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VULNERABILITY ANALYSIS IN THE NORTHERN COAST REGION OF BANDA ACEH CITY, INDONESIA

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Abstract

Coastal environments are particularly vulnerable to the effects of disasters; partly due to denser and unplanned urbanization and higher human populations, especially in cities of developing countries. Indonesia coastal regions tend to be relatively highly urbanized with higher concentration of human populations. The coastal village region of Alue Naga was finally classified in the category of low-density settlements by the Local Government of Banda Aceh City, after the original communities that were originally as fishermen insisted on returning to the village after the tsunami. However, in order to become a habitable and sustainable settlement, mitigation for this area must be planned based on the level of vulnerability of the coastal region. This study aims to identify disaster-prone zones and determine the level of vulnerability of the region. Data collection and analysis are carried out quantitatively and qualitatively, further simplified spatially and descriptively so as to produce overlay results from thematic maps. The results of the study based on indicators of land cover, type of buildings structure, environmental geomorphology, evacuation routes, and type of mitigation indicate the level of vulnerability of the coastal region of Alue Naga Village including high vulnerability classes and moderate vulnerability classes. Achieving the resilience of the Banda Aceh City to the category of implementing several disaster risk reduction actions with achievements that are still sporadic due to the absence of institutional or systematic policy commitments.

Keywords: Vulnerability, coastal region, Banda Aceh, settlement Alue Naga Village, mitigation.

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1. Introduction

Alue Naga region is located in the northern part City of Banda Aceh, is a coastal village that suffered considerable damage in the past December 26, 2004 strong earthquake and tsunami (Figure 1 A and B). Housing and settlements were damaged leave only material debris and the former site of the buildings. Before the tsunami, housing conditions in Alue Naga were mostly semi-permanent buildings which were increasingly growing in the area, even though the area was prone to strong winds and high tide disasters. This area is increasingly dense by housing development to the shoreline, coupled with the opening of ponds by exploiting mangrove forests that thrive in the region. After the tsunami disaster, majority of the population of Alue Naga became victims and settlements were washed away by the tsunami.

A.

B.

Figure 01. (A). Aerial photos of the Alue Naga Settlement Situation June 2004, very little vegetation is seen in the coastal area which should be a green belt for this region.
(B). The situation of Alue Naga in the aftermath of the earthquake and tsunami in December 2004, it was seen that the settlement was barren.
Source: Google Earth

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Even this area was designated as a protected area after the tsunami disaster in 2004. However, the community resettled in this village and the government could not do much even though the blueprint had categorized this village as not a residential area. Eventually, the village was categorized as a low-density settlement based on the 2009-2029 City Spatial Planning for the City of Banda Aceh. According to Kurniawan, Pramudiarta, Amri, and Yunus (2011), the community may choose to re-occupy its original location provided that the location has been equipped with protection facilities and infrastructure.

2. Problem Statement

The geographical position City of Banda Aceh is in areas that have the potential to face disasters that come from the sea, namely earthquakes that can be accompanied by tsunamis and hurricane disasters that cause tidal waves. The physical geographic structure City of Banda Aceh which has hills at a distance not too far from the coast, if its sustainability is not maintained can also pose a threat of flooding and inundation due to the swift flow of rainwater from the hills and meet with rising sea water due to global warming, beach abrasion, and tidal waves. Damaged mangrove forest is also one of the problems in coastal settlements because it causes ecosystems in coastal areas to be disrupted. The mangrove forest ecosystem serves to keep the coastline stable, and as a windbreak and coastal abrasion barrier. Here is the role of structuring coastal settlements that must be prepared to face and adapt to this event.

Edyanto and Herman (2011) stated that the identification of the analysis of the policy of spatial planning for disaster and environmental problems is now a very important thing and necessity in planning activities. Banda Aceh as a coastal city that has experienced earthquake and tsunami disasters with severe devastation needs to be carried out post-reconstruction studies, in order to become a disaster-responsive and sustainable settlement. Diposaptono and Budiman (2008) said that vulnerability analysis was emphasized on the physical condition of the area and the impact of the socio-economic conditions of local communities. Spatial development of the region needs to pay attention to the constraints of physical development, especially the risk of natural disasters. Furthermore, according to Sukawi (2008), to develop areas that have a high degree of vulnerability to natural disasters, regional development needs to be accompanied by the concept of disaster mitigation, so that the impacts of natural disasters can be minimized even though the disaster cannot be avoided/prevented for the future which will come. So that losses or the number of victims due to disasters can be reduced (risk reduction). The introduction of potential threats that are likely to result from various development activities is important in the preparation of coastal resource management plans. Resource degradation that is very prominent in coastal areas according to Tuwo (2011) is damaged to mangrove forests.

The level of vulnerability is important to know because it is a factor that influences the occurrence of disasters, and new disasters will occur if hazards occur in vulnerable conditions, as shown in the following risk matrix image (Figure 2).

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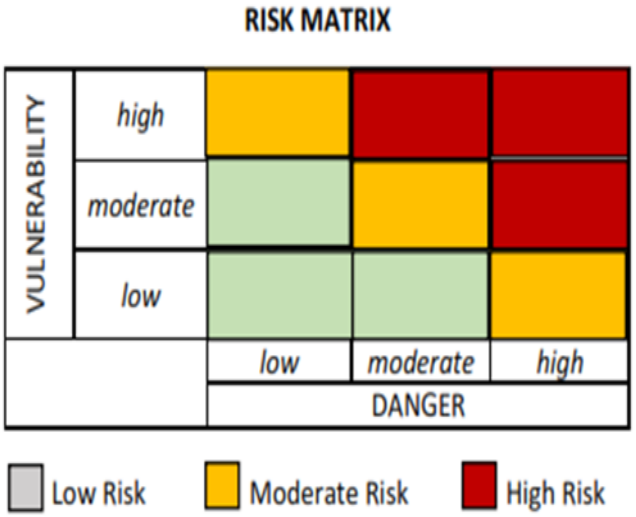

Figure 02. Risk Matrix Image *Source:* Bakornas PB, 2007)

Therefore, it is important to study the physical condition of the region to explore deeper threat factors and existing mitigation, so that it can determine the level of vulnerability of settlements to change the state of disasters from situations of high to low capacity vulnerability. Physical vulnerability according to Ebert, Kerle, and Stein (2009), is the nature of the physical structure that determines the potential for damage to disasters, including the type of material and the quality of the building. It is important that we evaluate and collaborate with local capabilities as the main basis of disaster management activities, so that Alue Naga coastal settlements are able to adapt to disasters.

3. Research Questions

The level of vulnerability is important to know because it is a factor that affects the occurrence of disasters, and new disasters will occur if hazards occur in vulnerable conditions.

- What is the condition of vulnerability to potential and zoning in the area of Alue Naga Village?
- What is the disaster-friendly spatial planning concept for Alue Naga Village?

4. Purpose of the Study

This study aims to draw up the spatial planning of the Alue Naga settlement as a disaster-friendly coastal settlement.

- Knowing the forms of mitigation that are in accordance with regional characteristics; Establish zoning for spatial planning based on and analysis of mapped disaster impact areas.

5. Research Methods

Variables to measure the vulnerability of Alue Naga Village to the threat of natural disasters consist of: coastal typology, coastline, wave height, canopy density, flow, vegetation, house permanence, and escape road. The indicators used for extreme wave and abrasion hazard maps are wave height, current of the waters (current), vegetation cover in coastal areas, coastline forms and coastal typologies. The index and equation conversion parameters are:

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$$Interval = \frac{\sum Max\ value - \sum Min\ Value}{Number\ of\ Clases}$$

where , Max value is the maximum number of vulnerability variables, Min value is the minimum number of vulnerability variables and Sums of class is 3

Maximum Value	30	≥	23	High
Minimum Value	10	≥	17	Medium
Sum of class	3	≥	10	Low
Interval	7			

Vulnerability shows the vulnerability faced by a community in facing threats from its environment. The parameters observed in the survey included: pre-post and post-disaster area conditions, land allotment data, type of closure and land use, composition of community livelihoods related to the use of mangrove forests. To deepen the study, also carried out a search of secondary data and the results of previous relevant research. Based on the method of data collection, the technique of determining the critical level of mangrove land in Alue Naga Village is carried out by means of evaluation using GIS (Geographic Information System) technology and Remote Sensing (satellite imagery). The analytical method used in this study is a quantitative descriptive method that is explaining the relationship between variables by analyzing numerical data (numbers) using statistics with ArcGIS software. Data interpretation in remote sensing according to Farizki and Anurogo (2017), done digitally for numeric data and manually for visual data, aims to convert numerical data or visual data into information for specific purposes. The quantitative approach was carried out to compare the existing conditions in the field as seen from vulnerability, exposure and adaptation in the coastal areas of Alue Naga. Existing conditions are converted into specified values and weights making it easier to carry out numerical analysis. After that, a map will be made to see the condition of the coastal area.

6. Findings

6.1. Geomorphology of the Study Area

The research is located in Alue Naga Village, a coastal village located in Syiah Kuala District, Banda Aceh City, located approximately 10 kilometers from the city center. Allotment of land as a limited settlement, buffer zone, and green open space. Alue Naga Village consists of four hamlets, namely Kutaran, Po Diamat, Bunot, and Musafir (Figure 3).

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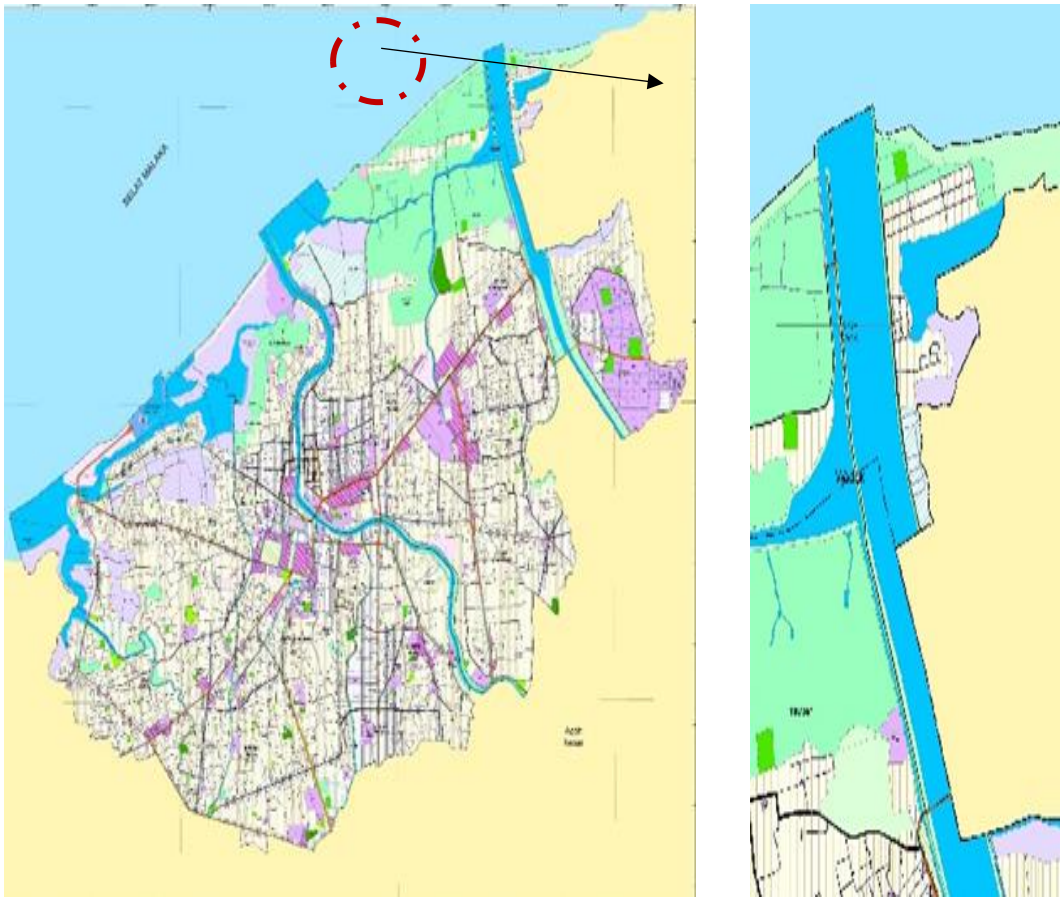

Figure 03. Study Location Source: Modified Map from RTRW City of Banda Aceh 2009-2029

6.2. Alue Naga Disaster Mitigation that has been done

The environmental disasters in Alue Naga identified were tidal waves, sea winds, coastal abrasion and tsunamis. In order to anticipate damage to coastal areas and protect the settlements around the coast due to large waves, the tidal embankment is built on the coast of Alue Naga. This embankment is made with a pile construction of large stones/boulders arranged in such a way that it can form like a beach belt. The use of embankments is not only a barrier for tidal waves, but also with economic, recreational and aesthetic functions. Soft protection disaster mitigation in the form of planting mangroves and making silvofishery system ponds are still pioneered, not maximally.

This type of mitigation will function as a green belt. Belts are the stronghold of coastal areas from tidal waves, tsunamis, or other threats from the sea. Diposaptono, Budiman, and Agung (2009) explained that mangrove forests in addition to functioning as absorbers of tidal waves and absorbing tsunami energy, were also able to absorb carbon dioxide gas in the earth's atmosphere.

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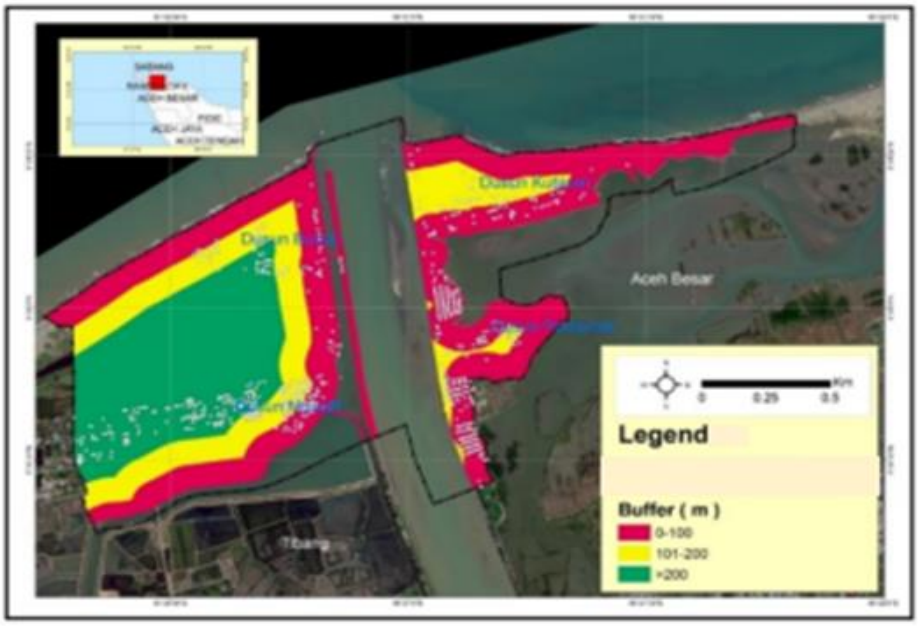

Figure 04. The ideal sea setback for Alue Naga Village

Based on the results of the analysis of the distance of residential buildings from the sea border (Figure 4), Po Diamat Hamlet and Kutaran Hamlet are in the most vulnerable areas of the tsunami, high tide and strong winds. The shape of the bay between Kutaran Hamlet and Hamlet of Po Observed has the potential to increase wave pressure to settlements if it is not inhibited, preferably with mangrove conservation to be in line with ecotourism planning. Of the four hamlets in Alue Naga Village, Dusun Musafir, most residential buildings are in areas of low vulnerability.

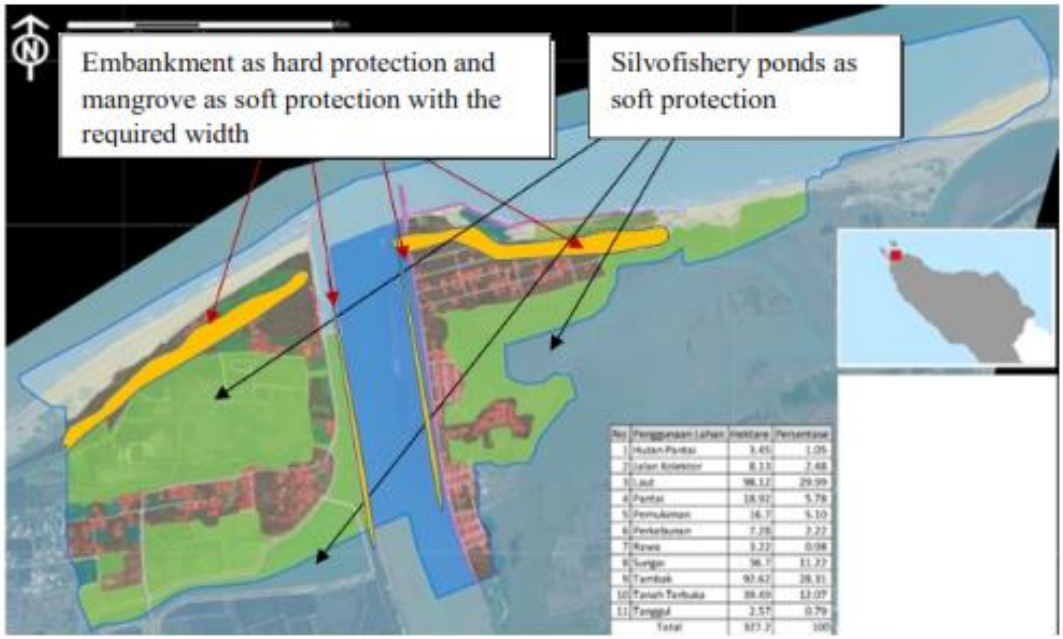

Figure 05. Concept Recommendation for Protection of Spatial Alue Naga Settlement

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Protection of the built-up area of the physical environment of the Alue Naga settlement needs to utilize both structural and non-structural mitigation approaches. The Alue Naga coastal village concept of spatial planning is directed at maintaining shoreline protection with retaining structures and breaking down the waves and towards the land where a natural protection zone is needed in the form of mangrove stands (Figure 5). The boundary between mangrove forests and the physical environment of the land can be built either by walls or walls made of rocks or rock mounds of a certain height which are built extending parallel to the coastline. In settlements, layout planning is directed to structuring buildings and roads that are parallel to the coastline and recommends being able to develop building forms in the form of stilt houses that have strong support poles. According to experts, to preserve marine biota the width of the beach green belt is 50 meters and the green belt width of the river estuary is 10 meters. The ponds in Alue Naga were damaged by the tsunami waves, so that both ponds and channels need to be rehabilitated/reconstructed first. Because of its location near the mangrove vegetation and before the pond was developed it was indeed a mangrove habitat, so the development of the pond in the future was carried out by planting mangrove trees in ponds, known as silvofishery systems. Mangrove vegetation tends to grow in wet or inundated habitats, so planting mangroves is concentrated in locations before the tsunami has mangrove vegetation.

6.3. Regional Vulnerability

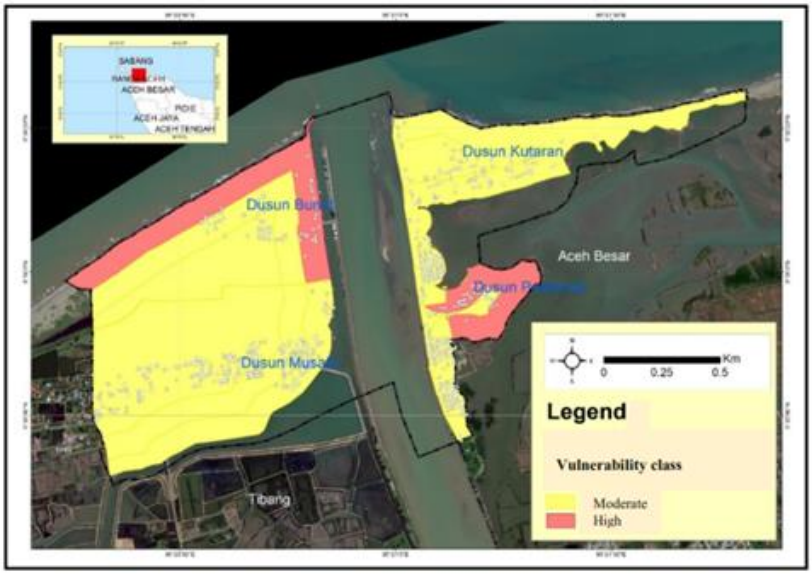

Figure 06. Mapping disaster vulnerability in Alue Naga Village Settlement Area
Source: GIS Analysis (2018)

Based on the results of the environmental vulnerability analysis using the GIS method, the level of vulnerability of residential areas in Alue Naga Village consists of high vulnerability classes and moderate vulnerability classes (Figure 6). Indicators used for environmental vulnerability are land cover (protected forest, scrub, mangrove), type of building structure, environmental geomorphology, evacuation route, type of mitigation available:

- High vulnerability zones in Po Hamlet Diamat (1) caused by the shape of the bay in the waters outside the settlement will cause higher speeds in the flow leading to settlements. During this

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time the hamlet is often inundated by high tides. To reduce and break down the water flow, the pond area is revived by structuring the silvofishery system. In addition, concrete embankments or elephant stones are also made to prevent abrasion and the erosion of residential areas is increasingly eroded;

- Whereas the high vulnerability zone in Bunot Hamlet (4) is caused by some residential buildings within 100 meters of the coastline, which should be a buffer zone for mangrove conservation. Even though the breakwater stone embankment has been installed, the buffer zone quality must be improved with mangrove conservation. Likewise, the river border section must be arranged with mangrove conservation. Furthermore, on the beach part vegetation is planted from the type of beach plants in a tight manner. For ponds arranged by applying silvofishery system. The condition of residential buildings in Bunot hamlet is semi-permanent so that buildings are vulnerable in terms of structure;
- Based on the results of the study in Kutaran Hamlet (2) included in the moderate vulnerability class, because from the coast there was a breakwater stone embankment, but the quality of the buffer zone must be improved with mangrove conservation, and on the beach planted coastal vegetation closely. Housing construction in this area is permanent with the type of stage and non-stage.
- Musafir Hamlet (3) is the safest among the four hamlets in Alue Naga Village. However, the threat of tidal and tsunami disasters from the river direction has the potential to come, so the quality of the environment must be increased in that part with mangrove conservation. Permanent housing building structure. However, the escape road in this hamlet has to be partially parallel to the coastline, and after that it is perpendicular to the coastline. Therefore, Hamlet Musafir is also included in the middle-class vulnerability zone;
- The existing escape road is too narrow so that it is considered not functioning optimally when a disaster occurs;
- The forms of disaster mitigation that already exist in Alue Naga Village, among others: canals on the left and right along the river have been planted with mangroves, but have not been maximized to reduce the flow velocity both in number and mature so that the canopy density is still lacking; rock embankments and breakwater, but not yet comprehensive, especially in the eastern part of the settlement, potentially high tide, high winds and tsunamis.
- Mitigation of the type of soft protection has not been maximized as a buffer zone, conservation of ponds, and coastal vegetation in the entire area of Alue Naga Village.
- The coastal border management pattern, which is to restore the beach border as a green open space that supports ecotourism activities, prevents the use of green open spaces for activities that can reduce ecological and aesthetic values, and composes coastal vegetation based on tree height to fulfil function and aesthetic values mangrove vegetation to prevent coastal abrasion.
- It is very important to build escape buildings in the area because the escape road is too long to reach a safe area in the event of a tsunami.

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7. Conclusion

Based on the above points conclusions can be drawn, as follows:

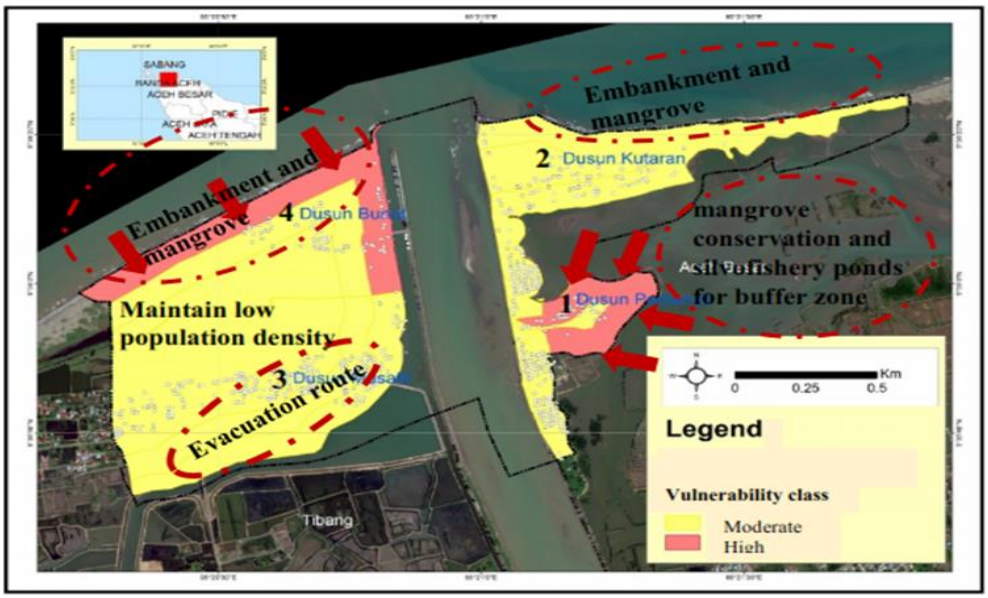

Figure 07. Mapping Disaster Mitigation Strategies through Spatial Planning and the Environment Life in Alue Naga Village Settlement Area
Source: GIS Analysis (2018)

The morphology of Alue Naga beach can be interpreted simply as a change in the shape of the coast based on observations of Google Earth imagery in 2002-2017. The coastline keeps abrasion caused by sea water. The most noticeable changes are seen in Kutaran Hamlet which continues to reduce coastal areas. High sea wave gampong Alue Naga which is part of the waters of the Sabang-Banda Aceh region is at an altitude of 2.5-4 meters. Besides that, the general wind conditions in Banda Aceh that are very fast require the protection of vegetation in the form of mangroves in this area to slow down the flow of air to settlements and protect the coast from abrasion. There are still many housing infrastructures in Alue Naga that have not been handled properly, such as drainage. This results in a residential environment in unhealthy conditions. Therefore, it is very necessary for Partner Agencies, namely the Housing and Settlement Agency of Banda Aceh City to fix the condition. Based on the results of the environmental vulnerability analysis using the GIS method, the level of vulnerability of residential areas in Alue Naga Village consists of high vulnerability classes and moderate vulnerability classes. Indicators used for environmental vulnerability are land cover (protected forest, scrub, mangrove), type of building structure, environmental geomorphology, evacuation route, type of mitigation available, wave height, and coastline. Conclusion achieving regional resilience in Banda Aceh City has implemented several disaster risk reduction measures with achievements that are still sporadic due to the absence of institutional / and or systematic policy commitments (Figure 7).

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