Spatial Modeling of Coastal Flood Due To The Fishpond To Tidal Waves in Bengkalis, Indonesia

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Abstract. Bengkalis Island is one of the small islands in Riau Province which is located on the east coast of Sumatra which is separated from the island of Sumatra and is in the middle of the Malacca Strait which is directly facing the ocean which is feared that some coastal areas will be affected by the large ener- gy of the tidal waves that propagate on the land surface. Make coastal areas in- undated by tidal floods. This is exacerbated by the conversion of mangrove land into Fishponds, which is carried out en masse to support the economy of the Bengkalis community. even though this is very vulnerable to the large energy of sea water waves which easily inundate coastal areas due to energy reduction in mangrove land cover. Along with the degradation of mangrove land, it is also exacerbated by global warming which causes sea air to rise. it is very vulnera- ble to coastal areas, especially in the research area. This research method uses geospatial modeling, using tidal data from the geospatial information agency (BIG), land cover image classification, soil surface roughness index, and flood scenarios. The results of this study we found that many coastal areas are prone to tidal flooding. At various maximum heights there are variations in the distri- bution of tidal flooding, for the final decision we use the worst scenario using the highest tidal discharge, which is 3.4 meters. This simulation model inundat- ed more than 74% of use in coastal areas, not only that, many agricultural areas were also affected by this tidal flood. We developed this simulation for analysis of losses due to the tidal wave, we found a loss index that reached 62% of the total loss of residential areas, including the loss of infrastructure and residential buildings.

Keywords: Environmental damage, disaster, coastal flood

1 Introduction

The mangroves forest in Indonesia around 4,251,011.03 hectares with distribution: 15.46 percent in Sumatra, 2.35 percent in Sulawesi, 2.35 percent in Maluku, 9.02 percent in Kalimantan, 1.03 percent in Java, 0.18 Bali and Nusa Tenggara, and 69.43 percent in Irian Jaya [13]. The conversion of mangrove forests into fish ponds strong- ly supports the community's economy is being empowered by the business sector in

Bengkalis. From an economic view, the fishery business it profitable value and it could increase people's income. However, this activity left an impact on the environment which we call environmental degradation. Based on the report from the [20] Director of Water and Land Conversion of the Ministry of Environment and Forestry, 2018 “Indonesia has lost 52 thousand hectares of mangroves per year. The high rate of mangrove damage has prompted the government to issue regulations to restore and rehabilitate this ecosystem. The strategic direction to minimize mangrove disturbance is to promote the function as biodiversity bank, protect coastal, and economic value by the mangroves vegetation. [5] as a researcher has said that Indonesia's mangrove deforestation rate was the fastest than other countries. The biggest case is because of the massive production of “fishponds”. Seeing this, of course, also greatly impacts climate change mitigation efforts, which are often discussed in international forums. The existence of global warming exacerbates the risk of exposure of coastal areas to tidal flood inundation due to the conversion of the land mangroves become fish ponds.

Riau Province has 234,517 hectares of mangrove (1997) and is concentrated in three districts (before the division) with details of 29% (66,920 hectares) located in Bengkalis Regency, 14% (31,697 hectares) located in Bantan District with 3 points stations, namely Jangkang Village, Selat Baru Village, and Bantan Tengah Village. In one decade (1987-1997) mangrove damage in Riau Province reached 43,935 hectares (18.7%) [10]. In general, the damage to mangroves in Bengkalis lately is due to the massive conversion of land into fishponds, this has an impact on the resistance of coastal areas in restraining the rate of abrasion to the amount of tidal wave energy so that they are vulnerable to tidal flood inundation on Bengkalis Regency as the re- search area needs serious attention because of the massive damage to mangrove land into ponds which are currently being massively empowered by a group of businesses in Bengkalis. To see the damage to mangrove forests in Bengkalis Regency, data from the Provincial Forestry Service can be seen. the following Riau:

Table 1. Damage of mangrove forests and Fish Pond status in Bengkalis Regency,

No	District	Land Area (Ha)	Mangroves Damaged	Large of Fish Ponds	
				Total	Activities
1	Rupat Utara	12,784	25,3	3.32	0.06
2	Rupat	5,806	1,5	3.38	0.45
3	Bantan	5,804	20,7	62.63	61.29
4	Bengkalis	4,254	0,5	23.33	15.34
5	Pinggir	2,125	5,3	3.32	0.06
6	Siak Kecil	3,452	7,8	0.05	0.05
7	Bukit Batu	898	7,8	3.23	1.37
Total		**41,718**	**64,1**		
2018				92.94	78,56
2017				61.28	44.59

2016	64.12	33.08
2015	64.49	32.65
2014	50.25	31.90

Source: Department of Forestry Service Reg Riau . Source Fishery Service of Bengkalis Regency

Based on the data above, it shows that the area and management of ponds is in- creasing intensively and extensively every year. This proves the results of the ground check with the massive opening of fishponds on the coast of Bengkalis Regency. Mangrove ecosystem is a resource of coastal wetlands and a life support system and natural wealth of very high value, therefore it is necessary to protect, preserve and use it sustainably for the welfare of the community. Mangrove ecosystems have various important functions, including as a life support system, food source, coastal protec- tion, maintaining rich biodiversity, and contributing to global climate control. Main- taining strategic mangrove areas, including their plants and animals, is essential for economic and social development [19]. Therefore, the existence of the Mangrove Ecosystem is very necessary for its existence in coastal areas.

Fig 1.(landcover conversion process) and land cover change on Coastal Bengka- lis,2021)

The figure above reveals the fact about changes on field existence of the mangrove ecosystem is highly threatened by the conversion of mangroves become fishponds carried out by the community for business opportunities. The sea-level rise is a fa- mous issue as the impact of climate changes, which has reported that sea-level rise (SLR) as a consequence of global warming is considered one of the most serious problems faced by coastal communities (IPCC 2001). Indonesia is an archipelagic country that has a coastline (coastal) along less than 54,716 kilometers. And this coastal area is dominantly overgrown with mangrove forests as land cover that can naturally reduce coastal waves. Passive mitigation of flood disasters can be done through scientific research based on science and technology with a spatial approach. This mitigation produces guidelines in the form of maps of flood-prone areas in an area, which can be used as reference material for active flood disaster, mitigation". [12] When detailed, about 80 percent of disasters that occur in Indonesia are classified as hydrometeorological disasters such as floods, landslides, and hurricanes. Floods require serious attention from various parties because they contribute 37 percent of all disasters that occur nationally [4]. The mapping of coastal flood hazard is a tool used to determine flood area limits inland and in other areas exposed to coastal floods due to different hazards such as storm, surge waves, sea level rise caused by climate change [6]. This study uses spatial modeling of tidal flooding due to the energy gen- erated by tidal air on coastal areas that are vulnerable to damage due to the conversion of mangrove land into ponds. With this modeling, it is expected that the area that generates more tidal waves is mathematically generated. Integration of Geospatial Technology is needed in a geographical phenomenon and phenomenon which is very important in facilitating spatial information that is spatial in representing a loca- tion.[3] This study aims to simulate or predict the tidal flood inundation that over- flows into the land during high tides as a mathematically measured release of energy and as a passive disaster mitigation effort to map the vulnerability of coastal areas to tidal flooding.

2 Data and Methodology

2.1 Data

Modeling the potential vulnerability of coastal areas assisted by GIS technology in interpreting the constituent variables in this study, namely the scenario of inundation heights reaching 3 meters refers to the maximum tide that occurs. the roughness coef- ficient map is obtained from the land use map resulting from the extraction of land cover which is connected to the roughness coefficient value developed by [7] the slope map is generated from the DEM (digital elevation model) water level decline on each pixel is calculated by the equation [7]

2.2 Analysis Data

2.2.1 Design of Land Surface Roughness

At this stage, raster data of the ground surface roughness coefficient (n) will be made, the data (n) is useful as a basis for calculating the ability of the surface roughness of objects on the ground to reduce the energy of sea water waves at high tide. The mate- rial coefficient value is based on the ability of each object to absorb waves such as water bodies such as in the estuary which has a very small value because river mouths are very fast in bringing waves to the beach. The following will show the steps in the modeling work in this study

Tabel 2 . Coefficient land surface roughness

Roughness	Land cover	Coefficient value
R1	Water Body	0.007
R2	Shrub	0.04
R3	Forest	0.07
R4	Plantation	0.035

R5	Bare land	0.015
R6	Agricultural area	0.025
R7	Built-Up	0.045
R8	**Mangroves**	0.025
R9	**Fish pond**	0.01

Source. The following is a mathematical process for making data on the coefficient of land surface roughness [7].

$$\boldsymbol{H_{loss}} = ((167\ n^2/H_0\ ^{1/3}) + 5 \sin S)$$

Where :

Hloss : Reduction of water level and energy in the interval of shoreline n
: Coefficient of land surface roughness
H0 : Maximum scenario of high water level of the tidal wave
S : Slope of the land surface.

2.2.2 Modeling Inundate of Coastal Flood

For modeling seawater inundation on land, spatial cost distance analysis is used. In the analysis of distance costs as a source of costs for seawater inundation, the input source is the coastline, and the cost raster is the result of the analysis of ground sur- face roughness or Hloss [11]. The basic principle of calculating the cost distance is to calculate the cost of each cell that is passed, the basic equation of the cost distance behind the ArcGIS software [13]

$$\boldsymbol{Cost\ Distance} = cds + \frac{crs + cr\ a}{2}$$

Where :
Cds = is cost distance sources
Crs = raster cost

After the results of the coastal flood analysis are obtained, these results must be subtracted from the flood height data that occurred at the research location. [11]. As in the location of this study, coastal flooding has a height of up to 100 centimeters above sea level, so data extraction is carried out at a height of 1 meter, in this study the land elevation was extracted from DEM images with a resolution of 10 meters. Based on previous research has been conducted by analyzing secondary data from spatial modeling to estimate a water inundation because of scenario tidal flood and impacts to building and infrastructure.

2.2.3 Impact Coastal Flood

The next stage is to assess the impact of coastal inundation on buildings and infrastructure. The map overlay technique is used to calculate the impact of flood inundation on environment. By using the overlay analysis technique, the length of the road infrastructure network affected by the flood can be known, and the number of houses, buildings affected by the flood can be calculated. [11]

3 Result and Discussion

Urban expansion on coastal zones for many purposes, it has been increasing by population grown and pressure of economic necessary. This process is highly increasing during last century. Climate changes has been changing for coastal urban, because this area will faced the flood growing, through both sea level rising and several meteorological phenomena accentuation [8] Result of this research we has founded the topography of the Bengkalis area is generally a flat and low area, as is the characteristic of the sloping landscape of the east coast of Sumatra. And it is dominated by peatland, making this research area vulnerable to tidal floods that hit coastal areas. The distribution of tidal inundation on the Bengkalis coast is shown by an inundation map that has been modeled with mathematical calculations in Arcgis 10.4 software using an iteration process, namely cost distance operations. The calculation is carried out through the surface roughness coefficient which has been inputted in value as a calculation in reducing waves or releasing energy sources from the shoreline.

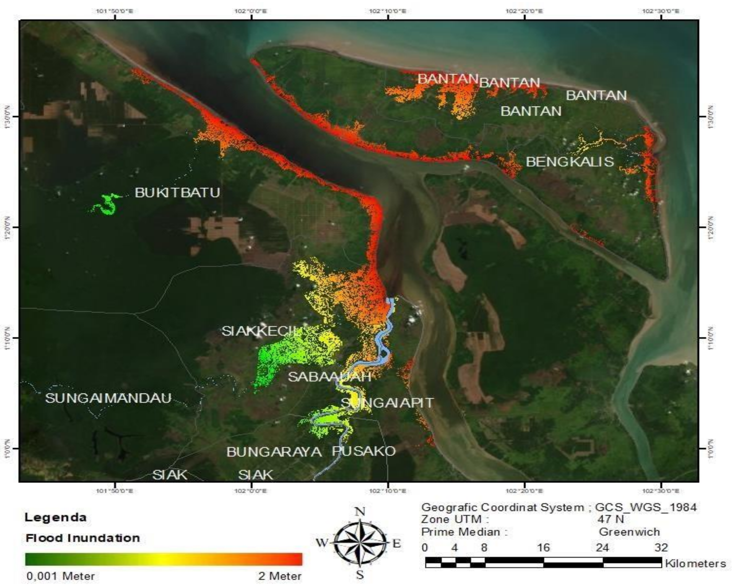

Fig. 3. Map of tidal flood inundation and documentation, in Bengkalis Coastal, Riau

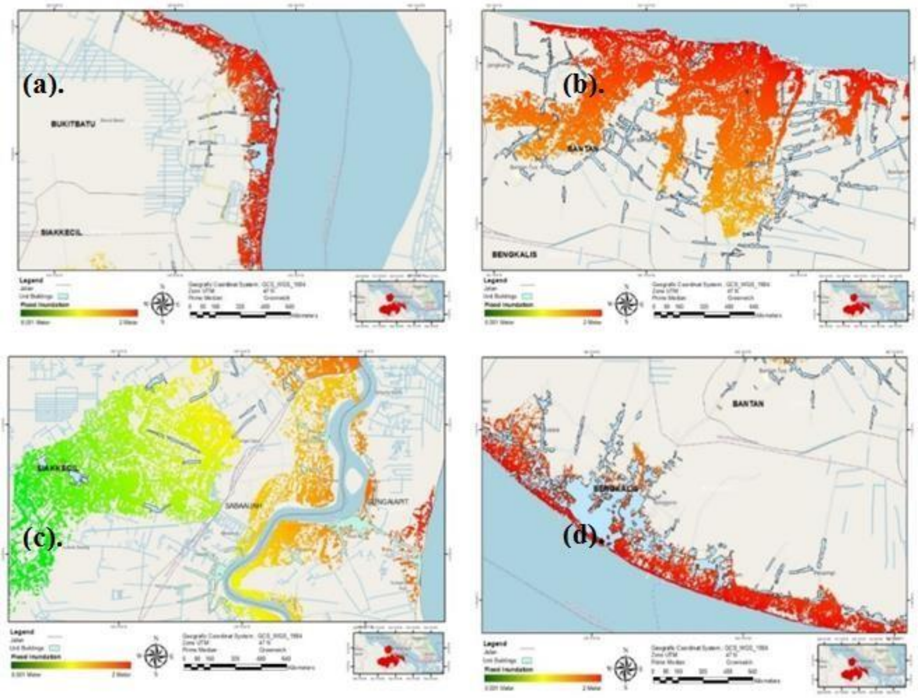

Fig 3. (a), it can be seen that the tidal wave range is quite wide reaching 6 km2 from the New Straits coastline, to be precise in Bantan district. Such conditions are in ac-cordance with the reality in the field and ground checks carried out at the research location. With the conversion of Mangrove Ecosystems into Ponds, it increases the vulnerability of coastal areas that lose reducing power to tidal wave energy that propagates to the mainland. (b), Bukit Batu Areas, Like the coastal areas above, this area is also affected by tidal inundation that reaches 1 km from the coastline. (c), Coastal of Bengkalis City, As an area that is concentrated in settlements, this area is vulnerable to tidal inundation. impact on the vulnerability of settlements submerged in tidal inundation that reaches 2 km from the coast. (d), coastal areas of Siak Kecil, the occurrence of tidal waves causes the area around the river to be vulnerable to large energy transmission because the tidal wave propagates without any significant reduction so that the area around the river becomes inundated.

From this Modelling we can find out the zone of exposure of the area to tidal inundation which is modeled with a maximum 3 meter high tide scenario, this is taken by considering variations in the distribution of tides along the coastline which are generally gentle and not more than 3 meters high from land to sea water.

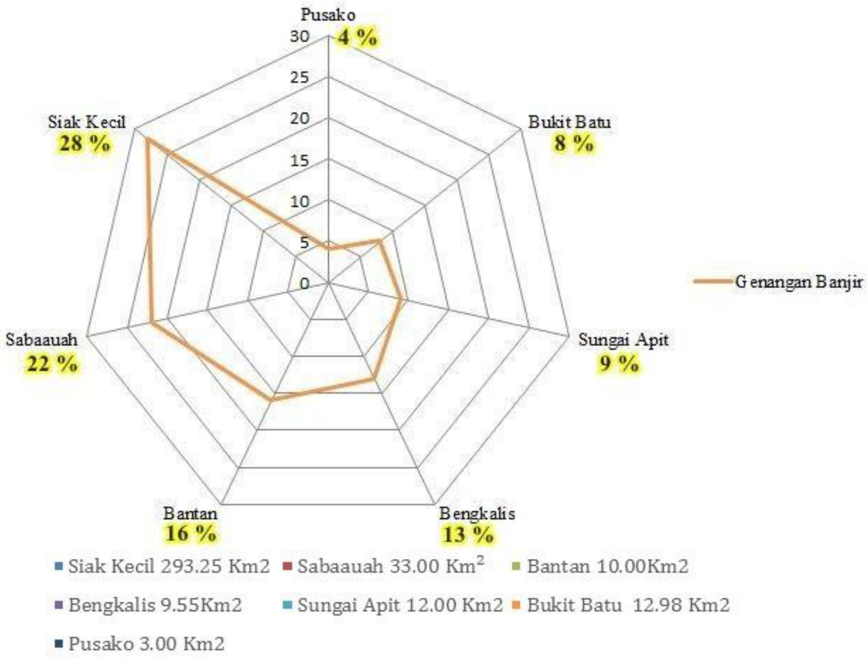

Fig 4. Persentase areas impact of tidal flood inundation in coastal Bengkalis

From the figure above, it can be seen that the Bengkalis Coastal Area is vulnerable to tidal flooding which is also dominant with the conservation of mangrove land into ponds which causes tidal wave energy to reach land with. Overall, the coastal area of Dumai City is affected by tidal flooding, due to topographical conditions that are not too high from an altitude point of 0 from the tidal limit of sea water. From the picture above, it is clear that the administrative areas are as a whole affected by the tidal flood disaster. So for the prevention of choice of other places in the event of a greater tidal flood disaster. The flood vulnerability is relatively high for the major coastal cities, where the values of all three assessment components together are larger [21].

Determination of disaster evacuation locations for communities in this sub-district must be evacuated to neighboring sub-districts that are closer and safer from tidal flooding, such as Pusako sub-district which the percentage of tidal flood inundation is not too significant. Directions for city development, especially the development of residential areas, also need to be reviewed and accommodate disaster zones as a disaster mitigation strategy in the form of developing development policies. The limitation of this reseacrh is which not use high resolution data. For better a coastal flood modeling we shoud use the multiscale, multi-physics aspects of this study are considerable and highly informationally provocative. Coastal storm surges are on the order of a meter or more in the vertical and extend alongshore for coastal distances of several kilometers, with a persistence of over several hours to several days [18]

Spatial modeling of tidal flooding with this mathematical approach has succeeded in visualizing locations that are inundated by tidal flooding from the sea following the surface roughness of the area that is vulnarable to tidal waves, in this case the duck. As the coefficient value previously described, duck land cover is not effective in reducing energy generated by tidal waves because its value is small, namely 0.01 compared to the mangrove coefficient, which is 0.025. Therefore, there is a need for modeling in order to estimate the inundation slope due to the amount of tidal wave energy which is currently vulnerable to occur in the Bengkalis coastal area. Based on this model, it was found that the inundation of the Rob Flood hit almost the entire coastal area of Bengkalis, where the area is an area dominated by the Mangrove Ecosystem whose existence is increasingly concerning by the conversion of land into ponds. In this study, coastal areas affected by tidal flooding due to the release of tidal energy are the coastal areas of Bengkalis Island, Bukit Batu, Siak Kecil and surrounding areas. On the resulting map, you can see a gradation of red to green in which areas that have dark red color are inundated areas with a maximum flood height of 3 meters from the tidal point of sea level, while the area symbolized in yellow is an area that is inundated in water. medium conditions or approximately 2.5 meters, and the green area is an inundated area of less than 1 meter. Outside of the zone that has red to green colors, the area is at an elevation that is free from tidal flooding.

3 Conclusion

Based on the results of this modeling, it can be concluded that the area located on the Bengkalis Coast is vulnerable to seawater inundation at high tide, this is due to the lack of reducing power that can withstand the wave rate so that the tidal flood inundation reaches far to land which is also flat, thus expanding the flood inundation area. rob. As a result, the area is submerged until it reaches the limit of energy release which varies depending on slope conditions and land cover which is generally not more than 3 meters above sea level. Based on the inundation area, it was found that 5 sub-districts from Bengkalis Regency were affected by tidal inundation with a tidal height scenario of 3 meters and Siak Regency 2, Sub-district with a maximum tide scenario of 3 meters. This method is appropriate to be used in spatial modeling of flood inundation, because with a very dynamic land cover, it calculates the coefficient of surface roughness based on land cover which can reduce the energy of the incom- ing waves. Currently in Bengkalis, the Mangrove Land Cover has turned into a Pond which will have an impact on the amount of energy carried by the land waves.

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