vulnerability was classified by processing research data using a Likert scale whose scores were adjusted based on the level of vulnerability of each criterion for physical, social, and economic vulnerability variables. Hence, higher scores indicate greater vulnerability. Nonetheless, numerous analyses were conducted by quantifying the population mean proportion corresponding to each criterion; for instance, the social vulnerability variable incorporates age and gender as criteria.

Table 8
Analysis of Physical, Social, and Economic Vulnerability

Variable	Percentage	Interpretation
Physical Vulnerability Analysis		
Distance from the Coastline	92%	High level of vulnerability to disaster.
House Type	67%	High level of vulnerability to disaster
Social Vulnerability Analysis		
Gender	54%	Medium level of vulnerability to disasters
Age	12%	Low level of vulnerability to disaster
Education	45%	Medium level of vulnerability to disasters
Disabilities	0	Low level of vulnerability to disaster
Family members	59%	Medium level of vulnerability to disasters
Resident Status	71%	High level of vulnerability to disaster
Economic Vulnerability Analysis		
Job	62%	Medium level of vulnerability to disasters
Income	90%	High level of vulnerability to disaster
Economic Facility	62%	Medium level of vulnerability to disasters
Social assistance	57%	Medium level of vulnerability to disasters

Source: processed primary data, 2022

Based on Table 8 of the physical vulnerability classification, the analysis results of the two variables indicate a significant degree of susceptibility, as evidenced by the distance from the coast (92%). Due to its proximity to the coast, the residence is exceptionally vulnerable to coastal disasters (Alam *et al*., 2017). The dwelling type also exhibits a similar pattern (67%). Upon calculation, the resulting value of 80% signifies a high level of average vulnerability to physical variables.



Figure 1
Settlements on the Coast of Tarakan City
Source: Primary Data (Personal Documentation), 2022

Figure 1 illustrates an example of a vulnerable house located along the coast of Tarakan City. The house's location on the water is within a vulnerable proximity of less than 10 meters to the coastlines. Moreover, it is of the plank house variety, which explains why this house falls under the high vulnerability classification for physical variables. This coastal community holds historical significance for Tarakan City as it was the initial settlement established in the area (Figure 1). People who have lived on the coast and been exposed to floods for years have developed houses on stilts to adjust to flood disasters. The defining attributes of a stilt house are synonymous with the pillars that support its foundation. This adapts to the prevailing conditions along the riverbanks, subject to the impact of the river's tides. Despite their inception as a response to flood, stilt houses remain vulnerable to the detrimental consequences of flood damage (Nurhidayati & Fariz, 2021). Due to their direct exposure to river water, houses elevated on stilts directly above a river are susceptible to damage to their foundation pillars, floor, and kitchen. In addition, the walls, terrace, and roof sustained light damage because they were not exposed to the river water directly. As shown in Figure 1, flood in areas not directly above the river obstructs road access. Ramadhan & Chamid (2022) identified vulnerability according to home type. Homes with building types costing less than IDR 400 million are relatively secure.

Social vulnerability is evaluated by considering the social aspects of the coastal communities of Tarakan City that are considered significant and affect the vulnerability to disasters along the coast. This assessment is conducted in accordance with established regulations and accredited sources. An analysis was conducted on the

gender and age criteria using population data from the study area. This was accomplished by calculating the average percentage of vulnerable populations according to the two criteria. The results of the analysis indicate, as shown in Table 8 that the classification of social vulnerability reveals that the majority of each vulnerability criterion carries is medium, with details of gender (54%), education (45%), and family members (59%). The population status criteria denote a significant degree of vulnerability (71%). The age criterion is categorized as having a low vulnerability (17%). In contrast, the vulnerability level pertaining to disability is minimal (0), as there are no respondents who identify as having a disability. This proportion falls within the moderate range, amounting to 52% upon averaging.

The population status indicator exhibits the greatest vulnerability within the physical vulnerability variable, attaining 71% (high vulnerability). Migrants are less vulnerable than indigenous populations (Mustafa *et al*., 2023; Zhou *et al*., 2021). The subsequent maximum degree of vulnerability is attributed to the quantity of family members (59%). In migrant coastal regions, the vulnerability of households to disasters increases with the magnitude of their family size (Putiamini *et al*., 2022). Women are more vulnerable to disasters due to the social roles that have been established by society. Prior studies have established that women are vulnerable to disasters (Babanawo *et al*., 2023; Khan *et al*., 2022).

Additionally, population density also affects vulnerability classification; a densely populated region is arguably more vulnerable. According to data provided by the Badan Pusat Statistik (2021), the population density of Tarakan City is projected to reach 979.67 inhabitants per square kilometre in 2021. This translates to 979–980 inhabitants per square kilometre, indicating that the area is densely populated and consequently has a high level of vulnerability. notably elevated in the coastal metropolis of Tarakan (Ehrlich *et al*., 2018).

The economic dimension of disaster vulnerability in the coastal city of Tarakan is assessed by examining the community's financial resilience in the face of climate change-induced catastrophes (Barbier, 2015). According to Table 8 of the classification of economic vulnerability, the majority of the percentages for each vulnerability criterion are categorized as medium. This is particularly true for social assistance (57%), economic facilities (62%), and employment (62%). The income criterion is classified as high vulnerability at a 90% level percentage because most respondents fall into disaster-prone groups or individuals, specifically those with an income below IDR 2,500,000. This proportion falls within the moderate range, amounting to 52% upon averaging.

Community Capacity Analysis

Table 9 presents the percentages of communities residing in the coastal region of Tarakan City that meet the medium to high-capacity levels for each capacity criterion. Specifically, the following are the details: knowledge of the existence of

disasters (78%), understanding of disaster management in coastal areas (74%), knowledge of returning sources of income (post-disaster adaptation) as a result of coastal disasters (89%), and knowledge of the existence and impact of coastal disasters (66%). When calculated as an average, all proportions of community capacity fall within the high-capacity category, totalling 69%. This indicates that the coastal communities residing in Tarakan City possess a considerable capacity for understanding coastal disasters. This value is considered positive because coastal communities, particularly in Tarakan City, can readily adjust to climate change-induced disasters if they have adequate knowledge of such occurrences. Increasingly, coastal hazards pose a grave threat to the welfare of coastal communities. Adaptive responses to these dangers have also been identified in other coastal regions. Particularly in remote islands and rural regions of the Pacific Islands, community knowledge of the perils of coastal disasters can foster an appreciation for indigenous wisdom in disaster adaptation (Narayan *et al*., 2020). Al-Maruf *et al*. (2023) explored the coastal region of Bangladesh. The findings indicate that human capital is an important resource that enables and facilitates using other resources in household responses to floods, storm surges, and another typhoon damage.

Table 9
Community Capacity Analysis

Community Capacity	Percentage	Interpretation
Knowledge of Coastal Disasters	78%	The level of community capacity for knowledge about the existence of a disaster is high.
Knowledge of the Impact of Coastal Disasters	75%	The level of community capacity for knowledge about the impact of disasters is high.
Knowledge of Coastal Disaster Management	64%	The community's capacity level for knowledge about disaster management is high.
Knowledge about returning sources of income due to coastal disasters (post-disaster adaptation)	61%	The level of community capacity for knowledge about post-disaster adaptation is high.

Source: processed primary data, 2022

However, several aspects of government policies pertaining to disaster response and remote catastrophe communities must be addressed (Kartini & Irna, 2023). For instance, the majority of respondents acknowledged experiencing climate change and believed that it was the cause of a catastrophe. Although several disaster indicators are detrimental to the community, they cannot access post-disaster assistance or disaster outreach facilities.

Correlation Test Analysis of Physical, Social, and Economic Vulnerability to Community Capacity

The correlation test results indicate a very low relationship between the vulnerability variables and the population's capacity along the coast of Tarakan City. Table 10 presents the correlation test results.

Table 10
Results of the Correlation Test Analysis of the Relationship of Physical, Social, and Economic Vulnerability to Community Capacity

Community Capacity	Capacity Criteria		Physique	Social	Economy
Knowledge of Coastal Disasters	Feeling climate change	Rho	0.076	-0.056	-0.090
		Sig	0.356	0.495	0.274
	Feel the disaster	Rho	-0.034	0.062	-0.077
		Sig	0.678	0.455	0.350
	Located in a disaster-prone area	Rho	-0.208*	0.009	-0.051
		Sig	0.011	0.911	0.532
	The Disaster That Arises	Rho	0.150	-0.061	0.024
		Sig	0.066	0.462	0.770
	Disaster Event Intensity	Rho	-0.095	0.105	0.007
		Sig	0.247	0.202	0.935
Knowledge of the Impact of Coastal Disasters	Risks to the Environment	Rho	0.190*	-0.109	0.002
		Sig	0.020	0.184	0.983
	Issued Funds	Rho	0.144	0.082	0.045
		Sig	0.078	0.318	0.583
	Felt Impact	Rho	0.136	0.035	-0.189*
		Sig	0.097	0.668	0.021
	Loss Estimation	Rho	0.064	-0.096	0.014
		Sig	0.437	0.244	0.862
Knowledge of Coastal Disaster Management	Trusted institution for disaster mitigation	Rho	0.034	0.047	-0.099
		Sig	0.678	0.568	0.228
	Disaster Response Outreach	Rho	0.017	-0.143	0.094
		Sig	0.835	0.081	0.254
	Community Group	Rho	0.057	0.097	0.067
		Sig	0.487	0.238	0.416
	Government Programs	Rho	0.179*	0.044	-0.049
		Sig	0.028	0.589	0.548
Knowledge about returning sources of income due to coastal disasters	Post-Disaster Assistance	Rho	0.036	0.022	0.059
		Sig	0.660	0.792	0.474
	Jobs other than the coast	Rho	-0.018	0.042	-0.077
		Sig	0.828	0.612	0.351
	How to return a source of income	Rho	-0.199*	-0.227**	0.058
		Sig	0.015	0.005	0.483
	Discussion on strengthening the economy, technology, and poverty alleviation	Rho	0.144	0.082	0.045
		Sig	0.078	0.318	0.583

Notes: *, ** indicate that correlation is significant at the 0.05 and 0.01 levels (2-tailed), respectively.
Source: processed primary data, 2022

In contrast, there is no correlation between community capacity variables (distance from the coast, residence, and employment status) and physical, social, and economic vulnerability variables (where rho is negligible or insignificant). The rho for the physical variables (distance) and being in the disaster area is -0.208, with a significance level of 0.011. Hence, these two variables have a negative correlation (not in the same direction) with a very weak coefficient. Risk to the environment and the physical variable (distance) have a rho of 0.190 and a significance of 0.020, indicating that both variables are related with a very weak coefficient. The perceived impact and the economic variable (occupation) have a rho of -0.189 and a significance of 0.021, indicating that both variables have a negative correlation (not in the same direction) with a very weak coefficient.

The correlation between the physical variable (distance) and government programs has a rho = 0.179, p < 0.028, indicating that both variables are very weakly associated. The physical variable (distance) and the method of returning the source of income have a rho of -0.199 and a significance of 0.015, indicating that the two variables have a negative correlation (not in the same direction) and a very weak coefficient. Furthermore, the correlation between social variables (specifically, population status) and how sources of income are returned is -0.227, with a significance level of 0.005. This indicates that the two variables are negatively correlated and have a weak coefficient. Consequently, the degree of community capacity is virtually unrelated to the physical, social, and economic vulnerability along the coast of Tarakan City (Maurischa *et al*., 2023). Hence, the vulnerability of the Tarakan City coastline to vulnerability is attributable to the vulnerability factors themselves. Furthermore, due to the community's limited comprehension of disasters, the resulting perception is insufficient; consequently, disasters are regarded as transient circumstances (Lambrou *et al*., 2023; Setyaningrum & Giyarsih, 2012).

The analysis findings indicate a weak correlation between vulnerability to coastal disasters and community capacity. Hence, despite having a high disaster capacity, the coastal communities of Tarakan City remain potentially vulnerable to disaster risks. This results in a diminished awareness of the dangers associated with disasters. Community preparedness for disasters includes a solid grasp of the subject matter, particularly for those who reside in a potential disaster zone. Kusumastuti *et al.* (2021) investigated disasters in Lombok and revealed that respondents residing in safe zones exhibit better disaster-related knowledge than those living in vulnerable zones. This condition suggests that respondents in vulnerable areas tend to be better prepared to anticipate disasters.

CONCLUSIONS, LIMITATIONS, AND SUGGESTIONS

Our results suggest that the variable distance from the coastline exhibits a vulnerability percentage of 92% in the context of physical vulnerability classification. This finding suggests that the variable significantly affects the vulnerability to disasters because most of Tarakan City's coastal communities reside in structures within a 200-meter vulnerable distance. In contrast, the variable representing dwelling type exhibits a vulnerability percentage of 67%, corresponding to a high susceptibility level to disasters. This is because most of Tarakan City's coastal communities reside in vulnerable structures, such as dwellings or plank buildings. As a result, the mean degree of vulnerability concerning physical vulnerability is medium (80%). An equivalent degree of vulnerability is attributed to both social and economic aspects of vulnerability, each with its own classification of medium (52%).

When considering the vulnerable category from a social perspective, one must account for migrants not deemed to have control over the territory, adapting to

disasters likely to be challenging (Huynh & Stringer, 2018). In the economic aspect, it is imperative to consider income criteria, as stable community income fundamentally supports the community's adaptive capacity (Eghdami *et al*., 2023). The classification of community capacity is at a high level (69%), indicating that the coastal community of Tarakan City has a high capacity for knowledge of coastal disasters. This value is considered positive because knowledge of coastal disasters enables coastal communities to adapt easily to climate change-induced disasters. However, implementing government policies to assist disaster response communities and deal with disasters is also contingent on several other factors. For instance, many participants reported perceiving climate change, experiencing a climate-induced disaster, and perceiving the consequences of multiple disaster indicators as detrimental to the community. However, they did not perceive infrastructure such as post-disaster assistance or disaster socialization.

The correlation analysis between physical, social, and economic vulnerability and community capacity reveals that only six of the seventeen capacity criteria examined have significant relationships with very weak coefficients. These relationships are as follows: distance and proximity to a disaster-prone area (-0.208), distance and environmental risks (0.190), work and the extent of the impact experienced (-0.189), distance and government programs (0.179), and distance and methods of returning sources of income (-0.199), as well as the status of residence and ways to return sources of income (0.227). The findings suggest that the vulnerability along the coast of Tarakan City might not be attributable to the community's inadequate disaster response capabilities but rather to their vulnerability factors. For instance, the proximity or even crossing of the coastline between the houses of the people of Tarakan City, their relatively low income, and the vulnerable age of the population residing in the coastal region of Tarakan City all contribute to the fact that individuals with low income may be ill-equipped to handle disasters when they occur, particularly in the realm of economics. Concerning the mitigation of vulnerability, the community's capacity is beyond your control; however, one can reduce the number of factors that comprise vulnerability categories, as determined by relevant agencies and the law concerning vulnerable groups.

Nevertheless, the Tarakan City Regional Disaster Management Agency has devised an adaptive capacity strategy to assist the community in enhancing their capacity to cope with disasters. An adaptive capacity assessment is conducted by determining the status of the capacity of governmental and non-governmental organizations, communities, and individuals to deal with threats using the resources at their disposal for prevention, mitigation, and emergency response, as well as to address existing vulnerabilities using the community's capacity.

Additional research on community capacity is required to supplement the results obtained from this study. In this respect, the issue pertains to knowledge and the community's proficiency in managing calamity risks. Moreover, assessment of vulnerability levels can be accomplished through approaches that involve greater

proximity to the affected populace, such as involving the community, policymakers, or local government, as they possess first-hand knowledge of the prevailing circumstances and surroundings. In addition, it is imperative to address and resolve conflicts and misunderstandings that may arise between the community and policymakers or the government to mitigate the hazards associated with coastal erosion.

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APPENDIX

Table 11
Analysis of Physical Vulnerabilities

Item	Number of Items	Score	F	E Average score	%
Distance from Coastal Line	150	< 200 m (3)	128	384	92%
		200 m - 500 m (2)	16	32	8%
		> 500 m (1)	6	6	1%
Total			150	416	100%
Maximum Score			450		
Average Percentage			92%		
Criteria			Vulnerable		
House Type	150	Plank House (3)	52	156	52%
		Half-stone House (2)	47	94	31%
		Full-stone House (1)	51	51	17%
Total			150	301	100%
Maximum Score			450		
Average Percentage			67%		
Criteria			Vulnerable		
Average			80%		
Criteria			High		

Table 12
Analysis of Social Vulnerabilities

Item	Number of Items	Score	F	E Average Score	%
Disabled Individuals	0				
Total			0	0	0%
Maximum Score			0		
Average Percentage			0		
Criteria			Not Vulnerable		
Demographics	150	Indigenous (1)	88	88	42%
		Migrants (2)	62	124	58%
Total			150	212	100%
Maximum Score			300		
Average Percentage			71%		
Criteria			Vulnerable		
Number of Family Members	150	<=3 (1)	49	49	18%
		>3, <=6 (2)	87	174	66%
		>6 (3)	14	42	16%
Total			150	265	100%
Maximum Score			450		
Average Percentage			59%		
Criteria			Medium		
Scholar	150	Senior High School/Tertiary (1)	97	97	48%
		Elementary/ Junior High School (2)	53	106	52%
		0 (3)	0	0	0%
Total			150	203	100%
Maximum Score			450		
Average Percentage			45%		
Criteria			Medium		
Average			52%		
Criteria			Medium		

Table 13
Analysis of Social Vulnerability Based on Sex

Sub-District	Male Population	Female Population	Total	Sex Ratio
Karanganyar Pantai	11.455	10.527	21.982	48%
Selumit Pantai	9.887	8.805	18.692	47%
Lingkas Ujung	6.411	5.887	12.298	48%
Mamburungan	5.481	5.058	10.539	48%
Pantai Amal	4.618	8.394	13.012	65%
Juata Laut	7.956	14.407	22.363	64%
Total	45.808	53.078	98.886	54%

Table 14
Analysis of Social Vulnerability Based on Age

Sub-District	Age >50 years, male	Age >50 years, female	Total	Sex Ratio
Karanganyar Pantai	1.669	1.418	3.087	14%
Selumit Pantai	1.515	1.387	2.902	16%
Lingkas Ujung	1.026	901	1.927	16%
Mamburungan	705	561	1.266	12%
Pantai Amal	577	445	1.022	8%
Juata Laut	1.148	958	2.106	9%
Total	6.640	5.670	12.310	12%

Table 15
Analysis of Economic Vulnerabilities

Item	Number of Items	Score	F	E Average Score	%
Occupation	150	Employed (1)	78	78	28%
		Job Seeker/Pensioner (2)	14	28	10%
		Unemployed (3)	58	174	62%
Total			150	280	100%
Maximum Score				450	
Average Percentage				62%	
Criteria				Medium	
Income	150	> 5 million (1)	10	10	2%
		2,5 million - 5 million (2)	23	46	11%
		< 2,5 million (3)	117	351	86%
Total			150	407	100%
Maximum Score				450	
Average Percentage				90%	
Criteria				Vulnerable	
Economic Assets	150	Car/Land/>2 assets (1)	37	37	13%
		Motorcycle (2)	98	196	71%
		Bicycle/0 (3)	15	45	16%
Total			150	278	100%
Maximum Score				450	
Average Percentage				62%	
Criteria				Medium	
Social Assistance	150	KIP, PKH, BLT (1)	78	78	33%
		KIS (2)	56	112	47%
		0 (3)	16	48	20%
Total			150	238	100%
Maximum Score				450	
Average Percentage				53%	
Criteria				Medium	
Average			51%		
Criteria			Medium		

Table 16
Analysis of Community Capacity

Item	Number of Items	Score	F	E Average Score	%
Aware of Disasters	150	Yes (2)	380	760	92%
		No (1)	70	70	8%
Total			450	830	100%
Maximum Score				900	
Average Percentage				92%	
Criteria				High	
Event Intensity	150	1 (2)	41	82	16%
		2 (3)	43	129	25%
		3 (4)	22	88	17%
		3+ (5)	42	210	41%
		0 (1)	2	2	0%
Total			150	511	100%
Maximum Score				750	
Average Percentage				68%	
Criteria				High	
Occurring Disasters	150	Yes (2)	277	554	63%
		No (1)	323	323	37%
Total			600	877	100%
Maximum Score				1200	
Average Percentage				73%	
Criteria				High	
Average				78%	
Criteria				High	

Table 17
Summarized SPSS Outputs on Spearman Correlation Test

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Spearman's rho	Distance to Coastal Lines	Correlation Coefficient	1.000	0.000	0.077	0.076	-0.034	-0.208*	0.150	-0.095	0.190*	0.161*	-0.199*	0.144	0.136	0.064	0.034	0.017	0.057	0.179*	0.036	-0.018
		Sig. (2-tailed)	0.000	0.995	0.352	0.356	0.678	0.011	0.066	0.247	0.020	0.050	0.015	0.078	0.097	0.437	0.678	0.835	0.487	0.028	0.660	0.828
		N	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
	Demographic Status	Correlation Coefficient	0.000	1.000	0.032	-0.056	0.062	0.009	-0.061	0.105	-0.109	-0.027	-0.227**	0.082	0.035	-0.096	0.047	-0.143	0.097	0.044	0.022	0.042
		Sig. (2-tailed)	0.995	0.0	0.701	0.495	0.455	0.911	0.462	0.202	0.184	0.747	0.005	0.318	0.668	0.244	0.568	0.081	0.238	0.589	0.792	0.612
		N	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
	Occupation	Correlation Coefficient	0.077	0.032	1.000	-0.090	-0.077	-0.051	0.024	0.007	0.002	0.032	0.058	0.045	-0.189*	0.014	-0.099	0.094	0.067	-0.049	0.059	-0.077
		Sig. (2-tailed)	0.352	0.701	0.0	0.274	0.350	0.532	0.770	0.935	0.983	0.698	0.483	0.583	0.021	0.862	0.228	0.254	0.416	0.548	0.474	0.351
		N	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150

1. Distance to Coastal Lines
2. Demographic Status
3. Occupation
4. Experiencing Climate Change
5. Occurring Disasters
6. Living in Disaster-prone Areas
7. Occurring Disasters
8. Even Intensity
9. Disaster Risks
10. Costs Incurred
11. Impacts Experienced
12. Estimated Losses
13. Mitigated Institutions
14. Socialization of Disaster Responsiveness
15. Community Groups
16. Government Programs
17. Post-Disaster Aids
18. Non-coastal Occupation
19. Ways to Improve Income
20. Technological Improvement

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed)