Tsunami Disaster Risk Reduction Strategy in Ciletuh –Palabuhanratu UNESCO Global Geopark

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Abstract. Indonesia's tsunami-prone areas are primarily located in the Pacific Ring of Fire, where the collision of three active tectonic plates (Eurasia, Indo-Australia, Pacific) results in significant seismic activity. This geological condition places several coastal regions at high risk, particularly for earthquakes and tsunamis. One such area is the Ciletuh-Palabuhanratu UNESCO Global Geopark (CPUGG) in Sukabumi Regency. This study aims to develop a tsunami disaster risk reduction strategy for the region, using a quantitative descriptive method. The study finds that the tsunami disaster risk level in CPUGG is 0.64, indicating a moderate risk that borders on high. The proposed risk reduction strategies are categorized into three levels, focusing on government, community, business, and tourist preparedness. The findings highlight that most hazard and vulnerability indicators remain high, while tourist capacity and preparedness are at a moderate level. The strategies suggested by the study could serve as valuable input for mitigating tsunami risks in CPUGG.

1 Introduction

Indonesia, with its many islands and long coastline, presents a unique and natural beauty that can attract tourists to come, so that tourism activities can develop and produce positive impacts by participating in improving the economy and people's income [1,2]. Many coastal areas are utilized by the government and the community as tourism spots, such as those in the coastal areas of the straits of the islands of Sumatra, Java, Bali and other islands which are the leading destinations for domestic and foreign tourists on each island [3,4]. In addition, many coastal areas in Indonesia are used for human life, such as residential areas, industrial areas, aquaculture areas, port areas and so on [5–7].

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In accordance with its development, Indonesia's increasingly complex coastal areas are used by various sectors and provide various benefits for human life. On the other hand, this area has a high enough disaster risk for both tourism areas and other areas on the coast. The coastal areas of the southern part of Indonesia are directly adjacent to the Indian Ocean and the Indo-Australian plate which have a very high threat of earthquakes and tsunamis [8,9]. Where the tsunami is a natural disaster that has a risk of threatening people who live and are in coastal areas and not only that the coastal tourism area is also threatened by the risk of a tsunami that can occur at any time [10].

Indonesia has a fairly high level of earthquake and tsunami disasters in the world, due to the frequent occurrence of earthquakes and tsunamis, especially in coastal areas of tourism areas which often cause more fatalities than other areas [9,11,12]. The earthquake disaster followed by the tsunami in Pangandaran, Aceh, Palu, as well as several parts of Indonesia, has made the public aware of the importance of studying disaster risk reduction strategies in coastal areas, especially tourism areas in dealing with earthquake and tsunami disasters so that tourists are prepared for disasters can minimize casualties in the event of a disaster [13 17].

The coastal tourism area of Sukabumi Regency is an area that is prone to Earthquake and Tsunami disasters [18]. The Sukabumi Regency area, especially the tourism area, is an area directly facing the Indian Ocean which has a depth of more than 100 meters. The area is a confluence between the Eurasian plate and the Indo-Australian plate, where plate movement often occurs which allows earthquakes to be followed by tsunamis. One of the areas directly adjacent to the Indian Ocean in Sukabumi district is the Ciletuh Palabuhanratu UNESCO Global Geopark tourism area which is located adjacent to the subduction zone [19 22]. This area has a coastal morphology that tends to be flat, so it has a high risk of a tsunami disaster. On the other hand, besides the potential for disaster, the Ciletuh Palabuhanratu UNESCO Global Geopark tourism area has great potential as a coastal tourism area and was selected as one of the nine leading tourist areas at the West Java Province level based on the uniqueness of the location and the high intensity of tourist visits [23,24]. In addition, Pelabuhanratu District, which is in the tourism area, is the capital of Sukabumi Regency, where there are many government offices and district-level facilities operating.

With the natural hazard potential that is owned as well as a leading tourist area and as a center of activity at the district level, the Ciletuh Palabuhanratu UNESCO Global Geopark tourism area has a great risk of earthquakes and tsunamis [25 27]. Disasters that occur in tourism areas will cause losses and casualties, the amount of which depends on the characteristics of the threat, vulnerability, and capacity of a tourism area. Losses will greatly affect survival, if local people's lives depend heavily on tourism, besides that sudden disasters such as earthquakes and tsunamis can endanger visitors to tourist attractions, especially if the disaster occurs when the tourist site is crowded with visitors, then the loss and the loss of life will be enormous. The strategic aspect of disaster risk reduction is very important to be implemented in tourism areas, especially in the Ciletuh Palabuhanratu UNESCO Global Geopark tourism area, so that a disaster-responsive tourism area is created. Therefore, this study aims to determine the tsunami disaster risk reduction strategy in the Ciletuh Palabuhanratu UNESCO Global Geopark tourism area.

2 Literature Review

2.1 Tsunami Disaster Risk Assessment

Indonesia's territory is located at the confluence of three plates which results in being surrounded by the ring of fire and flanked by two oceans, making Indonesia a disaster-prone

region. In 2005, UNESCO placed Indonesia in 7th place as the most vulnerable country in the world [28,29]. This determination has an impact on the tourism sector where the interest of tourists to visit is decreasing. With the high potential for disaster, it must be accompanied by good mitigation in the tourism sector, this is important so that the safety of tourists can be guaranteed. According to the Asian Disaster Reduction Center [30] a disaster is a serious disturbance to society that causes widespread losses and can be felt by the community, various materials and the environment where the impact exceeds human ability to overcome it with existing resources.

Measurements in analyzing disaster risk are a tool for measuring possible losses that can be incurred due to existing disaster threats [31–33]. With the emergence of possible losses, it will make it easier to deal with disasters that will occur. In other words, disaster risk assessment is a tool for measuring potential disasters and disaster management that can be carried out in an area [34–36]. Tsunami-prone areas are one of the areas that are required to have a risk assessment analysis. Coastal areas tend to be complex with community activities within them, and therefore, in order to ensure community safety, a coastal area tsunami disaster risk assessment must be carried out in each region [25,37,38].
The following is an overview of the tsunami disaster risk assessment in coastal area:

Table 1. Overview of the Tsunami Disaster Risk Assessment

Overview	Disaster Risk Notation	Explanation
1) Risk assesment and management for tsunami hazard, 2011 [39]	Risk = Hazard x Vurnerability	Risk can be measured as the harm associated with the likelihood of a disaster occurring and with the vulnerability of people to potential damage and loss.
	Risk = (Hazard x Vurnerability) / Capacity	Capacity is a system used by the community to use resources, abilities and knowledge to deal with adverse conditions caused by disasters.
	Risk = Hazard x Vurnerability x Deficiencies in preparedness	A planned approach to disaster preparedness and dealing with major disasters saves lives. Which focuses on readiness in relation to capacity.
2) Regulation of the Head of BNPB number 4 of 2012 [40]	Risk = (Hazard x Vurnerability) / Capacity	This approach focuses on showing the relationship between threats, vulnerabilities and capacities which will build views on the level of risk of a tsunami disaster in an area.

According to Law no. 24 of 2007 concerning Disaster Management [41] The potential losses resulting from a disaster in a certain area can be in the form of loss of security, disease, injury, death and/or loss of property, which is called disaster risk. All risks that can befall the community can be mitigated depending on the community's preparedness. The components of threat or danger, capacity and vulnerability are indicators in measuring the potential for disaster in an area.

When talking about the threat of disaster, a threat event indicates the possibility of a disaster that will occur in an area. Meanwhile, vulnerability is related to the magnitude of potential disasters that can be received and cause loss of life for the community. In other words, the greater the threat of a major disaster, the greater the vulnerability that society will accept. In assessing a disaster risk, the level of threat, vulnerability and capacity of an area in dealing with disasters will be known [42,43].

2.2 Overview of Disaster Risk Reduction Strategy

Disaster risk reduction is a concept and implementation of a disaster risk reduction program through systematic efforts to manage and analyze the causal factors of a disaster, including

through reducing hazard exposure, reducing human and property vulnerability, managing land and the environment in a sustainable manner [44–46]. prudent, and increased preparedness for adverse events [47].

Minimizing the losses caused by the tsunami disaster requires progress and sustainable ways both in terms of risk assessment, intergovernmental coordination, public education, detection and studies, and operation of warning centers. Sustained efforts are needed by the community and the government to prepare for eventualities that could occur years or decades in the future when a disaster occurs. But a catastrophic event only takes minutes to respond and save yourself. The tsunami risk reduction process must involve various components including:

1) Development of a tsunami hazard and risk assessment for all coastal areas.
2) Improved tsunami warning systems through advances in seismic and tsunami data collection.
3) Improve tsunami forecasting and tsunami warning capabilities throughout tsunami risk areas.
4) Provide scientific and technical knowledge to the community to facilitate international tsunami hazard development.
5) Promote the development of mitigation model measures and encourage communities to adopt land use planning practices that can reduce the impact of the tsunami on their territories.
6) Raising awareness, increasing preparedness, encouraging the development of tsunami response, mitigation and evacuation plans.

In the book Tsunami Preparedness Civil Protection – Good Practice Guide, 2012 [48], there are three stages in disaster risk reduction including preparedness and awareness before a tsunami occurs, recommendations for strategies during the tsunami, and recommendations for strategies after the tsunami. The following is an explanation of the three stages:

1) Pre-tsunami preparedness and awareness strategies

   In the pre-tsunami phase, the government and the community are required to have a strategy of preparedness and awareness of the potential for a tsunami disaster in the area they live in. Among them (1) having urban / regional and coastal planning to avoid or limit the possibility of damage in the event of a tsunami disaster. (2) Having public awareness in the form of training and education is an important aspect of the tsunami mitigation program. This could have avoided more fatalities and limited the possibility of damage in the event of a tsunami. (3) There are tsunami boards and signs as an essential component of any tsunami risk management system and an effective tsunami warning system. (4) Evacuation map depicting the maximum level of tsunami inundation and having routes for people out of the tsunami hazard zone to a safe place.
2) Recommended Strategies During a Tsunami

   (1) Individual and community responses must be calm, move to a higher place (following the evacuation route) and avoid returning to the beach until the situation is safe. (2) The government must activate emergency plans and emergency services must be immediately used in disseminating information, warning and guiding residents to safer locations.
3) Post Tsunami Strategy Recommendations

   (1) Individual and community responses create organizations that focus on preparedness issues and integrate tsunami preparedness into other institutions such as schools and businesses (2) create a series of rules and regulations to incorporate tsunami hazard into short and long term planning processes.

2.3 Tsunami Disaster Risk Assessment Framework

The measurement of the tsunami disaster risk assessment for the Ciletuh–Pelabuhanratu UNESCO Global Geopark area uses a framework which is an integration of all the literature used and also adapted to research [49] regarding risk assessment. The hazard and vulnerability literature is taken from the Regulation of the National Disaster Management Agency Number 02 of 2012 concerning General Guidelines for Disaster Risk Assessment. Furthermore, the capacity literature consists of a combination of three reference literatures. The first is Tsunami Preparedness Civil Protection – Good Practices Guide 2012, [48]. This literature focuses on three phases, namely the first phase of the strategy before the tsunami occurred, the second phase during the tsunami and the third phase of the strategy after the tsunami occurred. From this first literature, there are 3 stages, 9 targets and 30 indicators. The second literature is Tsunami risk assessment and mitigation for the Indian ocean - knowing tour tsunami risk and what to do about it July 2015 [47]. In this literature there are 3 phases, namely the first is preparedness in the context of early warning, the second is readiness to respond during and after the tsunami and the third is a risk transfer mechanism. From this second literature there are 3 phases and 19 indicators. The third literature is PP RI No. 64 of 2010 concerning disaster mitigation in coastal areas of small islands [50]. This third literature focuses on two subjects with 14 indicators.

From the three literatures above, an assessment was carried out to see whether there were indicators that overlapped one another. After this, it is adjusted to the disaster management phase by adjusting the existing conditions of the Ciletuh–Pelabuhanratu UNESCO Global Geopark. So based on the synthesis results obtained with 4 phases, 8 variables, 24 indicators and 53 sub-indicators for capacity.

3 Method

This research method uses a quantitative research approach with data analysis method used is risk analysis (R) in the form of vulnerability analysis and capacity analysis and analysis of tsunami disaster risk reduction strategies in the Ciletuh–Pelabuhanratu UNESCO Global Geopark [51,52]. The quantitative research approach is a method that uses research data in the form of numbers and analyzes using statistics. Quantitative research with a descriptive format is research that aims to explain, summarize and conclude the conditions or situations of various variables that arise in society as research objects. The quantitative approach was chosen because primary data was collected through an interview process referring to a questionnaire base for respondents in the Ciletuh Palabuhanratu UNESCO Global Geopark Tourism Area. The research results will be described in the form of tables, figures, charts, maps and descriptions. The general basic formula for risk analysis is as follows:

$$R = Hx\frac{V}{C} \quad (1)$$

Information:
R : Disaster Risk
H : Hazard Threat
V : Vulnerability
C : Adaptive Capacity

In disaster risk studies, the results of calculating vulnerability and threat have a straight relationship, while capacity is the opposite of disaster risk itself. It can be concluded that the higher the value of vulnerability and threat, the higher the level of disaster risk, while the higher the capacity, the lower the value of disaster risk in a place. Based on these conclusions, the formula for calculating disaster risk is as follows:

$$Risk = \sqrt[3]{Hazard\ x\ Vulnerability\ x\ (1 - Capacity)} \quad (2)$$

In this research, a quantitative approach was used, aimed at summarizing, concluding and explaining community variables related to the research object. The quantitative approach was chosen because primary data collection was through an interview process with reference to the questionnaire based on respondents in the Ciletuh–Palabuhanratu UNESCO Global Geopark. The research results will be described in the form of tables, figures, charts, maps and descriptions.

4 Results and Discussions

The results and discussion will present the results of field identification regarding the study of Tsunami disaster risk reduction (hazard, vulnerability, capacity). Variables and indicators in the research have been determined in the literature review process and then secondary data collection and primary data were collected. Next, an analysis of the study of tsunami disaster risk reduction strategies was carried out. Analysis and interpretation is carried out in the form of descriptive explanations and presentation of the analysis in tabular form.

4.1 Identification of Hazards in the Ciletuh–Palabuhanratu UNESCO Global Geopark

Tsunami hazard zone modeling in the study area was carried out by analysis using Arcmap 10.3 software based on InaRISK data referring to BNPB regulation no 2 of 2012. The data needed in the modeling process is integration data between administrative data for the Ciletuh–Palabuhanratu UNESCO Global Geopark land use data, Digital Elevation model (DEM) data and coastline data [53,54]. In this study, researchers determined the worst scenario with the possibility of a tsunami disaster measuring 9.3 SR with an estimated tsunami arrival time of 24 minutes. The results of the Arcmap 10.3 software modeling, the first information is the area inundated by the tsunami (inundation), the second information is the height of the tsunami and the third is the height of the tsunami inundation in the Ciletuh –Palabuhanratu UNESCO Global Geopark. Tsunami hazard zone modeling can be seen **fig 1** as follows:

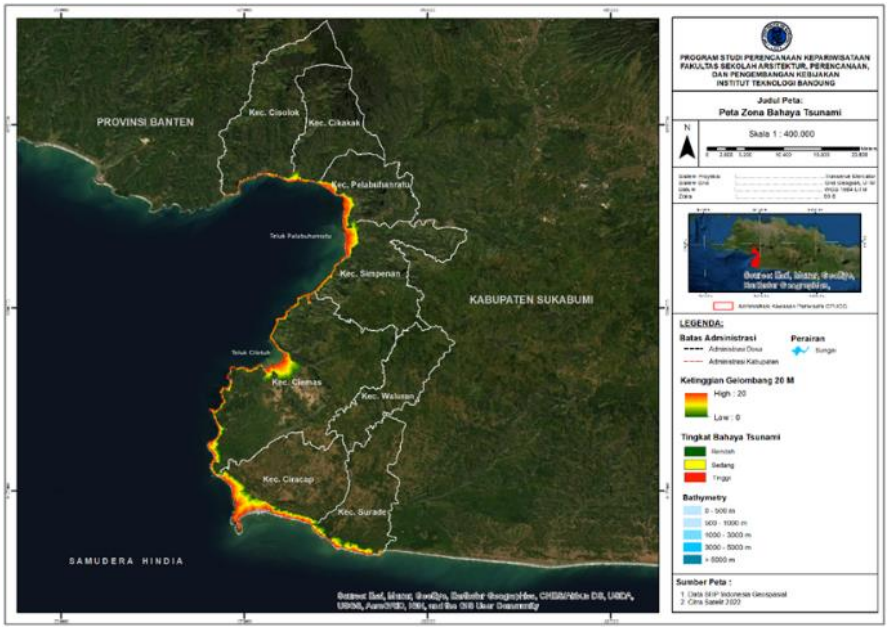

Fig. 1. Modeling the Tsunami Hazard Zone Map for the Ciletuh–Palabuhanratu, UNESCO Global Geopark

Table 2. Tsunami Hazard Index Data for the Ciletuh–Palabuhanratu UNESCO Global Geopark

Hazard Index		
Subdistrict	**Index**	**Explanation**
Cisolok (K1)	0,73	high
Cikakak (K2)	0,73	high
Palabuhanratu (K3)	0,73	high
Simpenan (K4	0,73	high
Ciemas (K5)	0,73	high
Ciracap (K6)	0,73	high
Surade (K7)	0,73	high
Hazard Value	0,73	high

Based on Table 1, it can be seen that the tsunami hazard index data in the Ciletuh–Palabuhanratu UNESCO Global Geopark are divided into seven sub-districts which have a hazard or hazard value of 0.73 with a high tsunami hazard index description. It has a total tsunami inundation area of 6,372.85 hectares spread across seven sub-districts in the Ciletuh–Palabuhanratu UNESCO Global Geopark with an inundated inundation height of 10 meters and an estimated tsunami arrival height of 20 meters. The following is **Fig. 2** of the tsunami hazard map for the Ciletuh–Palabuhanratu UNESCO Global Geopark

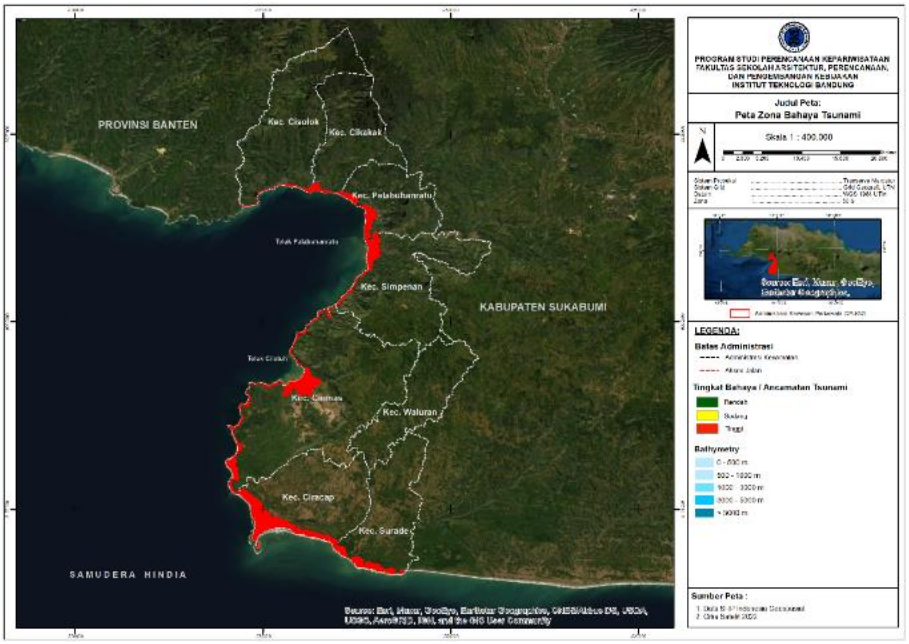

Fig. 2. Tsunami hazard map of Ciletuh–Palabuhanratu UNESCO Global Geopark

4.2 Identification of Vulnerabilities in the Ciletuh Palabuhanratu UNESCO Global Geopark

In analyzing tsunami disaster vulnerability, researchers took four variables to examine, namely environmental vulnerability, social vulnerability, physical vulnerability and economic vulnerability [55–57]. In calculating the vulnerability of the tsunami disaster in Ciletuh–Palabuhanratu, UNESCO Global Geopark refers to environmental vulnerability, physical vulnerability, economic vulnerability and social vulnerability, which are taken as reference from disaster management regulations, especially the general guidelines for assessing disaster risks, especially tsunami disasters. With the weight of each indicator, social vulnerability is 40%, physical vulnerability is 25%, economic vulnerability is 25% and environmental vulnerability is 10% [58–60]. The following table V.14 is the result of calculating the total vulnerability of the Ciletuh–Palabuhanratu UNESCO Global Geopark:

Table 3. Total Vulnerability of the Ciletuh–Palabuhanratu UNESCO Global Geopark

Number	Subdistrict	Vulnerability Index	Explanation
Weight		100%	
1	Cisolok	0.84	high
2	Cikakak	0.83	high
3	Palabuhanratu	0.92	high
4	Simpenan	0.82	high
5	Ciemas	0.85	high
6	Ciracap	0.86	high
7	Surade	0.83	high
Vulnerability Values		0.85	high

Based on Table 3, it can be seen that the total vulnerability index data to tsunamis in the Ciletuh–Palabuhanratu UNESCO Global Geopark has a total vulnerability value of 0.82–0.92, which means that the entire area is at a high level of vulnerability.

4.3 Identification of the Capacity of the Ciletuh –Palabuhanratu UNESCO Global Geopark

In the process of assessing the capacity of the UNESCO Ciletuh–Palabuhanratu Global Geopark, there are seven variables to look for, namely prevention, non-structural mitigation, structural mitigation, vigilance, preparedness, early warning systems and emergency response. Variables were asked to the Sukabumi district government as many as 16 agencies from the initial plan of 30 agencies, the business world as many as 10 business entities from the initial plan 20 business entities and the community 100 respondents from the initial plan 100 respondents in Ciletuh–Palabuhanratu UNESCO Global Geopark. Based on the results of field analysis regarding capacity levels, the capacity value of the Ciletuh–Palabuhanratu UNESCO Global Geopark is described in the event tree diagram 3 as follows:

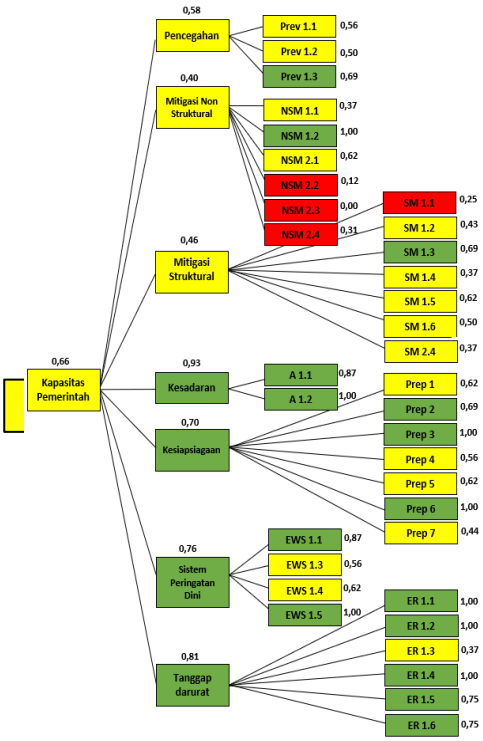

Fig. 3. Event Tree Diagram of Government Capacity Levels for Tsunami Disasters

The results are divided into 3 capacity levels with red color meaning low capacity value including the value (0.00-0.33). There are 4 sub-indicators, namely NSM 2.2, NSM 2.3, NSM 2.4 and SM 1.1. While the capacity in yellow, which means the average capacity value is included in the value (0.34-0.67) there are 16 sub-indicators, namely Prev.1.1, Prev.1.2, NSM 1.1, NSM 2.1, SM 1.2, SM 1.4, SM 1.5, SM 1.6, SM 2.4, Prep 1, Prep 4, Prep 5, Prep 7, EWS 1.3, EWS 1.4 and ER 1.3. For the green capacity which means the high capacity value includes the value (0.68-1.00) there are 15 sub-indicators namely Prev.1.3, NSM 1.2, SM

1.3, A 1.1, A 1.2, Prep 2, Prep 3, Prep 6, EWS 1.1, EWS 1.5, ER 1.1, ER 1.2, ER 1.4, ER 1.5, and ER 1.6.

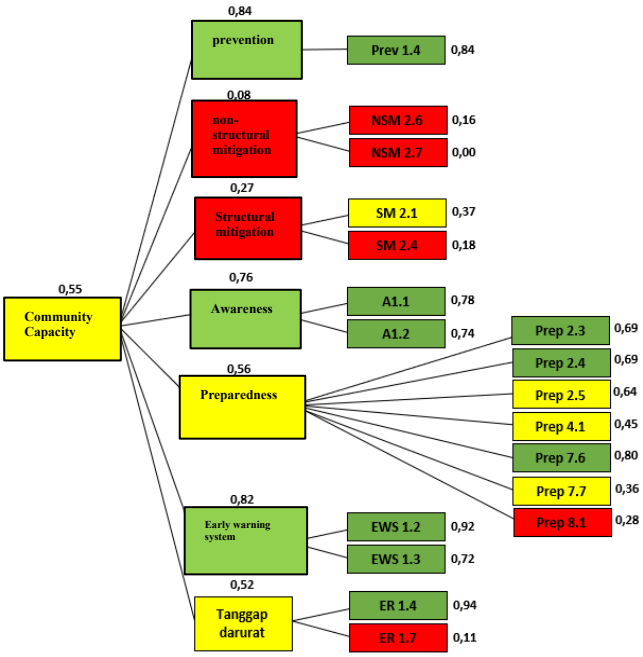

Fig. 4. Event Tree Diagram of Community Capacity Level for Tsunami Disaster

The results are divided into 3 capacity levels with red color meaning low capacity value including the value (0.00-0.33). There are 5 sub-indicators, namely NSM 2.6, NSM 2.2, SM 2.4, Prep 8.1 and ER 1.7. While the capacity in yellow, which means the average capacity value is included in the value (0.34-0.67) there are 4 sub-indicators, namely SM 2.1, Prep 2.5, Prep 4.1 and Prep 7.7. For the green capacity which means the high capacity value includes the value (0.68-1.00) there are 9 sub-indicators namely Prev 1.4, A1.1, A1.2, Prep 2.3, Prep 2.4, Prep 7.6, EWS 1.2, EWS 1.3, and ER 1.4.

Table 4. Capacity Value of the Ciletuh–Palabuhanratu UNESCO Global Geopark

No	Variable	Government Capacity Rating	Community Capacity Value	Business Capacity Value
1	Prevention	0.58	0.84	0.60
2	Nonstructural Mitigation	0.40	0.08	0.40
3	Structural Mitigation	0.46	0.27	0.60
4	Awareness	0.93	0.76	0.90
5	Preparedness	0.70	0.56	0.40
6	Early warning system	0.76	0.82	0.33
7	Emergency response	0.81	0.52	0.00
Value of Total Capacity of Respondents		0.66	0.55	0.46
Capacity Value		0.56 (medium)		

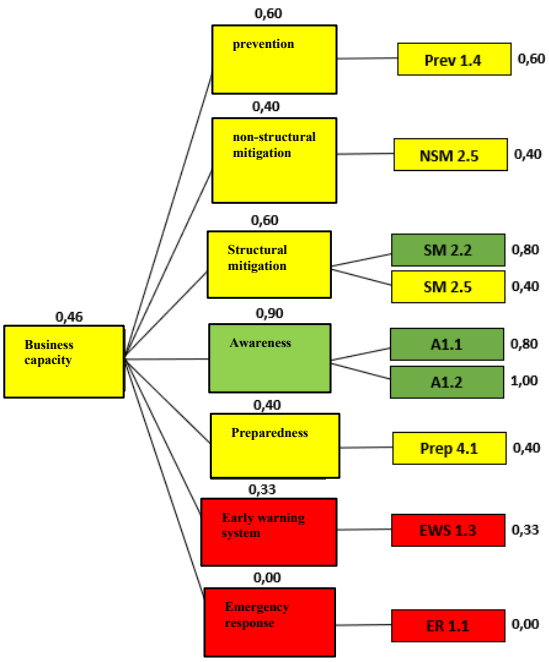

Fig. 5. Event Tree Diagram of Business Capacity Level for Tsunami Disaster

The results are divided into 3 capacity levels with red color meaning low capacity value including the value (0.00-0.33). There are 2 sub-indicators namely EWS 1.3 and ER 1.1. While the capacity in yellow, which means the value of medium capacity is included in the value (0.34-0.67) there are 4 sub-indicators, namely Prev 1.4, NSM 2.5, SM 2.5 and prep 4.1. For the green capacity which means the highcapacity value includes the value (0.68-1.00) there are 3 sub-indicators namely SM 2.2, A1.1 and A1.2.

In the process of assessing the capacity of the Ciletuh–Palabuhanratu UNESCO Global Geopark taken from the seven variables that have been assessed, namely prevention, non-structural mitigation, structural mitigation, awareness, preparedness, early warning systems and emergency response which are asked to the government, business entities and the community, the overall value are totaled to determine the level of capacity of the Ciletuh–Palabuhanratu UNESCO Global Geopark. The following is the capacity value contained in table 5 as follows:

Table 5. Capacity Value of the Ciletuh–Palabuhanratu UNESCO Global Geopark

No	Variable	Government Capacity Rating	Community Capacity Value	Business Capacity Value
1	Prevention	0,58	0,84	0,60
2	Nonstructural Mitigation	0,40	0,08	0,40
3	Structural Mitigation	0,46	0,27	0,60
4	Awareness	0,93	0,76	0,90
5	Preparedness	0,70	0,56	0,40

6	Early warning system	0,76	0,82	0,33
7	Emergency response	0,81	0,52	0,00
Value of Total Capacity of Respondents		0,66	0,55	0,46
Capacity Value		0,56 (medium)		

4.4 Tsunami Disaster Risk Assessment in Ciletuh–Palabuhanratu UNESCO Global Geopark

Risk analysis at Ciletuh–Palabuhanratu UNESCO Global Geopark was carried out referring to the Regulation of the National Regional Head for Disaster Management No. 2 of 2012 as a general guideline for disaster risk assessment. In analyzing disaster risk, the results of the hazard and vulnerability assessments are multiplied and then divided into capacity assessments [61–63].

Table 6. Tsunami Disaster Risk Assessment in Ciletuh–Palabuhanratu UNESCO Global Geopark

Disaster Risk	Value	Explanation
hazard	0.73	high
vulnerability	0.85	high
capacity	0.56	medium
Tsunami Disaster Risk Level	0.64	medium

The value of the risk of a tsunami disaster at Ciletuh–Palabuhanratu UNESCO Global Geopark is 0.64 which indicates a moderate risk level value that is close to the high risk value of a tsunami disaster at Ciletuh–Palabuhanratu UNESCO Global Geopark.

4.5 Tsunami Disaster Risk Reduction Strategy in Ciletuh–Palabuhanratu UNESCO Global Geopark

In the previous explanation, a risk study has been carried out at the Ciletuh–Palabuhanratu UNESCO Global Geopark. The results of the risk assessment of the parameters of hazard, vulnerability, capacity and preparedness of tourists will be used as material for consideration in the risk reduction strategy and tsunami disaster preparedness efforts undertaken. The grouping of strategies into three namely; level 1, applied to the red zone with low capacity levels - high risk, medium capacity - high risk, low capacity - medium risk. level 2 is applied to the yellow zone with levels of low capacity – low risk, medium capacity – medium risk and high capacity – high risk. level 3 is applied to the green zone with a level of high capacity – low risk, high capacity – medium risk, medium capacity – low risk. The capacity building= strategy based on the Government, the Business Community and tourists in reducing the risk= of a tsunami disaster is as follows:

Tabel 7.Tsunami Disaster Risk Reduction Strategy in Government Aspects in Ciletuh–Palabuhanratu UNESCO Global Geopark

No	Level 1 (High Risk Level Low Capacity)	Low Capacity	Medium Capacity	High Capacity	Agencies/Services Involved

1	Make a building permit that takes into account the building's resilience to disasters for buildings located in the red zone of a tsunami-prone area.	√			Department of Public Works and Spatial Planning
2	Develop a policy for land use adapted to tsunami inundation in Ciletuh–Palabuhanratu UNESCO Global Geopark.	√			Regional Agency for Disaster Management
3	Efforts to relocate or move critical infrastructure to a safer location.	√			Department of Public Works and Spatial Planning
4	Making tsunami absorber buildings like sea walls in Ciletuh–Palabuhanratu UNESCO Global Geopark.	√			Department of Public Works and Spatial Planning
	Level 1 (High Risk Level Moderate Capacity)				
5	Improving coastal protection efforts from tsunamis by maintaining and increasing the area of trees, mangroves, mangroves, contaminants, coastal forests and limiting the use of built-up land on the coast.		√		Nature Conservation Agency, Regional Agency for Disaster Management
6	Incorporate disaster risk reduction efforts into planning documents consisting of prevention, mitigation, preparedness, emergency response and rehabilitation and reconstruction phases.		√		Regional Development Planning, Research and Development Agency, Department of Public Works and Spatial Planning
7	Make a regulation prohibiting development on the coast which will reduce the availability of pine trees, mangroves and mangroves.		√		Department of Agriculture and Forestry,

8	Building tsunami-dampening structures such as breakwaters, reinforced concrete, floodgates, high-altitude artificial embankments, and disaster-resistant houses in the Ciletuh–Palabuhanratu UNESCO Global Geopark.		√		Department of Public Works and Spatial Planning, Regional Development Planning, Research and Development Agency
9	Create an organization or community that focuses on disaster preparedness issues.		√		Regional Agency for Disaster Management
10	There is a need for education in the field of education related to potential disasters at the school and community level.		√		Education authorities
11	Improving the information management system at Ciletuh–Palabuhanratu UNESCO Global Geopark.		√		Meteorological, Climatological, and Geophysical Agency, Regional Agency for Disaster Management
12	Evacuation zones, evacuation routes, evacuation signs and tsunami safe areas have been carried out by the government of Sukabumi Regency.		√		Regional Agency for Disaster Management
13	Traditional forms of early warning against disasters should be provided.		√		Subdistrict
14	Conduct periodic testing of communication equipment, especially tsunami sirens.		√		Regional Agency for Disaster Management
15	Updating and disseminating existing contingency plans, especially in sub-districts with moderate to high hazard levels.		√		Regional Agency for Disaster Management
	Level 2 (High Capacity High Risk Level)				
16	Updating and disseminating existing contingency plans,			√	Regional Agency for Disaster Management

	especially in sub-districts with moderate to high hazard.				
17	The spatial plan for the Sukabumi Regency area has entered a tsunami-prone area and needs to be socialized to the community.			√	Regional Agency for Disaster Management
18	The need for socialization of high shelters for the community.			√	Regional Agency for Disaster Management
19	Educating and convincing the public that there will be a tsunami threat in Ciletuh–Palabuhanratu UNESCO Global Geopark one day.			√	Regional Agency for Disaster Management
20	Making preparedness programs into government programs in disaster risk reduction.			√	Regional Agency for Disaster Management
21	Integrating and educating tsunami preparedness into schools and businesses.			√	Department of Education and Tourism
22	Improving the disaster information management system in Ciletuh–Palabuhanratu UNESCO Global Geopark.			√	Meteorological, Climatological, and Geophysical Agency, Regional Agency for Disaster Management
23	Early warning systems already exist in the Ciracap and Palabuhanratu sub-districts in anticipation of the tsunami threat, but it is necessary to add an early warning system in the Ciemas sub-district given the large number of tourist and community activities.			√	Regional Agency for Disaster Management
24	The media used for the dissemination of early warning and evacuation news media must be prepared so as to assist the community in the evacuation process as soon as			√	Meteorological, Climatological, and Geophysical Agency, Regional Agency for Disaster Management

	possible when there is an early warning.				
25	Prepare logistics in the event of a tsunami disaster.			√	Regional Agency for Disaster Management
26	Prepare medical support for emergency services in the event of a tsunami disaster.			√	Public health Office
26	Prepare the readiness of the rapid response team and SAR when a disaster risk occurs.			√	Public health Office
27	Setting up equipment to clean up post-tsunami debris.			√	Regional Agency for Disaster Management
28	Providing search and rescue equipment for victims.			√	Regional Agency for Disaster Management

Table 8. Tsunami Disaster Risk Reduction Strategy in Community Aspects in Ciletuh–Palabuhanratu UNESCO Global Geopark

No	Level 1 (High Risk Level Low Capacity)	Low Capacity	Medium Capacity	High Capacity
1	Participate in a community that provides disaster information to the public.	√		
2	Communities are involved in disaster risk assessment.	√		
3	Participate in knowledge dissemination of tsunami-prone areas, especially people who live in the red or high zones.	√		
4	Communities need to prepare disaster preparedness bags.	√		
5	Availability of temporary buildings for emergencies in the community	√		
	Level 1 (Tingkat Risiko Tinggi Kapasitas Sedang)			
6	People do not know about disaster resistant houses. There needs to be socialization by the government to the community so that they know tsunami-resistant houses and apply them.		√	
7	Communities need to take part in education/socialization and information programs for tsunami preparedness.		√	
8	Obtain disaster education in response when a tsunami occurs.		√	
9	Increasing interest in reading tsunami evacuation route signs.		√	
	Level 2 (High Capacity High Risk Level)			
10	The community knows the types of disasters that exist in Ciletuh–Palabuhanratu UNESCO Global Geopark.			√

11	Participate in education to believe that one day a tsunami will occur in Ciletuh–Palabuhanratu UNESCO Global Geopark.			√
12	The community participates in education/ outreach/ training to save lives.			√
13	There is useful information from outreach and disaster training			√
14	Communities need to know the evacuation routes / routes that have been provided by t.he government in saving themselves when a tsunami occurs			√
15	Communities Need to know the traditional forms of early warning against disasters.			√
16	The community knows the early warning system so that the process of saving themselves is easier.			√
17	There needs to be efforts made by the community in the tsunami disaster.			√

Tabel 9. Tsunami Disaster Risk Reduction Strategy in Business Aspects at Ciletuh± Palabuhanratu UNESCO Global Geopark

No	Level 1 (High Risk Level Low Capacity)	Low Capacity	Medium Capacity	High Capacity
1	Business Entities provide special early warning or information on disasters at business locations, especially those in the red zone	√		
2	Provide logistical preparations before the tsunami disaster occurs	√		
	Level 1 (High Risk Level Moderate Capacity)			
3	Business entities located in tsunami-prone areas participate in protecting the environment such as maintaining cleanliness and environmental sustainability		√	
4	Business entities must protect their assets, such as insuring their business		√	
5	Business entities rent out buildings to serve as temporary evacuation sites if a tsunami disaster occurs		√	
6	Business entities need to take part in outreach/training/related to the tsunami disaster in order to have knowledge regarding disasters that may occur in their environment		√	
	Level 2 (High Capacity High Risk Level)			
7	Business entities use building rules or building codes according to the standards used			√
8	Business entities believe that one day a tsunami disaster may occur			√

5. Conclusion

The risk level for a tsunami disaster based on data on the level of hazard, level of vulnerability and level of capacity of the Ciletuh–Palabuhanratu UNESCO Global Geopark has a value of 0.64 which indicates a moderate risk level value that is close to the high risk value of a tsunami disaster in Ciletuh–Palabuhanratu UNESCO Global Geopark, therefore the risk value This should be of concern to both the government, society and business entities. In

determining the strategy for reducing the risk of a tsunami disaster, it is seen based on the results of a risk assessment of the hazard and vulnerability parameters, the results show a high level of risk for a tsunami disaster. while the capacity parameter of each indicator is divided into low, medium and high. This is taken into consideration in the preparation of the tsunami disaster risk reduction strategy undertaken. From the results of grouping strategies into two, namely; level 1 and level 2.

References

1. S. Puah, C. H., Jong, M. C., Ayob, N., & Ismail, Int. J. Bus. Manag. **13**, 151 (2018).
2. I. C. S. Pratama, I. G. S., & Mandaasari, Int. Res. J. Manag. IT Soc. Sci. **7**, 31 (2020).
3. T. Pratminingsih, S. A., Rudatin, C. L., & Rimenta, Int. J. Innov. Manag. Technol. **5**, 19 (2014).
4. K. Kamsma, T., & Bras, Tour. Sustain. Community Dev. 188 (n.d.).
5. R. Dahuri, J. Coast. Dev. **1**, 97 (1998).
6. F. Safitri, D. A., Bespalova, L. A., & Wijayanti, R-Economy **5**, 198 (2019).
7. U. elussa, R. F., Limbong, M., & Rahmani, Aquac. Aquarium, Conserv. Legis. **15**, 2560 (2022).
8. H. E. Widiyantoro, S., Gunawan, E., Muhari, A., Rawlinson, N., Mori, J., Hanifa, N. R., ... & Putra, Sci. Rep. **10**, 15274 (2020).
9. Y. Pasari, S., Simanjuntak, A. V., Mehta, A., Neha, & Sharma, Pure Appl. Geophys. **178**, 2789 (2021).
10. R. Isya, H. R. M., Wibowo, W. A., & Arrasyid, J. Pendidik. ILMU Sos. **30**, 137 (2021).
11. Y. M. Afif, H., Nugraha, A. D., Muzli, M., Widiyantoro, S., Zulfakriza, Z., Wei, S., & Husni, Geophys. J. Int. **226**, 1814 (2021).
12. S. Song, R., Hattori, K., Zhang, X., & Sanaka, J. Atmos. Solar-Terrestrial Phys. **205**, 105291 (2020).
13. A. Cahyanto, I., Kingsbury, A. J., Widodo, E., Puspita, N. Y., & Harnadi, Int. J. Tour. Res. **23**, 928 (2021).
14. J. Ichinosawa, Disaster Prev. Manag. An Int. J. **15**, 111 (2006).
15. B. N. Rittichainuwat, Cornell Hotel Restaur. Adm. Q. **47**, 390 (2006).
16. B. N. Rittichainuwat, Tour. Manag. **34**, 112 (2013).
17. J. K. Robinson, L., & Jarvie, Disasters **32**, 631 (2008).
18. S. Muslim, D., Zakaria, Z., Sophian, I., Haerani, E., & Yamaoka, J. Phys. Conf. Ser. **1363**, 012022 (2019).
19. M. J. De Hoog, J. C. M., Taylor, B. E., & Van Bergen, Earth Planet. Sci. Lett. **189**, 237 (2001).
20. J. . . J. . **13**, 39 (1996).
21. A. N. Patria, A., & Aulia, Ris. Geol. Dan Pertamb. **30**, 65 (2020).
22. T. Kennett, B. L. N., & Furumura, Geophys. J. Int. **172**, 363 (2008).
23. H. Putri, S. M., Deliarnoor, N. A., & Nurasa, J. Ilm. Ilmu Pemerintah. **6**, 171 (2020).
24. S. Raharjo, S. T., Apsari, N. C., Santoso, M. B., Wibhawa, B., & Humaedi, Soc. Work J. **8**, 158 (2018).
25. F. Ar-rouf, F. B., & Masitoh, Jambura Geosci. Rev. **5**, 42 (2023).
26. G. O. Muslim, D., Haerani, E., Muslim, F. N., & Muslim, IOP Conf. Ser. Earth Environ. Sci. **248**, 012036 (2019).
27. K. S. A. Nugraha, Int. J. Geotourism Sci. Dev. **3**, 1 (2023).
28. A. Maulana, IOP Conf. Ser. Earth Environ. Sci. **921**, 012056 (2021).
29. H. Aidi, Z., & Farida, Adv. Environ. Sci. **12**, 137 (2020).
30. D. R. C. Asian, *Living with Risk. A Global Review of Disaster Reduction Initiatives* (Preliminary version, 2002).

31. M. G. De Bono, A., & Mora, Int. J. Disaster Risk Reduct. **10**, 442 (2014).
32. K. Satake, Geosci. Lett. **1**, 1 (2014).
33. V. Nijman, Int. J. Disaster Risk Sci. **12**, 764 (2021).
34. H. Aerts, J. C., Botzen, W. J., Clarke, K. C., Cutter, S. L., Hall, J. W., Merz, B., & Kunreuther, Nat. Clim. Chang. **8**, 193 (2018).
35. C. W. Tsai, C. H., & Chen, Tour. Manag. **32**, 158 (2011).
36. A. Y. Kussul, N. N., Sokolov, B. V., Zyelyk, Y. I., Zelentsov, V. A., Skakun, S. V., & Shelestov, J. Autom. Inf. Sci. **42**, (2010).
37. T. E. B. Sari, D. A. P., & Soesilo, Earth Environ. Sci. **448**, 012092 (2020).
38. S. Aguirre-Ayerbe, I., Martínez Sánchez, J., Aniel-Quiroga, Í., González-Riancho, P., Merino, M., Al-Yahyai, Nat. Hazards Earth Syst. Sci. **18**, 2241 (2018).
39. LIPI / DLR / UNU-EHS, *GUIDELINE FOR TSUNAMI RISK ASSESSMENT IN INDONESIA: SCIENTIFIC PROPOSAL FOR PRACTITIONER AND END USERS. Provided by the Indonesian – German Working Group on Tsunami Risk Assessment.* (2011).
40. BNPB, *Peraturan Kepala BNPB No. 02 Tahun 2012 Tentang : Pedoman Umum Pengkajian Risiko Bencana* (2012).
41. UU No. 24 Tahun 2007 tentang Penanggulangan Bencana, Pemerintah Republik Indones. (2007).
42. J. Titko, M., & Ristvej, Sustainability **12**, 9121 (2020).
43. M. M. Gaillard, J. C., Cadag, J. R. D., & Rampengan, Nat. Hazards **95**, 863 (2019).
44. B. Fathianpour, A., Wilkinson, S., Babaeian Jelodar, M., & Evans, Nat. Hazards **118**, 1315 (2023).
45. V. H. Jihad, A., Muksin, U., Suppasri, A., Ramli, M., & Banyunegoro, Int. J. Disaster Risk Reduct. **51**, 101800 (2020).
46. F. Suppasri, A., Maly, E., Kitamura, M., Pescaroli, G., Alexander, D., & Imamura, Int. J. Disaster Risk Reduct. **66**, 102597 (2021).
47. UNESCO, *Tsunami Risk Assessment and Mitigation for the Indian Ocean - Knowing Tour Tsunami Risk and What to Do about It* (2015).
48. UNESCO, *Tsunami Preparedness Civil Protection – Good Practices Guide* (2012).
49. R. Sylviani, Kajian Strategi Pengurangan Risiko Bencana Tsunami Di Pesisir Kota Bengkulu Dengan Fokus Pada Penguatan Kapasitas Pemerintah Entitas Bisnis Dan Masyarakat, Institut Teknolohi Bandung, 2020.
50. P. Perundang-undangan, *Peraturan Pemerintah (PP) Nomor 64 Tahun 2010 Tentang Mitigasi Bencana Di Wilayah Pesisir Dan Pulau Pulau Kecil* (2010).
51. M. Al Fayed, M. A., Maarif, S., Syamsunasir, S., Widodo, P., Kusuma, K., & Ihsan, mplementation of the Disaster Risk Reduction Program in Japan as an Effort for Disaster Risk Reduction in Indonesia. Int. J. Humanit. Educ. Soc. Sci. **3**, (2023).
52. R. H. T. Anggraini, S., & Koestoer,. Environmental perspective on tsunami disaster mitigation and its implications: a critical review. ASEAN Nat. Disaster Mitig. Educ. J. **1**, (2023).
53. D. P. Setyaningsih,. Sutiono, H. E. C. P., Paramanandi, A. R. G., Khasanah, E. U., Wahyuni, T., Jati, B. A. E. K., ... & Wibowo, T. W. (2023). Tsunami Hazard Modeling in the Coastal Area of Kulon Progo Regency. Int. J. Remote Sens. Earth Sci. **19**, 184 (2023).
54. M. Tursina, T., Syamsidik, S., Kato, S., & Afifuddin, Incorporating dynamics of land use and land cover changes into tsunami numerical modelling for future tsunamis in Banda Aceh. EDP Sci. **340**, 01014 (2022).
55. A. Nasution, B. I., Kurniawan, R., Siagian, T. H., & Fudholi, Revisiting social vulnerability analysis in Indonesia: An optimized spatial fuzzy clustering approach. Int. J. Disaster Risk Reduct. **51**, 101801 (2020).

56. M. M. Yavuz, C., Kentel, E., & Aral, Tsunami risk assessment: economic, environmental and social dimensions. Nat. Hazards **104**, 1413 (2020).
57. J. H. Wijaya, A. P., & Hong,Quantitative assessment of social vulnerability for landslide disaster risk reduction using gis approach (case study: Cilacap regency, province of central Java, Indonesia). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Inf. Sci. **42**, 703 (2018).
58. M. Hejazi, S. J., Sharifi, A., & Arvin. Assessment of social vulnerability in areas exposed to multiple hazards: A case study of the Khuzestan Province, Iran. Int. J. Disaster Risk Reduct. **78**, 103127 (2022).
59. A. F. Sambah, A. B., Miura, F., & Febriana. Geospatial Model of Physical and Social Vulnerability for Tsunami Risk Analysis. GEOMATE J. **17**, 29 (2019).
60. I. Fatemi, F., Ardalan, A., Aguirre, B., Mansouri, N., & Mohammadfam. Social vulnerability indicators in disasters: Findings from a systematic review. Int. J. Disaster Risk Reduct. **22**, 219 (2017).
61. F. P. Robielos, R. A. C., Lin, C. J., Senoro, D. B., & Ney, Development of Vulnerability Assessment Framework for Disaster Risk Reduction at Three Levels of Geopolitical Units in the Philippines, Sustainability **12**, 8815 (2020).
62. S. M. Ramli, M. W. A., Alias, N. E., Mohd Yusof, H., Yusop, Z., & Taib, Development of a Local, Integrated Disaster Risk Assessment Framework for Malaysia, Sustainability, Sustainability **13**, 10792 (2021).
63. M. A. Løvholt, F. J. M. R., Griffin, J., & Salgado-Gálvez, Tsunami hazard and risk assessment on the global scale, Complexity in Tsunamis, Volcanoes, and Their Hazards **213** (2022).