Analysis of Greenbelt in Sibolga for Tsunami Mitigation

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Abstract. West coast of Sumatra is one of the vulnerable areas to natural disaster, such as tsunami. The prevention of potential destruction has to be done in order to reduce victim and economical loss. Naturally, coastal vegetation can reduce the wave strength, hence reducing the destructive force. The aim of this research was to obtain the potential area for greenbelt to support rehabilitation and prevention of potential destruction. Most of coastal area of Sibolga has very low Normalize Difference Vegetation Index (NDVI) value, indicating that area has less vegetation. Field checking showed that the coastal area has dense settlement with less vegetation. Land system found in the coastal area is Kahayan which is suitable for mangrove. The area is alluvium plain, behind the coastal is mountainous and hilly areas. In 100, 200. and 500 meters of greenbelt area width, highest vegetation density was very low, followed by low vegetation class. It means most of the area has no vegetation or less vegetation, therefore Greenbelt planning is needed to protect the beach from potential destruction of natural disaster, mainly tsunami.

1. Introduction
As an archipelago country, Indonesia has lengthy coastline along its islands. Indonesia has 81,000 km of coastline [1] and considerable amount of people live along the coastline and do many activities for their livelihood. The coastal zone is one of important ecosystem for people who lives in the area. So, the area should be protected from any potential destruction which can harm their lives.

Earthquake and tsunami can create high damage in the coastal area. People needs to prepare themselves to protect their home and lives from any disastrous cases. Tsunami has caused huge loss of lives and materials. Tsunami in Aceh has taken more than 200,000 lives and destroyed the area [2].

Indonesia is divided into six zones based on the relationship between tsunami, earthquake activity and characteristic of seismotectonic, where Sumatra belongs to zone A. Historical record mentioned 16 cases of earthquake in period between 1790 to 2005. Therefore, the repeat period of Zone A is 10-15 years. In 2004, more than 200,000 peoples became victim of Tsunami in Nanggrooe Aceh Darussalam and North Sumatera [2]. Tsunami along the southern coast of West Java, Cilacap and Yogyakarta took 378 lives and material destruction with the estimated loss of more than 70 billion rupiahs [3].

Most of Tsunami incident in Indonesia caused by tectonic earthquake along subduction area [2]. Eastern part of Sumatera is one of vulnerable area to tsunami. Its position is in line with subduction line between Eurasian and Indo-Australian plates which have West-East axis in the deep of Indonesian
Ocean [4]. Earthquake with 9.0 R will create energy bigger than 100,000 times of Hiroshima bomb. Shape of beach and bottom of the sea in the coastal area, incident angle of wave and front shape of tsunami wave which come to the beach will influence to the potential damage [5].

Disaster mitigation is crucial to minimize any potential destruction. According to Republic of Indonesia Constitution Number 27 Year 2007, disaster mitigation is the effort to reduce disaster risk, both structure and physical through development of natural physical and/or man-made, both non structural or non physical, through the improvement of capability in dealing disaster threat in coastal area and small islands. Greenbelt is one of the option to protect the shore by using vegetation to reduce the strength of the wave. The aim of this research was to build a spatial model for greenbelt in order to support the rehabilitation effort and prevent the potential destruction of tsunami.

Harada and Imamura (2003) in [2] did a research on effectivity of coastal forest to overcome tsunami. They did the simulation on different width of forest which are 50 m, 100 m, 200 m, and 400 m. The result showed that the coastal forest with width of 200 meters, 30 trees per 100 square meters and diameter of 15 cm can overcome 50% of energy of tsunami with the height of 3 meters. Furthermore, the research of Harada and Imamura showed that the wider the width of the forest the more energy to be reduced. The existence of the forest in the coastal area can reduce the run up distance, height of inundation, current and hydraulic force that reach the beach.

Study on vegetation density in the coastal area is important in order to support protection planning to prevent any potential destruction caused by disaster especially tsunami. Information on land suitability of the area is needed to find out which area is potential to have a greenbelt for coastal protection. The specific aims of the research were to obtain the vegetation density level on the area, to find out the potential area for coastal vegetation and to find out the vegetation density in potential greenbelt area. The specific aims led to the main aim of the research.

This research is conducted to give an insight to stakeholders and decision makers on the potential and condition of the coastal area. Recommendation on greenbelt planning will be given to prevent the possible future damages.

2. Material and Methods
The research area was in the coastal area of Sibolga and Central Tapanuli as the part of eastern area of North Sumatera Province. It was conducted from May to September 2017. There were 3 stages of research including preliminary, fieldwork and spatial analysis. The preliminary stage including proposal compilation, data and information gathering and fieldwork preparation. Fieldwork included field check, vegetation survey/analysis and supportive data compilation. The analysis was including satellite image and map analysis.

Data and equipments of the research were needed for data preprocessing, analysis and fieldwork activity. Those were computer, softwares (ArcGis, Erdas, Microsoft Word) for maps and images analysis. Satellite image used in this research was Landsat 8. Maps including administration, land system. For the fieldwork, there were plan map, observation sheets, GPS receiver, compass, measurement tape and camera.

Vegetation density map was obtained from NDVI (Normalized Difference Vegetation Index) analysis. The steps can be seen in Figure 1. NDVI value is the result of image processing using transformation of Normalized Difference Vegetation Index (NDVI) which is the ratio between reflectance of Red Band (R) and Near Infrared Band (NIR). NDVI value can give an information on condition of vegetation and non vegetation such as water, soil and rocks. The value is between -1 to +1. The closer value to 1 shows that the land cover has dense vegetation.

The representation of NDVI value to vegetation and soil relation in land cover is mentioned in [8]. Very low value of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high value indicates temperate and tropical
rainforests (0.6 to 0.8). Bare soil is represented with NDVI values, which are closest to 0 and water bodies are represented with negative NDVI values.

Buffer analysis was conducted using 3 buffer width that are 100, 200 and 500 meters. The buffer was then combined with NDVI map. Therefore, there is information on NDVI in each buffer area. This will give an insight of how the condition of the vegetation in those areas. It will lead to the need of rehabilitation in terms of planting trees in the area.

Land system map gives an information on which land system are in the coastal area of Sibolga. There will be a potential zone or area that is suitable for greenbelt.

3. Results and Discussion

Sibolga is part of North Sumatera Province (Figure 1). The area is in a border of Central Tapanuli and in across with Nias Island. Sibolga coastline is in the western part of Sumatera stretching from north to south. It is in the area of Tapian Nauli bay. Sibolga harbor is a place of transit to Nias Island and other cities in western coast of Sumatera.

Figure 1. North Sumatera (left) and surrounding cities of Sibolga (right)

Sibolga is in the surrounding of some districts of Central Tapanuli Regency. There are districts of Tapian Nauli, Sitahuis and Sarudik. Other districts include in the bay area are Pandan and Badiri (Figure 1).

Islands in the area of Sibolga are Poncan Gadang, Poncan Ketek, Sarudik and Panjang. The Island of Mursala is in across the Sibolga which is in the part of the area of Central Tapanuli. Sibolga is in the border with Cental Tapanuli Regency in the east, south and north part and the west is in the border with Indian Ocean. Coastal area of Sibolga is part of bay area with mainland and small islands in the surrounding.

Shown image gave visual display on coastal area of Sibolga and the surrounding (Figure 2). Sibolga is in the bay area and the coast is directed to Nias Island. In the west there is an island and a part of Central Tapanuli called Mursala Island.

Figure 2 also shows that coastal area of Sibolga is an area with dense settlement with only small portion of vegetated area. The area with vegetation is shown by green colour.

Field observation was conducted along the coastline of Sibolga and Central Tapanuli (Figure 3). The field checking showed that the land cover along the coastal area is dominated by settlement and hotel. Only small portion of vegetated area was found (Figure 4). Vegetation found in the area are cemara laut, ketapang and coconut. Shrub was also found in the area. There are also bare land and sandy beach.

Condition of coastal area of Central Tapanuli is different with Sibolga. Vegetation analysis was conducted in Central Tapanuli. The area were Pandan, Tapian Nauli, Badiri dan Sorkam. In Jago-Jago Village of Badiri District and Tapian Nauli 1 Village of Tapian Nauli District mangrove was found while in other area there were coastal vegetation (Figure 5).
Figure 2. Coastal area of Sibolga

Figure 3. Observation location along the coast of Sibolga and Central Tapanuli (green dots)

Figure 4. Settlements and bare land and sandy field in Sibolga
Figure 6. Landsat Image year 2017 of Coastal area of Sibolga and the surrounding

NDVI analysis was conducted using Landsat imagery of year 2017. The result was classified into some classes with 0.1 interval. Figure 6 shows the Landsat year 2017 in coastal Sibolga and Central Tapanuli.

Physical efforts are aimed to decrease the energy of tsunami wave that come to the beach, which can be divided to physical and natural efforts. Those efforts are complementary, depending on the condition of the area. Naturally, it can be done by having greenbelt in the form of coastal forest and mangrove. Mangrove has a strong and unique root system with dense canopy. Mangrove is ideal to protect the beach naturally [7].

Finding in Cuddalore district of India showed that at the river mouth, the tsunami completely destroyed parts of a village and removed a sand spit that formerly blocked the river [7]. The area with mangroves and tree belts were significantly less damaged than other areas. There were different conditions between villages in coast and villages behind the mangrove. The villages on the coast were completely destroyed. Villages behind mangrove did not show any destruction.

Figure 7 shows that most of coastal area of Sibolga has very low value of NDVI which is less than 0.1. It is relevant to the field observation along the coastal area which are covered by building mainly settlement. Higher value can be seen more in the mainland (Figure 15).

Along the area of the bay the NDVI value tends to be lower than the mainland especially in Sibolga which has the lowest NDVI value comparing to other areas (Figure 16). Some part in the mainland shows higher value of NDVI.

Figure 8 shows that the highest vegetation density is in Low class covering 32.5% of the area. Some small part of the area has very dense vegetation which is in the mountainous area of Sibolga.
Also the dense vegetation area. In the coastal area it can be clearly seen having less vegetation and no vegetation at all.

Buffering has been done to find out the condition of vegetation density in some distance for potential greenbelt area of Sibolga. In each buffer, the vegetation density along the coastline can be seen. The vegetation density in 100, 200, and 500 meters buffer can be seen in Figure 9. Figure 9b gives us an information on percentage of vegetation density in the area of 100 m buffer.
Figure 9. Vegetation density class; a. in Sibolga area, b. In 100 m buffer c. in 200 m buffer, d. In 500 m buffer

Figure 10. Buffer of 100, 200, 500 m in the coastal area of Sibolga
In the area of 100 m buffer, most part of the area has very low vegetation density. It can be seen clearly in the map on **Figure 11**. Moderate and dense classes of vegetation density are only in very small part of the area.

**Figure 11.** NDVI value in buffer area

**Figure 9 c** shows the percentage of vegetation density area in 200 meters buffer. The trend is quite similar to the density in 100 meters buffer. The class is dominated by very low class and followed by low class. Moderate and dense vegetation density are still very small portion of the area.

The trends is consistent in the area of 500 meters buffer (**Figure 9d**). The most part of the area has less vegetation and even no vegetation in the area. It means that most part of the coastal area from the coastline to 500 m buffers has small vegetation area.

**Figure 12.** Land system of Sibolga

Land System Map provided the an information that the coastal area of Sibolga has Kahayan as a land system which also mentioned as aluvial plain (**Figure 12**). Regulation of Ministry of Forestry of Republic of Indonesia Number P. 35/Menhut-II/2010 [6] mentioned that Kahayan (KHY) is coastal area with sand sediment in the form of plains which some part is the result of accumulation of sediment in river mouth. The area has slope less than 2% with 2-10 meter relief. Rocks/mineral is alluvium dominat, young estuary and marine mix, river young alluvium and peat. Mangrove
vegetation can grow in this type of land system. The area behind the coastal area is a mountainous area. Mangroves and Casuarina plantations attenuated tsunami-induced waves and protected shorelines against damage. Conserving or replanting coastal mangroves and greenbelts should buffer communities from future tsunami events. Mangroves also enhance fisheries and forestry production [8].

The regulation mentioned about the area along the coastline with important benefit to maintain the coastal function sustainability. The width is proportional to shape and physical condition of beach in minimum of 100 meters from the highest tide to the land. The rehabilitation of this area is aimed to build a greenbelt considering the community’s dependence on the area and forest sustainability. Agroforestry can become part of the rehabilitation effort in this area.

Field observation shows that coastal area of Sibolga and Central Tapanuli do not have dense vegetation. Most part of the area is tourism area with lodging and settlement. In the northern part of coastal area of Central Tapanuli we can see an open coast with no dense vegetation. There is a need to do coastal protection from possible destruction caused by tsunami. Zone planning should put consideration to build greenbelt based on the land system, give consideration to community’s benefit and coastal protection.

4. Conclusions
The conclusion of the research are: The highest percentage of the coastal area of Sibolga has low NDVI value. This indicates that the area has less vegetation. The field check shows that the coastal area has dense settlement with less vegetation. Land system found in the coastal area is Kahayan which is suitable for mangrove. The area is an alluvium plain while behind the coastal is mountainous and hilly areas. In 100, 200 and 500 meters width of greenbelt area, the highest vegetation density is very low and followed by low class. It means most of the area has no vegetation or less vegetation, Greenbelt planning is needed to protect the beach from any potential destruction of natural disaster mainly tsunami.

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