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Potential and risk reduction of geological disasters (Case study in Sabu Island, Raijua District – East Nusa Tenggara)

Irwan Susilo; Moh Abduh

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Potential and Risk Reduction of Geological Disasters (Case Study in Sabu Island, Raijua District – East Nusa Tenggara)

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Abstract. Sabu Island is one of the islands on the outer border line of The Indonesia Archipelago. The lack of detailed geological data is a challenge in regional planning especially related the disaster risk reduction. The purpose of the study is to understand the geological processes in Sabu Island as a part of Risk Reduction of Geological Disaster (RRGD). The qualitative descriptive method is used to explore regional geological data to identify the important factors that influence RRGD. The risk reduction for subsidence in karst morphology in East Sabu Districts and Middle Sabu Districts can be synergized with local cultural and social-economic potential empowerment. Although, the historical data is insignificant and the potential threat is evenly distributed in the Sabu Island area. The threat of a tsunami in the southern coastal area of Sabu Island is greater than that of the north coast, especially in the coastal plain area. Potential liquefaction is in coastal alluvial plains. The potential threat of landslides is primarily in the middle of Sabu Island. Understanding the regional geological process is useful guide the GDRR.

INTRODUCTION

Geologically, Sabu Island is a dynamic island that experiences horizontal and vertical movements. The Sabu establishment is a result of the collision of the Australian continental margin with the Banda arc-continent with the average rate of surface uplift is 1.5-2.3 mm/year [1] [9].

GDDR works well if the understanding of regional conditions is also good. In this study, the priority is to reduce disaster risk from factors of geological processes that exist on Sabu Island [2].

The purpose of this study is to identify the main of geological factors that influence the existence of Sabu Island. Include geological processes and their implications for the community safety and the environment of Sabu Island. This study aims to provide direction in planning regarding the reduction of geological disaster risk on Sabu Island.

General Condition

The location of Sabu Raijua Regency is between 10º25'7,12" SL - 10º49'45,83" SL and between 121º16'10,78" EL - 122º0'30,26" EL. The northern part of Sabu Raijua District faces the Sawu Sea, the east faces the Sawu Sea/Rote Ndao, the south faces the Indonesian Ocean, and the west faces the Sumba Sea/East Sumba. The area of Sabu Island is 422 km^2 with an elevation of 0-350 meters, the length of the coastline is 991.18 km. Sabu Island has a dry climate with an average annual rainfall of <1250 mm/year. The rainy days are uneven (KRB Sabu Raijua District, 2019). Sabu Raijua District tends deficit of water balance from the month of July until September. Depending on KLHS Sabu Raijua Regency 2020 the kinds of disasters in the study area are earthquakes, landslides, floods, tsunamis, droughts, and windstorms. The inhabitants of Sabu Island are generally farmers, cultivating seaweed and catching fishers. **FIGURE 1** below shows a complete description of the administrative area.

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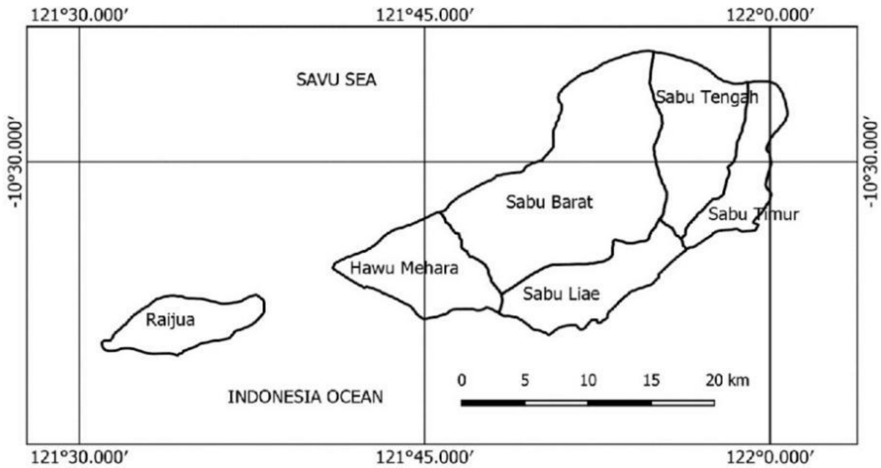


FIGURE 1. Administrative area of Sabu Raijua District

Morphological and Topographical Condition

The morphology of Sabu Island is in the form of hills in the central and coastal lowlands, and the type of beach is a sloping beach and a steep rocky beach. The location of the Sabu Island area is from 0 meters to 350 meters, and slopes range from 0 to >41 degrees (KLHS of Sabu Raijua 2016, Disaster Risk Natural Study 2019-2023 Sabu Raijua), as shown in **FIGURE 2**. Meanwhile, the level of vulnerability in Sabu Island is as described in **TABLE 1** below.

Map data: @2024 Airbus TerraMetrics, Maxar Technologies

FIGURE 2. Sabu Island Elevation Model Map

TABLE 1. The level of Vulnerability in Sabu Raijua District

Sub District	Slope Degree Area (Ha)				
	0-8%	9-15%	16-25%	26-40%	>41%
Hawu Mehara	2.635,20	1.912,64	1.495,24	163.74	44,36
Raijua	2.207,37	1.029,50	536,42	74,43	27,77
West Sabu	9.040,64	4.447,41	4.240,91	571,46	121,54
Sabu Liae	1.934,95	1.643,82	1.860,04	222,35	58,04
Central Sabu	5.194,75	860,34	385,68	48,43	12,82
East Sabu	4.409,74	438,12	184,32	14,70	7,68

Geological Conditions

17 10 Sabu Island is in the forearc of the Sunda-Banda volcanic arc [3]. Sabu Island is an accretion resulting from the uplifting of the continental crust due to the collision of the edge of the Australian Continent plate with the Banda Fore-Arc [4] [5]. Velocity ranges from 7 cm/year (Tregoning et al., 1994 quoted from Nugroho & Harris, 2009). The speed of removal of Sabu Island ranges from 0.5 to 1.5 mm/year (Nugroho & Harris 2009). Referring to the model, Sabu 14 Island is geologically more controlled by thrust fold faults. In the north of Sabu Island is The Sabu basin. It is situated in the fore-arc of the Sunda–Banda Arc [4] and has a low potential for tsunami triggers [6] depending on historical data.The rise of Timor Island and the formation of intra-arc troughs such as Flores and Sabu basin are marks of the Australian continent-island arc collision at the outer edge of the Sunda-Banda fore-arc [7]. Depending on the karst 15 that occurred Sabu Island is composed island [8]. Both carbonate and noncarbonate rocks are exposed at the surface.

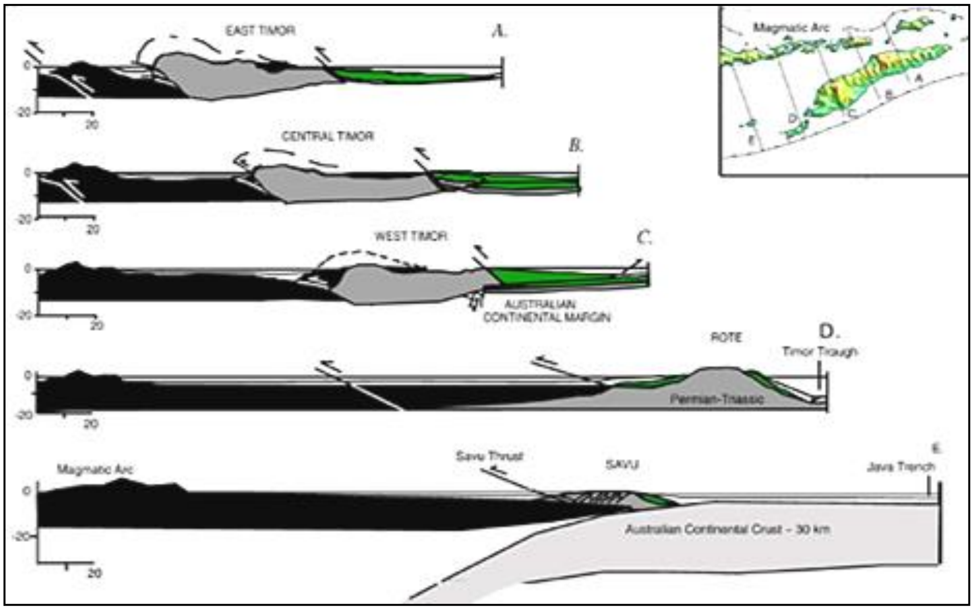
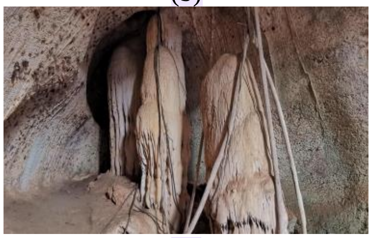


FIGURE 3. Tectonic model of Timor-Rote-Sabu Island and Its Surroundings



16 (a) (b) (c)


(d) (e) (f)

FIGURE 4. Rock Outcrop and Alluvial Plains Describe the Surface of Geological Conditions (a) rocky hills, (b) rocks at the top, (c) rocks on the slopes, (d) rocks that form hills (e) rocks in caves, and (f) rocky ground surface

Based on the Geological Map Sheet Kupang-Atambua (**FIGURE 3**), Timor, Rock formations in Sabu Island include; The Bisane Formation (Pb), Ofu Formation (Tko), Bobonaro Complex (Tmb), Noele Formation (Qtn), Coral Limestone (Ql), and Alluvial [9]. Figure 4a; Purple Siltstone, Red Quartz Sandstone, and Micaceous Sandstone members of The Bisane Formatian occur in Hawu Mehara Subdistrict. Folding of the layers indicated the area has intensively deformed. Figure 4b; Marl member of The Ofu Fomation occur in Sabu Liae Subdistrict.The rock has eroded by surface water and resulted a beautiful landscape. Figure 4c; Weathered dark Scaly Clay and rock fragments in many sizes are members of The Bobonaro Complex. Figure 4d; Sandstone, Marl, and Sandy Tuff are members of The Noele Formation. The outcrop occurs in Hawu Mehara Subdistrict. Figure 4e; Stalagmite in The Mabala Cave indicates one of the features of karst morphology. Karts morphology occurs in a part of East Sabu Island. Figure 4f; Rice fields on alluvial deposits in East Sabu Subdistrict. Its area abundance of groundwater resources. The alluvial deposits such as sands, gravel, and pebbles are building material resources in Sabu Island [10].

The geological structure in Sabu Island is very intensive, including; faults, folds, and joints so that the bearing capacity of the rock is reduced [11]. Weathering and dissolution of intensive coral limestone as mapped in **FIGURE 5**.

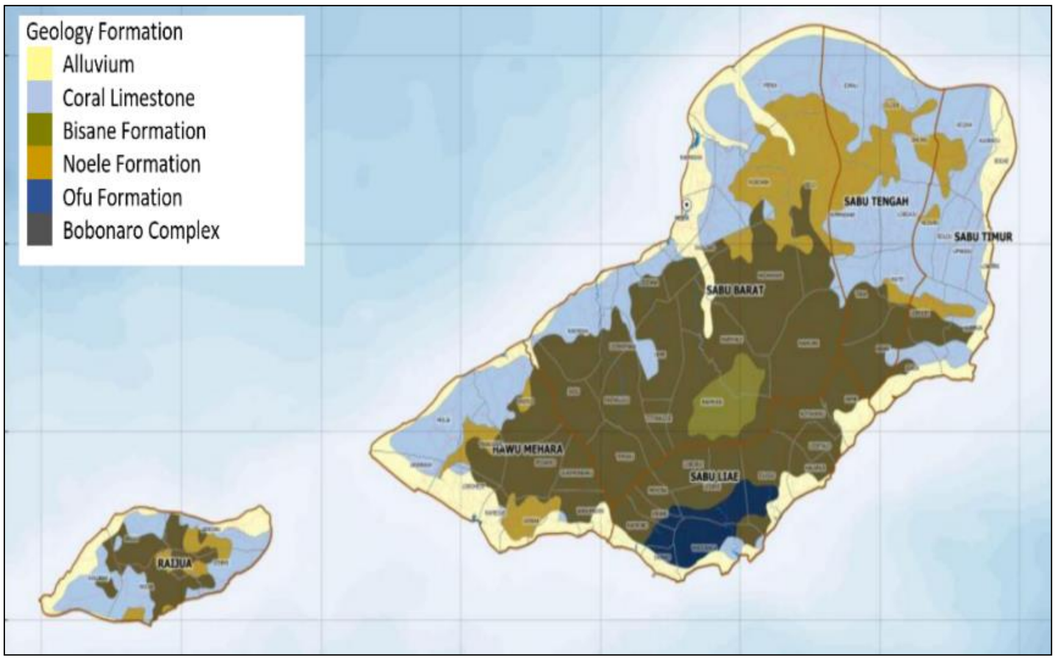


FIGURE 5. Geological Map of Sabu Island

According to the Decree of the National Disaster Management Agency (BNPB) No. 4, 2008, a disaster is an event/series of events that threatens and disrupts the lives and livelihoods of the community, both by natural and/or non-natural and human factors. Every symptom/natural disaster or event that can cause a disaster is a threat of disaster. Potential disasters include potential disasters by natural factors, non-natural factors, and social factors. Disaster risk in equation (1) [12] is the potential loss due to a disaster in an area and a certain period, and the amount is proportional to the existing threat (hazard) and vulnerability, inversely proportional to the capacity (ability) to deal with it.

$$\text{Disaster Risk} = \text{Threat}\,\frac{\text{Vulnerability}}{\text{Capacity}} \tag{1}$$

Geological Disaster

Geological disasters in this study are natural disasters that are dominantly triggered by geological processes on the surface or the earth [13]. These geological disasters include volcanic eruptions, earthquakes, tsunamis, liquefaction, landslides, and land subsidence.

Disaster Risk Reduction

In **FIGURE 6**, the following describes the disaster management cycle following BNPB Code No. 4, 2008. Disaster Risk Reduction (DRR) includes Pre-Disaster in a non-disaster situation and Pre-Disaster in situations with a potential for disaster. After disaster hapend includes emergency response and recovery. The GDRR keys are how to deeply identified of the geological processes and identified the potential risks in the area.

FIGURE 6. Disaster Management Cycle

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METHOD AND MATERIAL

Method

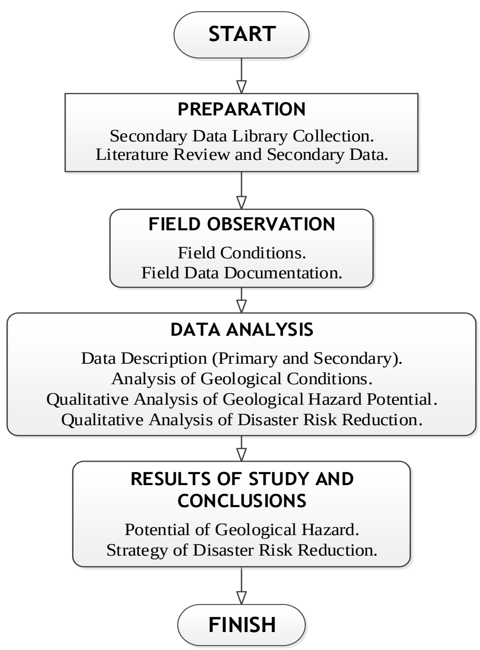

FIGURE 7. Flowchart of Study

The RRGD study on Sabu Island was conducted using secondary data qualitative descriptive method and the results of a review and observation of field conditions. The preparation step includes data collecting especially all the results of previous studies in the study area. The regional geological data and tectonic setting information that play in Sabu Island are basic information for developing RRGD scenarios. Field observations and documentation include surface rock observation, geological features, and land use observation. The local geological conditions and geological hazard potentials are derived from the analysis of geology and tectonic regional influences in local contexts. The flow of the research stages is arranged as shown in **FIGURE 7**.

Data and Material

The data and materials used in this study include basic data and thematic data. Basic data includes; Geological Map Sheet Kupang–Atambua [11] and the Indonesian Earth Map (RBI). While thematic data supports disaster data contained in the KRB or Disaster Risk Assesment, 2019-2023, Sabu Raijua District. Field observation data in the form of descriptions and documentation as part of the completeness of visual data.

RESULT AND DISCUSSION

Potential Geological Disasters

Earthquake and Tsunami Potential

Sabu Island and its surroundings have the potential to be threatened by an earthquake. The Java Trench-Timor Through ocean trough in the south of Sabu Island is a potential source of tsunamis. Based on the Indonesian Tsunami Catalog for 1900-2018, the earthquake points around Sabu Raijua Island are located on Flores Island and its surroundings and tend to be mainland earthquakes. The threat of a tsunami on the north coast of Sabu Island, apart from the earthquake in the Sabu Sea, is also avalanches/falls of active volcanic material on the southern coast of Flores Island that enters the sea. Based on the data on the distribution of the earthquake over Sabu Island, it is relatively safe from the threat of a large earthquake. However, vigilance against the potential threat of an earthquake and tsunami must be taken into account, although so far, no significant tsunami disaster has been recorded.

Disaster management and management measures aimed at reducing disaster risk are fully described in **TABLE 2**.

TABLE 2. Reducing the risk of an earthquake and tsunami disaster on Sabu Island

Stages	Physical Aspect	Social-Economic Aspect	Institutional Aspect	Notes
Pre-disaster	Determination of the area of vigilance against the threat of earthquake and tsunami. Installation of hazard area signs related to potential hazards. Preparation of the early warning system against the threat of earthquakes and landslides. Determination of evacuation routes. Preparation/ determination of land as evacuation locations.	Alternative work/ skills training to deal with work vacuums during infrastructure recovery after the earthquake and tsunami that disrupted their main livelihoods.	Strengthening and disseminating information regarding the potential threat of earthquakes and tsunamis, Strengthening community resilience through disaster response drills. Understanding evacuation scenarios. Earth-quake and tsunami literacy for coastal communities and school children.	Locations of potential earthquakes are almost all over the Sabu Island area. The potential for a tsunami on the south coast of Sabu Island is greater.
Emergency response	Provision of logistics for victims. Provision of temporary, simple earthquake-resistant housing, provision of raw/clean water needs, provision of health facilities, telecommunications facilities, and other public facilities.	Emergency response efforts to fulfill basic needs. Handling and distributing aid, Mutual awareness to rise and roll out the community's economy, handling trauma problems	Coordination between institutions and community groups for common steps and a natural vision of disaster management.	Prioritizing the handling of the safety of the victim community. Involvement of community social groups.
Post-disaster	Affirmation of delineation of earthquake-prone and tsunami-prone areas, Installation of new signs, Improvement of residential infrastructure and public services, resettlement, ensuring that the early warning system infrastructure is functioning properly.	Restoration of local socio-economic conditions. Mental and spiritual assistance for victims Maintenance of new infrastructure facilities after the disaster	Institutional strengthening in preparedness for earthquake and tsunami emergencies. Increase awareness and mutual concern regarding the early warning system. Good literacy education is related to earthquake and tsunami disasters.	

Liquefaction

The lowlands scattered in some coastal areas of Sabu Island are composed of loose sandy material deposits that have not been well consolidated. The presence of saturated sand and clay-sand at a depth of 0.1-15 meters indicates vigilance against the potential threat of liquefaction hazard in the event of an earthquake above 5.5 Mw. Completed handling steps as in **TABLE 3**.

TABLE 3. Sabu Island Liquefaction Disaster Risk Reduction

Stages	Physical Aspect	Social-Economic Aspect	Institutional Aspect	Notes
Pre-disaster	Determination of the area of vigilance against the threat of liquefaction disasters, setting standards for building planning that accommodates the risk of liquefaction hazards	Alternative job training/skills to deal with during the recovery of land damage due to liquefaction or when you have to leave land damaged by liquefaction.	Strengthening and disseminating information regarding the potential threat of liquefaction and how to avoid it.	Potential liquefaction sites are sandy alluvial deposits that are saturated with water
Emergency response	Provision of temporary housing, provision of raw/clean water needs, provision of health facilities, telecommunications facilities, and other public facilities. Handling land and infrastructure due to liquefaction	Provision of logistics for victims and mental and spiritual assistance.	Collaboration of relevant stakeholders for institutional handling regarding land management and land status. Promote community collaboration.	
Post-disaster	Affirmation of liquefaction-prone areas, rebuilding disaster areas with functions that are by the characteristics of the land. Resettlement to locations that are guaranteed to have minimal disaster risk. Reducing the level of water saturation at the location of potential liquefaction	Generating a community-based economy based on togetherness and humanity. Limited use of liquefaction-prone land.	Increased literacy concerns the danger of liquefaction. The introduction of the environment by community groups regarding the site of the location of residence, especially related to the potential for liquefaction.	Utilization of liquefaction-prone areas for agriculture and gardens

TABLE 4. Reducing the Risk of Landslides on Sabu Island

Stages	Physical Aspect	Social-Economic Aspect	Institutional Aspect	Notes
Pre-disaster	Determination and application of boundaries for landslide hazard protection areas. Installation of landslide hazard signs. Strengthening slopes/soil at risk of landslides.	Alternative work/skills training by utilizing local resources that are not affected by the risk of landslide hazard	Strengthening and disseminating information regarding landslide-prone locations and their mitigation efforts.	Landslide prone areas, slopes >30 degrees & cracked weathered rock
Emergency response	Delineation of landslide locations and safe locations. Victim handling. Provision of environmental infrastructure for victims. Transfer and construction of a temporary shelter in a safe location. Public facility rescue. Transfer and arrangement of landslide material. Mapping slip planes and landslide triggers	Fulfillment of basic needs during emergency response. Social and psychological assistance for victims. Ensuring basic needs are met properly	Mobilizing the social power of the community to see similar potentials to avoid the threat of subsequent landslides. As well as gathering social strength for the social resilience of the community.	Precautions for aftershocks and mass movement of landslide material
Post-disaster	Affirmation of landslide disaster areas, resettlement after disaster events, determination of landslide hazard border areas. Improvement of slopes/soil prone to subsequent landslides.	The economic recovery of the landslide victims. Environmentally friendly use of landslide-prone land. The application of natural resources and environmental management is based on local wisdom.	Strengthening community social institutions in landslide disaster mitigation. The development of an early warning system involves the active role of the community. Provision of community capabilities in identifying the threat of landslides.	

Landslide

The central part of Sabu Island is in the form of hills with rocks that have many cracks, tend to experience weathering, and are easily eroded by surface flow. Landslide potential, especially when there is an additional load on the slopes by the influence of rainwater or other factors. The potential for landslides is found in the Districts of West Sabu, Sabu Liae, Sabu Hawu Mehara (Bobonaro complex). About the risk of landslides, disaster risk reduction efforts are carried out as described in **TABLE 4**.

Land subsidence

Cracks in coral limestone control the dissolution of rocks to form underground rivers and cavities/caves. The potential for subsidence arises due to the reduced strength of the rock bearing capacity. The Mabala Cave in Central Sabu shows that the dissolution of limestone in the Districts of East Sabu and Central Sabu is quite intensive. The risk of land subsidence in this unit needs to be followed up by strict karst management policies. The steps that must be taken in reducing disaster risk are as described in **TABLE 5**.

Volcanic eruption

Sabu island is far from volcanic threats and is not the result of volcanic processes. The closest series of volcanoes are on Sumbawa Island, Flores Island, and Alor Islands, which are part of the active volcanic ring in Indonesia.

Disaster Risk Reduction

11

RRGD on Sabu Island includes pre-disaster, emergency response, and post-disaster stages. The preparation of RRGD is carried out by looking at the potential for disasters and taking into account the natural conditions of Sabu Island. The following is a matrix of analysis results related to efforts for RRGD in Sabu Island. Geological disaster risks include the potential for earthquakes and tsunamis, the potential for liquefaction disasters, the potential for landslides, and land subsidence.

TABLE 5. Reducing the Risk of Land Subsidence on Sabu Island

Stages	Physical Aspect	Social-Economic Aspect	Institutional Aspect	Notes
Pre-disaster	Determination and application of area functions by regulations, Provision of signs and directions for potential subsidence areas. Construction of subsidence prevention structures or other mitigation efforts.	Training & development of karst geo-tourism potential concerning environmental conser-vation and local economic empowerment. Empowerment of local, local potential (customs, culture, natural resources).	Strengthening and disseminating information regarding the characteristics, potential, and limitations of limestone morphology (karst). Increased awareness among the community.	Subsidence-prone areas in karst areas in Kec. East Shabu and Kec. middle
Emergency response	Delineation of disaster locations and locations that are safe from disasters. Provision of environmental facilities and infrastructure for victims. Transfer and construction of a temporary shelter to a safe location. Construction of a subsi-dence hazard limiting structure.	Fulfillment of basic needs for victims. Social and psychological assistance for victims.	Collaboration between stakeholders for handling subsidence cases by emphasizing the provision of basic needs, raw water, and handling land problems. Literacy concerning karst areas	
Post-disaster	Affirmation of disaster zone areas, repairing damage to infrastructure and relocation of resettlement if the disaster location does not allow for resettlement, determination of subsidence hazard boundaries. Karst mapping	Community economic recovery, nature-based economic development, and local wisdom. Explore the potential of local customs and culture. Sustainable karst area development	Strengthening group literacy concerns the area of karst morphology, both regarding its potential and threats. Forming awareness of a shared commitment to community groups for sustainable management of karst areas.	Sustainable management of karst areas

CONCLUSION

Sabu Island is accretion in front of the banda arc. Tectonic influences are the potential for geological disasters; earthquakes, tsunamis, liquefaction, landslides, and subsidence of coral limestone in east sabu district and central sabu district. The limited resources on sabu island need to be understood so that drr efforts can run and be sustainable. Community involvement in disaster risk reduction increasing disaster literacy on sabu island are the keys to successful disaster management.

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