The vulnerability of housing on the north coast of Banda Aceh to disasters from the sea

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Abstract. Alue Naga is an example of a coastal village in the northern city of Banda Aceh which was severely damaged during the earthquake and tsunami in 2004, but until now there has been no maximum environmental improvement and mitigation for this coastal settlement. The ideal initial mitigation study to be carried out for coastal settlements is to analyze the physical vulnerability of housing as a physical structure characteristic that determines the potential damage to disasters. This study uses a qualitative descriptive method with data collection through observation, a global positioning system, interviews and questionnaires. Data were analyzed using geographic information system techniques to determine the spatial condition of the area. Assessment of the potential vulnerability of housing in each cluster of Alue Naga settlements is obtained by scoring and weighting methods for variables that contribute to the level of disaster vulnerability, namely the type of building construction, the shape of the ground floor of the building, and the orientation of the building to the coast. The results showed that the potential vulnerability in each cluster was different for each variable being reviewed, there were clusters that were vulnerable, more vulnerable, and very vulnerable to the threat of disasters from the sea. It takes serious action from stakeholders to further improve protection and mitigation against disasters from the sea in the northern coastal settlements of Banda Aceh City with structural mitigation and non-structural mitigation.

1. Introduction

Coastal areas are very vulnerable to damage caused by various natural phenomena from their geographical conditions. The tsunami disaster has reminded us of the importance of urban spatial planning that considers disaster aspects. According to [1], the devastating damage that hit the city of Banda Aceh in 2004 was due to the lack of barriers to the breakthrough of sea waves entering the city, due to the vertical road structure to the coastline. Even a ship weighing hundreds of tons is capable of "landing" into a city up to five kilometers from its place of origin by the sea. The road structure on the northern coast of Banda Aceh is indeed dominant with its position perpendicular to the coastline, while the function of vegetation as a barrier is very important in these coastal environmental conditions. This phenomenon happened in Alue Naga Village (Figure 1), causing the village to suffer very serious damage when the tsunami disaster occurred in 2004. Before the tsunami, Alue Naga was very arid, due to exploitation of mangrove forests for ponds. According to [2] coastal vegetation is effective in dissipating incoming wave energy, offering valuable protection to coastal communities.
Figure 1. Due to the lack of coastal vegetation to block the breakthrough of sea waves, the collector road and river that divides Alue Naga Village functions like an ocean flow tunnel in the 2004 tsunami disaster.

Currently, the damage to the settlement of Alue Naga Village has not been fully reconstructed and mitigated, so there is still a risk of further environmental damage. The barren and non-ecological conditions of the coast as seen in Figure 2 will not be able to protect the environment if a disaster comes from the direction of the sea. Coastal areas without mitigation are prone to disasters that can instantly destroy all facilities for houses, boats, coastal resources, etc. as a source of daily livelihoods. [3] concluded that disaster risk reduction actions on the Banda Aceh coast are still sporadic and there is no commitment to more detailed institutional policies.

Figure 2. The phenomenon of Alue Naga Village as an example of the northern coast of Banda Aceh City has not been optimally mitigated.

Ideally, mitigation studies on coastal settlements begin by looking at the physical vulnerability of the settlement. [4] mentions vulnerability as a specific condition that results in increased damage, losses and losses due to a disaster depending on characteristics such as types of building materials, demographics, and geographic location. Furthermore, [5] stated that physical vulnerability is defined as a characteristic of the physical structure that determines the potential damage caused by a disaster (type of material and quality of the building). Assessing the potential vulnerability of housing in coastal areas is very important to determine how resilient these settlements are when a disaster occurs. This is one of the mitigation efforts to minimize and reduce the impact of disasters on society. Special considerations must be made when selecting materials for coastal buildings. [6] said harsh environments require more substantial building materials to be used and more caution when using these materials to ensure
durability, resistance to hazards, and less maintenance. [7] stated that buildings with stilt is safe against extreme ocean waves and buildings with an orientation position perpendicular to the coastline are relatively safe against these disasters.

2. Methods
This research according to its purpose is a qualitative descriptive study by combining quantitative data and qualitative data.

2.1 Collection of data
Primary data collection is carried out in two ways:

- Field observations to observe the housing characteristics of each cluster in the study location and determine the housing location using the Global Positioning System. The collected data is overlaid with google earth imagery to get a spatial picture with attribute information, then various maps are made according to the condition of Alue Naga Village.
- Interview and distribution of questionnaires to the people of Alue Naga Village to obtain information and perceptions related to the characteristics of residential housing. The data from the questionnaire was then processed in descriptive form to support the results of research based on community perceptions regarding housing and disasters in the area.

2.2 Data analysis

- Geographical information system technique with ArcGIS software is used as a spatial analysis technique / georeference. To determine the potential for disaster vulnerability, scoring and weighting methods are used for each variable.
- Assessment of building vulnerability is obtained by measuring the physical element variables of the building that contribute to the level of vulnerability to earthquakes, tsunamis, tidal waves, and strong winds. The element variables used are 1) The quality of the building is indicated by the materials that compose the building based on three types of materials including reinforced concrete and plastered bricks (permanent), concrete and wood construction (semi-permanent), and wood construction; 2) The form of the ground floor includes, houses constructed on stilts are considered more capable of escaping water runoff compared to houses built on the ground with openings and closed ones; 3) Building orientation is the tendency of the shape of the building towards the shoreline divided into three orientation classifications (to the coastline), namely the long side of the building tends to be perpendicular, the long side of the building tends to tilt, and the long side of the building tends to be parallel.
- Each element has a different weight to the physical vulnerability of the building. It is given the numbers 5 (very good), 4 (good, 3 (not good), 2 (not good), 1 (very bad).

2.3 Study location
The research location is in Alue Naga Village and divided into four clusters based on the hamlets in the village, namely Beunot, Musafir, Kutaran, and Po Diamat. Each cluster has a different distance from the coastline, can be seen in Figure 3.
3. Results and discussion

3.1 Identification of disaster prone conditions

The northern coastal area of Banda Aceh, especially Alue Naga village, is a flat area where around 89% is an area with a slope of 0 to 2%. In this area, development can still be carried out but must pay attention to the safety factor which is closely related to the type of geological hazard. Geological protected areas, particularly geological disaster prone areas in this region include:

a. Earthquake-prone areas
   To anticipate earthquake disasters it is necessary to have a building code (Building Code), such as residential development needs to use earthquake resistant buildings that are traditional in nature, while for heavy buildings it is necessary to consider earthquake acceleration.

b. Tsunami prone areas
   To minimize the impact of damage from the tsunami threat, development in the Alue Naga coastal area needs to pay attention to the height of the tsunami run-up, namely elevation up to <5 m above sea level, coastal morphology (the shape of the bay, river estuary, and the topography of the plains parallel to the coastline). It is necessary to build a representative escape building for the evacuation of the population, because in this area which is very close to the sea, there are no buildings for rescue. Alue Naga Village is located at an altitude of 1 meter above sea level.

c. Areas with High Liquefaction Potential
   The threat of liquefaction is high because in this area there are lanauan sand deposits with a carrying capacity of 0.2-0.5 kg/cm², which are currently filled with trade and service activities. Therefore, for buildings on this type of soil, it is necessary to choose a building construction that is liquefaction-resistant, to build according to civil engineering standards and following the characteristics of the threat.

The people who have lived in the study locations are very familiar with the various kinds of disasters that often hit their villages and understand the causes of disasters. According to the community, the main causes of disasters are heavy rain and strong winds, beach / wave abrasion, natural / weather factors and due to "Allah's Power". Even the community already knows that disasters occur because they do not protect the environment, global warming, changing seasons, shifting plates and there is no greening.

Based on various types of threats, the most frequent ones are strong winds, tidal waves and coastal abrasion. Meanwhile, the threat of earthquake and tsunami disasters are also very familiar to these coastal communities. They are very aware that the potential for a tsunami disaster someday threatens the area where they live again. Potential disasters that threaten the coast of Alue Naga can be seen in
Table 1 below. Table 1 shows the types of disasters that have hit the study location, and how much threat the community feels from each of these disasters. The “total column” shows the ranking of the most feared disasters according to the community, namely earthquakes, then tsunamis, high winds, tidal waves, coastal abrasion, and finally floods. Meanwhile, the "Rank column for disaster threat in the cluster" shows the position of the cluster against the threat, that is, the community feels the threat of disaster in the Beunot cluster is the biggest of the four clusters, while the safest is in the Musafir cluster.

| No. | Kind of disaster       | Cluster Po Diamat (1) | Cluster Kutaran (2) | Cluster Musafir (3) | Cluster Bunot (4) | Total | Disaster Threat Ranking |
|-----|------------------------|-----------------------|---------------------|---------------------|-------------------|-------|------------------------|
| 1   | Strong wind            | 2                     | 3                   | 1                   | 3                 | 9     | 3                      |
| 2   | Tidal wave             | 3                     | 1                   | 3                   | 3                 | 8     | 4                      |
| 3   | earthquake             | 3                     | 3                   | 3                   | 3                 | 12    | 1                      |
| 4   | Beach abrasion         | 1                     | 2                   | 1                   | 3                 | 7     | 5                      |
| 5   | Tsunami threat         | 3                     | 3                   | 2                   | 3                 | 11    | 2                      |
| 6   | Flood                  | 2                     | 1                   | 1                   | 1                 | 5     | 6                      |

Disaster threat rating on the cluster

|   | Bunot and Musafir | Australian government | Concrete, Zinc roof, Mountain rock foundation, Wooden door, Glasses window, Concrete truss |
|   | Kutaran and Po Diamat | Catholic Relief Services | Concrete, Zinc roof, Mountain rock foundation, Wooden door, Glasses window, Concrete truss |

3.2 Housing quality parameters
The majority of housing in Alue Naga Village are houses of type 36 plus square meters which were reconstructed by the Rehabilitation and Reconstruction Agency (BRR) NAD-NIAS and several countries that donated housing after the tsunami disaster. Generally, the residential buildings in this area are constructed from brick and cement materials totaling 521 houses with a total percentage of 78%. Meanwhile, the number of buildings that are not permanent is 150 with a percentage of 22%.

The Australian Government built housing in Beunot and Musafir with a green zinc roof. The Catholic Relief Services (CRS) Institute built housing in Kutaran and Podiamat with a blue zinc roof. Furthermore, housing assistance from Caritas Germany in Podiamat characterized by red zinc roofs and housing construction in Kutaran characterized by white zinc roofs. Meanwhile, housing development assistance from BRR in Musafir and Beunot was characterized by red zinc roofs and green walls. Table 2 shows the housing model and types of housing construction materials in Alue Naga.

| No. | Cluster                  | Housing Models | Donor                      | Materials                                      |
|-----|--------------------------|----------------|----------------------------|-----------------------------------------------|
| 1.  | Bunot and Musafir        |                | Australian government      | Concrete, Zinc roof, Mountain rock foundation, Wooden door, Glasses window, Concrete truss |
| 2   | Kutaran and Po Diamat    |                | Catholic Relief Services   | Concrete, Zinc roof, Mountain rock foundation, Wooden door, Glasses window, Concrete truss |
The community considered that the construction and materials of their houses were adequate for protection and safe from disasters. About 26% rated their house construction as very good, 33% of the people rated their house construction as good, 23% considered it not good, 14% thought it was not good, and 1% considered their house construction very bad. The results of the translation of the hamlets in the Alue Naga village are presented in Figure 4.

For residential buildings, in terms of structural strength, they have met the strength standard for housing in the earthquake area, namely a one-story concrete building using reinforced concrete construction, using concrete truss and stucco brick.

The buildings in the study location that are not permanent (constructed with wood) are the community shops in the conditions shown in Figure 5. These wooden stalls are built in the coastal location and its surroundings on silt clay sediment types that are prone to liquefaction. The building is very vulnerable to disasters, however, the wooden building is not used by the community as a shelter.
3.3 Ground floor condition parameters

The types of buildings in the study location are dominated by residential buildings. The characteristics of the buildings in the area show that the ground floor is more closed than the open ground floor / stilted. The floor height of a dwelling that is constructed on the ground is too low, causing the dwelling to be at risk of becoming damp and accessible to tidal waves because in this area the ground water level is high. It is better if the houses are made on stilts such as those built by Caritas Germany in Kutaran cluster and Po Diamat cluster.

Figure 6 shows that the stilt-floored residential building in Kutaran has a floor height of half a meter from the ground level, and the stilt floor dwelling in Po Diamat has a height of 1 (one) meter from the ground. The open ground floor conditions can allow water to pass and reduce the pressure load of the tsunami. However, the resistance to tsunamis with the construction of houses on stilts has no guarantee of strength and is highly dependent on the wave height, because the height of the stage is relatively low compared to the height of the tsunami waves that occur in coastal settlements. In this case the role of vegetation as a barrier to wave speed, as well as protection for beaches and settlements is very decisive. The complete relationship between construction and vulnerability can be seen in Table 3.

Building structures that respond to tsunamis are structures that can break and are strong enough to withstand the impact of the waves that hit them. As well as having an area that is higher than the tsunami wave front as a means of saving the building users themselves, see Figure 7.
Table 3. Housing Models and Vulnerability

| No. | Housing Models          | Cluster        | Construction | Vulnerability          |
|-----|-------------------------|----------------|--------------|------------------------|
| 1.  | Bunot and Musafir       | On the ground  |              | - Damp                 |
|     |                         |                |              | - Tsunami threat       |
| 2.  | Kutaran and Po Diamat   | On the ground  |              | - Damp                 |
|     |                         |                |              | - Tidal wave           |
|     |                         |                |              | - Tsunami threat       |
| 3.  | Po Diamat               | Stilted 100 cm |              | - Tsunami threat       |
| 4.  | Musafir and Bunot       | On the ground  |              | - Damp                 |
|     |                         |                |              | - Tidal wave           |
|     |                         |                |              | - Tsunami threat       |
| 5.  | Kutaran                 | Stilted 50 cm  |              | - Tsunami threat       |

Figure 7. Good structure to respond to tsunamis (Source: [8])

3.4 Building orientation parameters
The observation result of building orientation at the study location shows the tendency of buildings that are perpendicular to the coast resulting in a low vulnerability of buildings to tsunamis and strong winds, related to the area of impact received by the buildings. The impact of the tsunami caused the building to be destroyed, while the impact of the strong winds coming from the direction of the sea resulted in the tightening force of the roof area, as shown in Figure 8.

The greater the angle of the roof, the greater the area of the roof that is in direct contact with the incoming wind (high risk of wind damage). As stated by [9], the amount of air pressure on the roof depends on the slope of the roof itself. The gable forms a large angle / ramps and the ramps are larger than other roofs. Therefore, it is better if in windy areas to avoid the shape of the roof with large angles / ramps. Houses in windy areas can use a roof with a small angle or a roof with a curved model to make it more aerodynamic.
The group of buildings with the orientation perpendicular to the coast indicates that in this area the buildings tend to be more dominant to be built with their long sides perpendicular to the coastline. This condition is considered good enough in terms of building orientation to reduce the level of vulnerability to tsunamis. Table 4 shows the vulnerability between the orientation of the buildings towards the coast in each cluster in Alue Naga Village.

![Figure 8](image)

**Figure 8.** a). Wave behavior towards building orientation and b). Wind behavior towards roof slope (Source: [8])

**Table 4.** The orientation of the building towards the coast in relation to its vulnerability.

| No. | Cluster   | Description                                                                 | Vulnerability                                      |
|-----|-----------|------------------------------------------------------------------------------|---------------------------------------------------|
| 1.  | Beunot    | The orientation of the buildings and dwellings in this cluster is irregular. 70% of the buildings are perpendicular to the coast and 30% of the buildings are parallel to the coast. | Vulnerable to Tsunamis and strong winds            |
| 2.  | Musafir   | The orientation of the buildings and dwellings in this cluster is irregular. 50% of the buildings are perpendicular to the coast and 50% of the buildings are parallel to the coast. | Very vulnerable to Tsunamis and strong winds       |
| 3.  | Kutaran   | The orientation of the buildings and settlements in this cluster is somewhat irregular. 90% of the buildings are perpendicular to the coast and 10% of the buildings are parallel to the coast. | Somewhat prone to Tsunamis and strong winds        |
| 4.  | Po Diamat | The orientation of the buildings and dwellings in this cluster is irregular. 90% of the buildings are perpendicular to the coast and 10% of the buildings are parallel to the coast. | Somewhat prone to Tsunamis and strong winds        |
4. Conclusions
From the discussion above, several conclusions can be drawn, including:
1. Housing in each cluster in Alue Naga village has used reinforced concrete construction and building materials that comply with civil engineering standards to respond to earthquakes;
2. Construction of buildings on the ground applies a very low peil floor height to the Beunot and Musafir clusters which will cause the building to become damp, because the water level of the swampy / brackish soil in the area is high. Brackish water seeping into building walls also has the potential to make plaster and brick walls porous;
3. The ideal housing form for Alue Naga Village and the northern coastal area of Banda Aceh is one which constructs a stage to respond to humidity and tidal waves. However, to respond to tidal waves and tsunamis, there must be environmental protection in the form of soft protection and hard protection, which the government strives to help empower local communities. The ideal stilt construction to respond to tsunamis is a reinforced concrete frame construction structure;
4. The stage construction in the Kutaran and Po Diamat clusters, if seen from the height of the floor, the stage has not responded optimally to the tsunami. It is necessary to build a rescue building for this coastal village area because the achievement of evacuation must go through a fairly long road;
5. The orientation of the building towards the coast in order to respond to strong winds and the threat of tsunami has not been carried out optimally (house orientation is irregular), the vulnerability of each cluster varies, vulnerable clusters (Kutaran and Po Diamat), more vulnerable clusters (Beunot), and highly vulnerable clusters (Musafir).

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