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The Role Of Coastal Forest In Tsunami Reduction Using Comcot

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Abstrak

Panimbang sub-district is one of the areas affected by the tsunami in 2018, located directly opposite the Krakatau Volcano and close to the Sunda Strait subduction zone (megathrust), making it an area with a high threat of tsunami levels. This study aims to determine the impact of coastal forests in reducing tsunamis using COMCOT as one of the mitigation efforts. The tsunami generator uses the worst scenario earthquake that can occur in the Sunda Strait subduction zone area. . The results showed that the coastal forest in Panimbang sub-district has a role in reducing the inundation area, water level height and tsunami speed.. In addition, the manning coefficient (n) value also has an influence in reducing the inundation area, inundation level height, and tsunami velocity.

Keywords: comcot, coastal forest, mitigation, tsunami modeling.

1. INTRODUCTION

According to BNPB data in 2013, Pandeglang Regency is one of the areas with high vulnerability to tsunami threats in Banten Province. Research [1] shows that Banten province has the potential to produce a magnitude 9.1 Mw earthquake. In addition to its geographical location adjacent to the Sunda Strait subduction zone (megathrust), the tsunami threat in Pandeglang Regency can also be triggered by the volcanic activity of Mount Anak Krakatau. One of the most affected areas is the Panimbang sub-district, which was a tsunami victim in 2018 [2]. The tsunami hit the coastal area and caused significant damage and losses.

Given this threat, mitigation efforts need to be made to reduce the impact of tsunamis. Coastal forests are one of the natural structural mitigation efforts that can be used as a tsunami shield. These mitigation efforts are intended to dampen or reduce tsunami energy [3]. Based on research conducted by Harada and Imamura [4], forest vegetation can reduce tsunami energy and height and can even reduce the area of inundation. Another study on modeling the effectiveness of coastal forests [5] showed that coastal forests with a vegetation density of more than 2000 individuals per hectare and a forest width of about 120 to 325 meters can reduce tsunami energy by 41.18%. In addition, a numerical modeling study [6] showed that a coastal forest with a width of 100 meters can reduce the tsunami wave speed by 40% compared to an area without coastal forest cover.

Therefore, this study aims to analyze the role of coastal forests in the Panimbang sub-district in reducing tsunami impacts. However, as tsunamis are rare and difficult to predict, field data related to the tsunami process is limited. Therefore, this study used numerical modeling to simulate the process of tsunami occurrence [7]. The modeling was conducted using a tsunami generator based on the worst-case scenario of an 8.9 Mw earthquake in the Sunda Strait subduction zone (megathrust). The simulation was conducted using COMCOT (Cornel Multi-Grid Coupled Model) software. This modeling uses the leap-frog finite difference method and a nested grid system to obtain results with high data resolution [8]. The modeling results will be used to analyze the role of coastal forests in reducing tsunamis as part of disaster mitigation efforts in the Panimbang District area.

2. METHODS

This research was conducted in Panimbang District Banten, as seen in Figure 1. The research location focuses on areas that have coastal forest land cover. The data used in this study consisted of bathymetry data in the form of BATNAS publication. Geographic Information Agency (BIG); topographic data of FABDEM publication, which is further processed into DEM (Digitised Elevation Model) data, which will later be inputted into the modeling; land cover data of Pandeglang Regency in 2022 published by BIG; and tsunami generating earthquake parameter data based on the calculation of the Meteorology Climatology and Geophysics Agency (BMKG).

2.1 COMCOT Modeling

This study uses the COMCOT software for numerical modeling. According to the COMCOT user manual [9], this modeling uses linear and non-linear Shallow Water Equations to simulate tsunami propagation.

$$\frac{\partial \eta}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \qquad (1)$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{gn^2}{h^{4/3}}\sqrt{u^2+v^2}\,u = -g\frac{\partial \eta}{\partial x} \qquad (2)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + \frac{gn^2}{h^{4/3}}\sqrt{u^2+v^2}\,v = -g\frac{\partial \eta}{\partial y} \qquad (3)$$

Description:
η: water surface elevation (m), h: total water level (m), u and v: depth-averaged velocity in x and y directions (m/s), ρ: water density (kg/m3), g: speed of gravity (m/s2), n: manning coefficient of land cover.

COMCOT implements a nested grid (layer grid) system to obtain results with good resolution. In this study, the nested grid consists of 5 layers, with the focus of the research area located on the fifth layer. Information about the layer grid set-up is presented in Table 1.

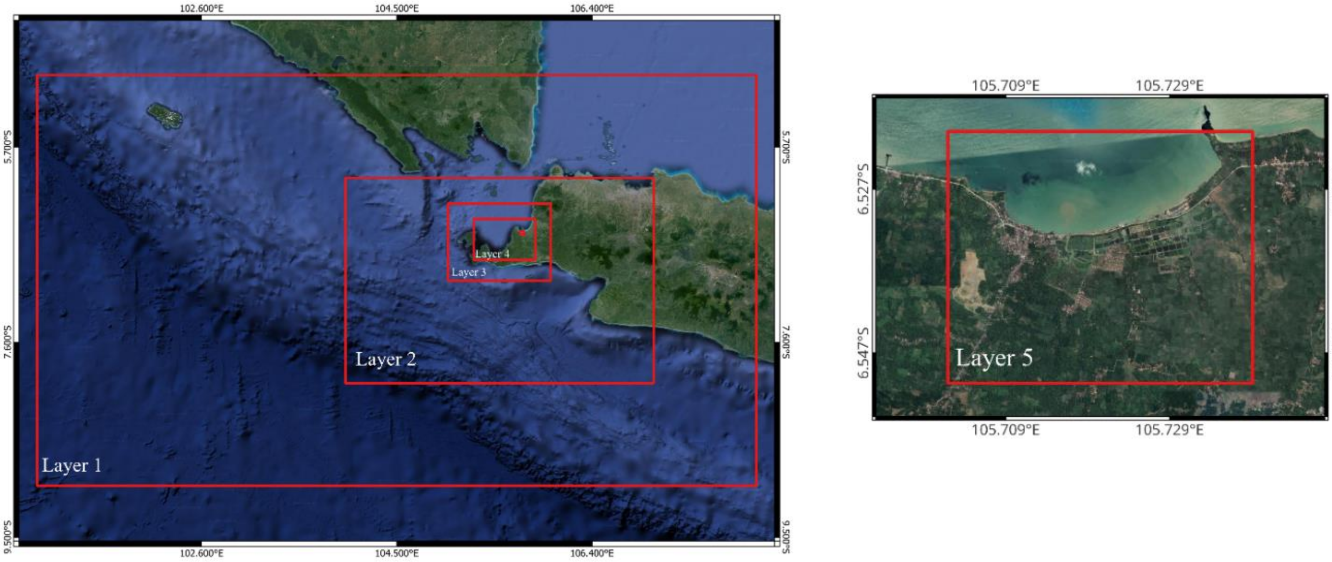

Figure 1. COMCOT Simulation Layer

Tabel 1. COMCOT Layer Set-up

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Grid Size (m)	1.215	405	135	45	15
Longtitude (^{0})	101.00^0 108.00^0	104.00^0 107.00^0	105.00^0 106.00^0	105.25^0 105.84^0	105.70^0 105-73^0
Latitude(^{0})	-9.0^0 -5.0^0	-8.0^0 -6.0^0	-7 .0^0 -6.25^0	-6.79^0 -6.4^0	-6.5^0 -6.52^0
Grid Size Ratio	3	3	3	3	3
SWE	Linear	Linear	Linear	Linear	Non-linear

2.2. Tsunami Generating Earthquake Parameters

The modeling was run using earthquake parameters as inputs. The tsunami generation used in this study uses earthquake parameters, with the worst scenario in the Sunda Strait subduction zone (megathrust) having an earthquake strength of 8.9 Mw.

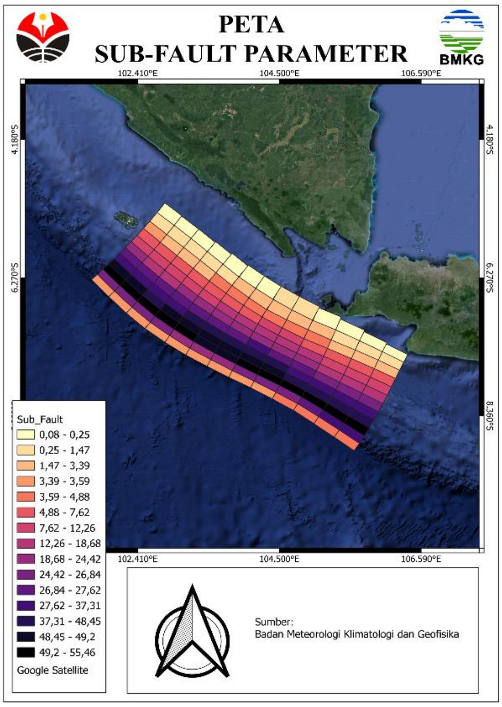

Figure 2. Sub-Fault Parameter

2.3 Manning Coefficient (n)

The effect of land roughness is considered by using Manning's roughness coefficient (n). Based on numerical simulation research [10] and [6], Manning's roughness coefficient influences the reduction of tsunami wave velocity and the reduction of inundation area. Therefore, this study uses two scenarios to analyze the effect of coastal forests in reducing tsunamis. Scenario (1) uses a uniform manning coefficient value, assuming all land cover areas are considered bare land without land cover [11]. Scenario (2) uses a manning coefficient value that is adjusted to the type of land cover in Panimbang District. Based on the RBI Map of Pandeglang Regency, the land cover in Panimbang Sub-district consists of paddy fields, ponds, settlements, rivers, plantations, and mixed crops. Manning coefficient (n) [12] will be determined according to each land cover type.

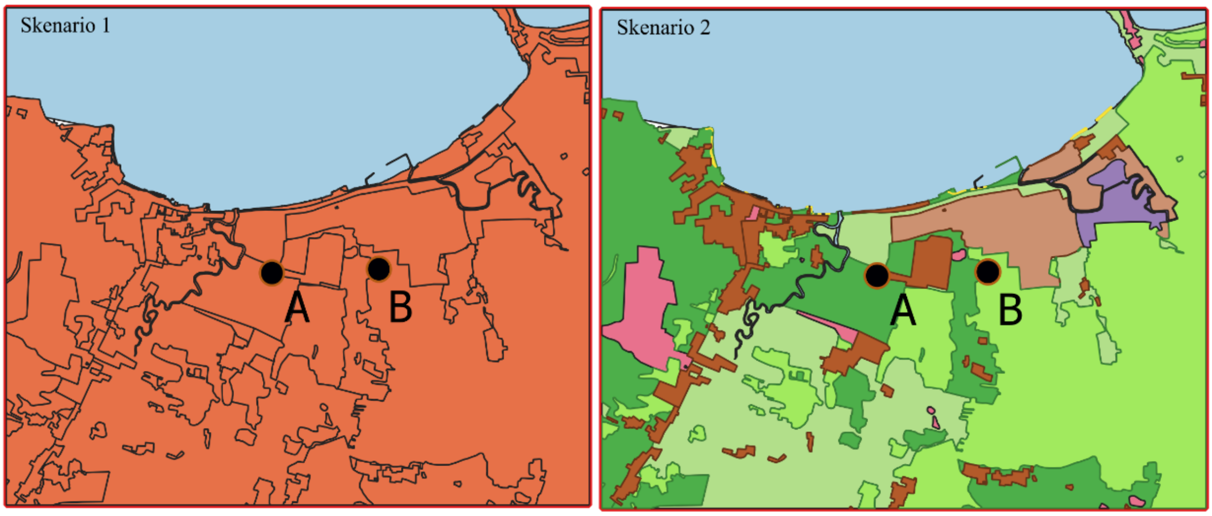

Figure 3. Land Cover, Scenario 1 and Scenario 2

Koofisien Manning (n) :

🟧 Land - 0.025
🟫 Settlements - 0.040
🟪 Bushes - 0.025
🟩 Paddy fields - 0.022
🟥 Fields - 0.025
🟦 Rivers - 0.013
🟨 Coastal - 0.020
🟫 Ponds - 0.017
🟩 Plantation - 0.030
🟩 Coastal forest - 0.035
🟦 Sea - 0.013
🟩 Mixed crop - 0.035

The observation location points in this study were placed in areas with 380 m wide coastal forest land cover (point A) and in areas with 30 m wide coastal forest land cover (point B) to analyze the role of coastal forests in reducing tsunamis. In addition, the placement of the location points was also determined based on the direction of arrival of tsunami waves towards the land area.

3. RESULT AND DISCUSSION

The results presented in the COMCOT modeling will then be re-analyzed to produce data on the inundation area, water level height, and tsunami velocity at the research location.

3.1 Inundation

The COMCOT simulation results show no significant difference in the tsunami wave propagation area of both scenarios. However, both scenarios show differences in the inundation area. In scenario 1, the inundation area reaches 7.3 km^2, while in scenario 2, it reaches 6.6 km^2.

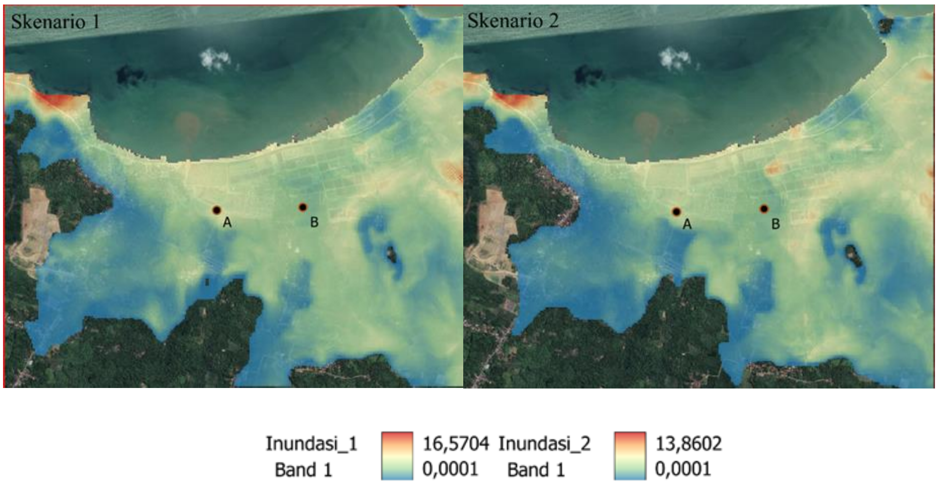

Figure 5. Inundation, Scenario 1, Scenario 2

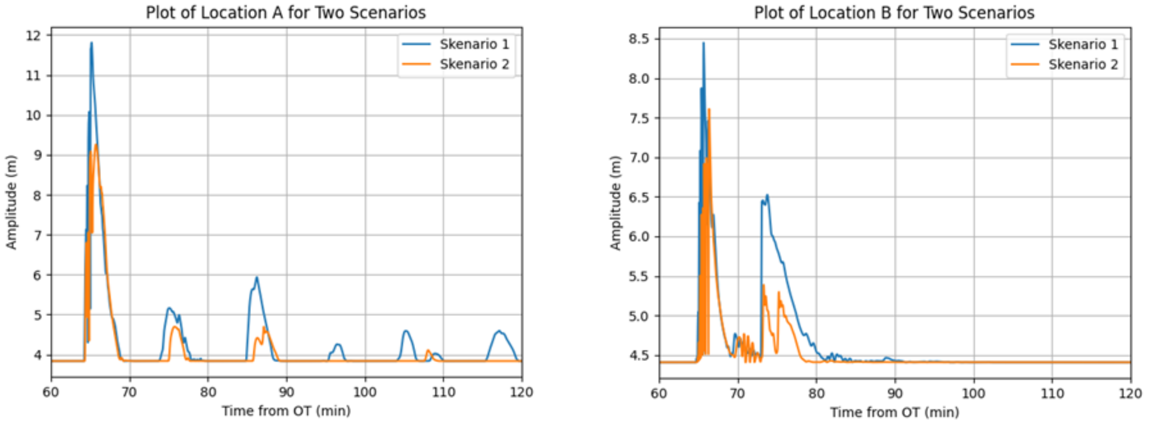

Figure 6. Water Level Differences

Figure 6 shows the height values at the location points in both scenarios. Tsunami waves started to arrive 60 minutes after the earthquake occurred. The maximum tsunami height value is found in scenario 1, with a height of 12 m. At location point A, the maximum value in scenario 1 reached 12 m, while scenario 2 maximum value reached 9 m. At location point B, the maximum value in scenario 1 reached 8.5 m, while scenario 2 reached 7.5 m. This shows that the coastal forest in Panimbang sub-district has a role in reducing the height of tsunami inundation compared to locations without coastal forest land cover. This shows that in addition to topography, the land cover also affects the height and extent of inundation [13], and the value of the manning coefficient (n) also affects the modeling results [14].

3.2 Tsunami Velocity

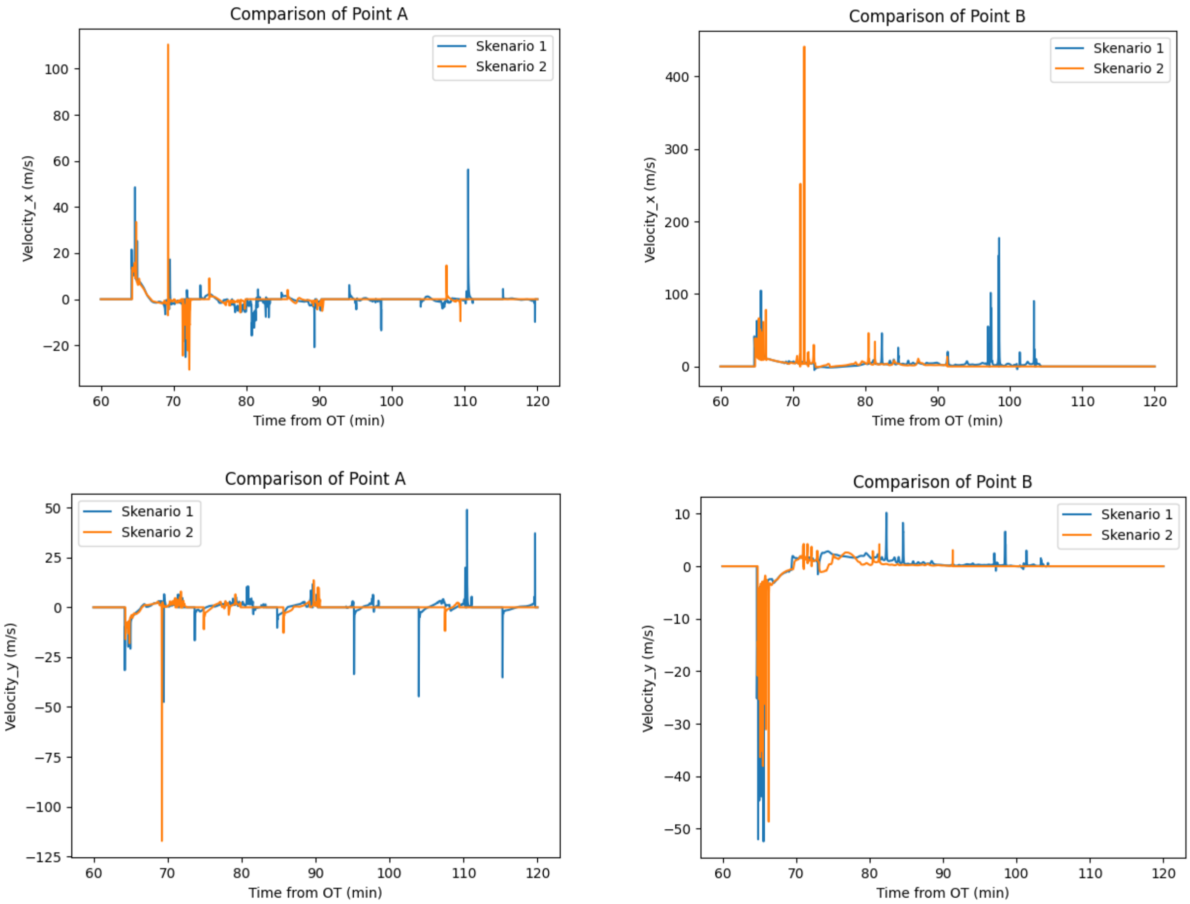

Figure 7. Velocity difference

$x\ positive$: east direction, $x\ negative$: west directiom, $y\ positive$: north direction, $y\ negative$: south direction

For the velocity values, both scenarios show differences at each location. At Point A in scenario 1, the current direction of the first tsunami wave traveling towards land after 60 minutes of the earthquake shows a negative y (south) and positive x (east) direction with speeds of more than 25 m/s to the south and 50 m/s to the east. After more than 110 minutes, the tsunami wave experienced a high-speed backflow, reaching 50 m/s to the north and almost 60 m/s to the east. At point B in scenario 1, the current speed of the first tsunami wave traveling towards land was more than 50 m/s to the south and almost 100 m/s to the east. Afterward, the tsunami wave experienced a high-speed backflow, almost 200 m/s to the east.

At point A in scenario 2. After 60 minutes, the first wave of the tsunami traveled inland at speeds less than 25 m/s towards the south and 30 m/s towards the east. Approaching the 70th minute, the wave reached its maximum speed of up to 125 m/s to the north and more than 100 m/s to the east. As for point B in scenario 2, the first wave of the tsunami traveled southwards with speeds of up to 50 m/s and less than 100 m/s eastwards. At the 70th minute, the wave reached a maximum speed of more than 400 m/s to the east. However, in scenario 2 at points A and B, when the tsunami wave experienced a backflow, the current speed dropped to 0 m/s.

When compared, the first wave current velocity in scenario 1 at both points A and B is higher than that in scenario 2. In addition, the return current speed in both scenarios also shows a significant difference, where the wave current speed in scenario 1 still reaches a maximum value of up to 50 m/s to the south and almost 200 m/s to the east. In scenario 2, the wave-current velocity at both points decreased to 0 m/s until the last minute. These results show that the value of the manning coefficient (n) affects the tsunami flow velocity, where the greater the value of the manning coefficient (n), the slower the acceleration of the wave current, and the smaller the value of the manning coefficient (n) the faster the wave current [10] [12].

In scenario 2, the first wave at point B, with a coastal forest width of 30 m, had a higher velocity value than point A, with a coastal forest width of 380 m. This shows that the width of the coastal forest has an effect in reducing tsunamis [4], where coastal forests with a width of 380 m in Panimbang sub-district have a greater role in reducing tsunami wave speed compared to 30 m wide coastal forests. Based on [15], coastal forests, especially in the Panimbang sub-district, have a function in reducing tsunami flow velocity.

4. CONCULSION

The modelling results show that the coastal forest in Panimbang sub-district can reduce the water level compared to areas without coastal forest cover. The 380 m wide coastal forest in Panimbang sub-district can reduce the tsunami velocity more than the 30 m wide coastal forest. In addition to topography and bathymetry data, the value of the manning coefficient (n) is also influential in providing more detailed information in this study. Therefore, topographic data, bathymetry and the value of manning's coefficient (n) will be given more attention for future research. The modelling results in this study are also expected to be a source of information for the surrounding community and recommendations for stakeholders in managing tsunami-prone coastal areas as one of the mitigation efforts that can be carried out in the Panimbang District area.

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