Spatial Distribution of Tidal Floods Using Geographic Information System (GIS) in Medan Belawan District

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Abstract. Tidal floods are one of the threats that occur in coastal areas. The impact is felt for the community, as well as other impacts felt for the surrounding ecosystem, namely the mangrove population, where tidal floods that continue to occur can have a serious impact on the community and mangrove vegetation because they can threaten the sustainability of the mangroves. This research uses GIS to map tidal flood inundation areas and determine their relationship with biophysical factors. Spearman correlation is used to determine the relationship between points in tidal flood areas and biophysical factors such as elevation, slope, distance from rivers and distance from the beach. The research results show that the four variable factors are related to the point of tidal flood inundation. Distance from the river greatly influences the tidal flood point in Medan Belawan District, with a correlation coefficient value of -0.100. This is because rivers act as a medium for the entry of water from the sea without any obstacles to entering the land, so when the river flow reaches its carrying capacity, sea water immediately overflows into residential areas.

1. Introduction

Tidal floods occur due to rising seawater towards the surrounding land. This incident was also triggered by several factors that caused tidal floods. The occurrence of sea level rise accompanied by land subsidence results in seawater inundation when the sea level is higher than the land level, which is usually called coastal flooding or tidal flooding [1]. Tidal floods often occur in coastal areas of Indonesia [2]. Including the coastal area of Medan Belawan District. This results in huge losses for residents because they are unable to carry out their activities and are forced to look for higher places to live. Tidal Flooding is a natural disaster phenomenon on the coast of Medan Belawan District that occurs during the full moon or new moon and is known as the Spring Tide process. Tidal floods are a serious disaster for cities in coastal areas [3].

Apart from that, one of the phenomena in Medan Belawan District is the reduction of mangrove forests due to the conversion of mangrove forests for various purposes. One example of over-utilization is fish farming activities, which convert mangrove ecosystems into ponds so that some of the functions of this ecosystem do not take place optimally, so the reduced role of mangroves becomes one of the factors in the lack of sea level infiltration, which results in tidal floods [4]. Mangroves play an important role in storing carbon reserves and as a source of life for coastal communities [5].

Remote sensing has become a solution in providing benefits for observing, analyzing, measuring, and monitoring temporally and spatially, as well as helping decision-making in this context as science and technology obtain information about materials on the earth's surface from a distance [6,7]. By utilizing this technology, this research aims to determine the relationship between the distribution of tidal flood points in Medan Belawan District and biophysical factors such as elevation, slope, distance from the river, and distance from the coast with the incidence of tidal floods in Medan Belawan District [8,9]. This research aims to map tidal flood inundation points and analyze the relationship between flood inundation points and biophysical factors.

2. Materials and Methods

2.1. Study Location

This research was conducted in Medan Belawan District, Medan City, North Sumatra Province. The research location is presented on the map in Figure 1.

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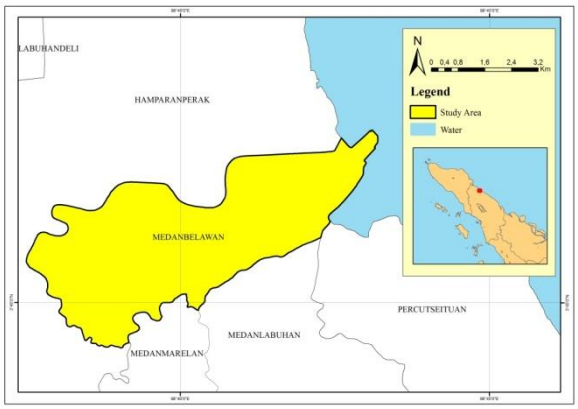


Fig. 1. Research Sites

2.2. Data Analysis

Primary data in this research was obtained through descriptive analysis, namely interviews with people affected by the tidal flood. The information recorded is locations affected by tidal floods in Medan Belawan District from January 2022 to January 2024. Data on tidal flood points was overlaid with biophysical factors using ArcGIS 10.8. Secondary data in this research includes Sentinel 2A satellite imagery, Digital Elevation Model (DEM) data, and regional administrative maps.

2.3. Correlation Test of Biophysical Factors with Tidal Flood

This study used the Spearman correlation test to test the correlation between biophysical factors and tidal flood points. Spearman correlation was used to evaluate the correlation between two variables, and the correlation coefficient took a value range of (-1.1) [10]. Spearman correlation analysis can be represented as follows [11].

$$r_s = 1 - 6 \sum d^2 / n(n^2 - 1) \quad (1)$$

Note:
r_s = Spearman rank correlation value
d = Margin of each pair value
n = Spearman rank pair value.

3. Results and Discussion

3.1. Distribution of Tidal Flood Points Based on Land Cover Type

The results of land cover classification using the Supervised Image Classification method from sentinel 2A images obtained five land cover types: mangroves, water body, built-up land, open land, and ponds. The distribution of tidal flood points based on land cover type can be seen in Table 1.

Table 1. Distribution of Tidal Flood Points Based on Land Cover Type

No	Land Cover Type	Area (Ha)	Number of Tidal Flood Points	Percentage (%)
1.	Water Body	431,01	0	0
2.	Built Up Land	737,62	126	90
3.	Open Land	181,10	9	6,43
4.	Mangrove	1286,17	2	1,43
5.	Pond	401,92	3	2,14

The highest tidal flood points at the research location were found in the built land cover type with 126 points (90%) and open land 9 points (6.43%). Then, in the pond land cover type, there were 3 tidal flood points (2.14%), and the fewest tidal flood points were found in the mangrove land cover type with 2 points (1.43%). The following is a map of the distribution of tidal flood points based on land cover type, presented in Figure 2.

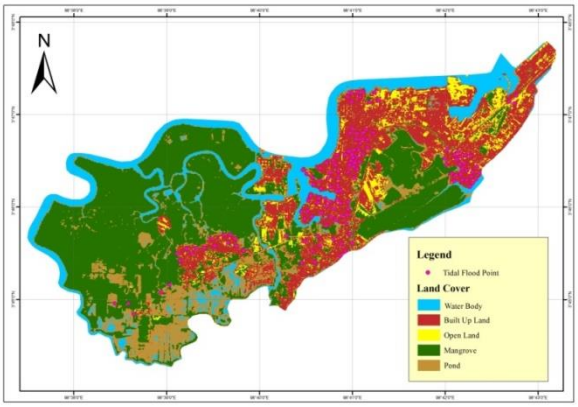
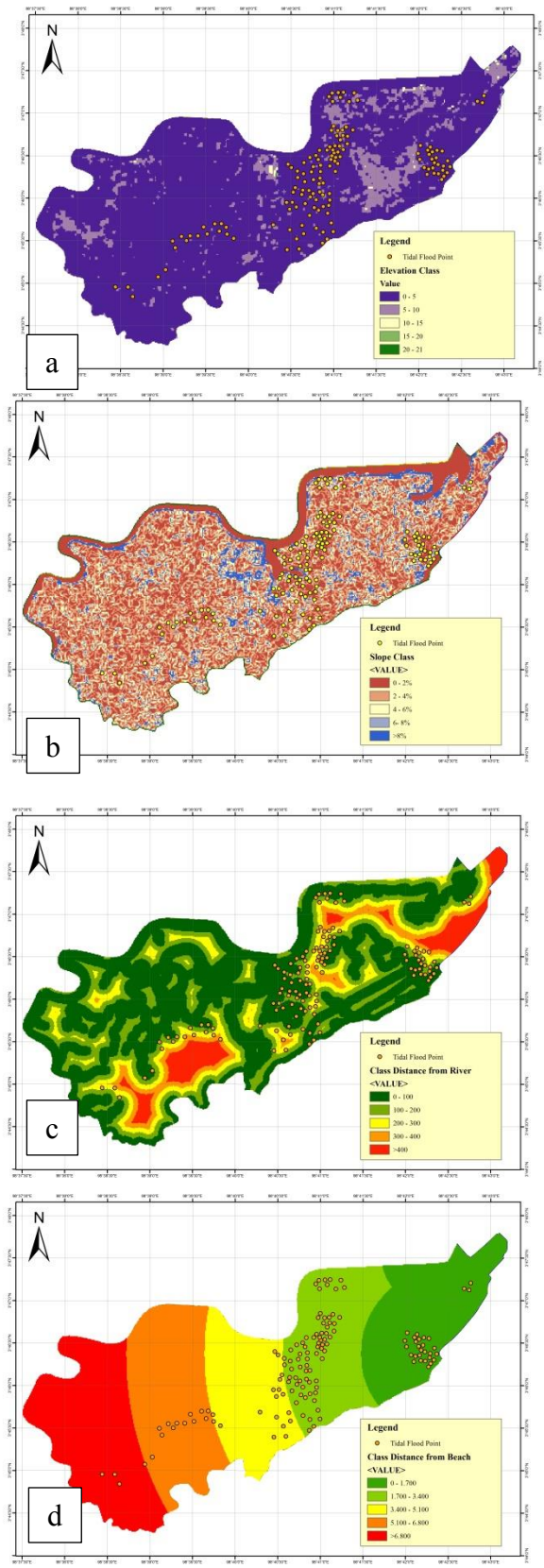


Fig. 2. Distribution of Tidal Flood Points Based on Land Cover Type



Information :
a. Elevation
b. Slope
c. Distance from river
d. Distance from beach

Fig. 3. Map of Biophysical Factors that Influence Tidal Floods

3.2. Biophysical Factors that Influence Tidal Floods

The areas affected by the tidal flood include 6 sub-districts, namely, Belawan Bahagia Subdistrict, Belawan Sicanang Subdistrict, Belawan Bahari Subdistrict, Belawan I Subdistrict, Belawan II Subdistrict and Bagan Deli Subdistrict. The number of sample points found is 140 points obtained from direct field surveys, which will be overlaid with biophysical factors in the form of elevation, slope, distance from the river, and distance from the beach, which are believed to be factored in this case study. A map of biophysical factors for areas prone to tidal flooding is depicted in Figure 3, while information on the distribution of tidal flood points based on biophysical factors is explained in Table 2.

Table 2. Biophysical Factors with the Distribution of Tidal Flood Points

Class	Area (Ha)	Number of Tidal Flood	Percentage (%)
Elevation			
0-5 m	2697,05	108	77,14
5-10 m	331,26	32	22,86
10-15 m	8,02	0	0
15-20 m	0,98	0	0
>20 m	0,12	0	0
Slope			
0-2%	1089,94	59	42,14
2-4%	1077,26	57	40,71
4-6%	479,08	14	10,00
6-8%	173,27	4	2,86
>8%	159,03	6	4,29
Distance from River			
0-100 m	1600,95	59	42,14
100-200 m	710,13	41	29,29
200-300 m	342,13	34	24,29
300-400 m	191,36	6	4,29
>400 m	192,74	0	0
Distance from Beach			
0-1700 m	592,46	30	21,43
1700-3400 m	565,37	76	54,29
3400-5100 m	493,40	17	12,14
5100-6800 m	666,34	13	9,29
>6800 m	719,83	4	2,86

Based on the elevation factor in Table 2, it shows that tidal flood events at the research location were mostly found in the elevation class 0-5 meters above sea level with a total of 108 tidal flood points (77.14%), followed by the elevation class 5-10 meters above sea level. 32 tidal flood points were found (22.86%), then in the elevation classes 10-15 meters above sea level, 15-20 meters above sea level, and >20 meters above sea level, no tidal flood points were found at the research location. This is because the land in the classes 10-15 meters above sea level, 15-20 meters above sea level, and >20 meters above sea level is already higher than the surrounding land, so tidal floods do not inundate it. The higher the land, the safer it is from tidal floods [12].

Based on the slope factor, it shows that the incidence of tidal floods at the research location is quite

varied and spread across each slope class. However, the most flood points were found in the gentle slope class, namely 59 tidal flood points with a percentage of 42.14%. This shows that the water that comes during tidal floods cannot flow downstream (the sea) because it has a relatively gentle slope. Medan Belawan District has steepness characteristics ranging from 0% to 17%, which means it has a flat to slightly steep relief slope class, meaning that Medan Belawan District is very vulnerable to waterlogging if it does not have the infrastructure to support flood runoff because the water will stagnate and flow into downstream slowly due to the gentle slope [13].

Based on the distance from the river, the most affected tidal floods occurred in the 0-100 m distance class with 59 tidal flood points. This was followed by a 100-200m distance with 41 tidal flood points. Then, in the 200-300 m distance class, 34 points were found, 6 points were found in the 300-400 m distance class, and no tidal flood points were found in the >400 m distance class. Green areas that are 0-100 meters from the river are very vulnerable to tidal flooding. Areas that are 0-100 meters from the river are vulnerable to overflowing river water mixed with sea water during high tides when tidal floods hit the area [14].

Based on the distance from the beach, the most affected tidal floods are seen in the class area 0-1700 meters from the coast. In this area, there are many settlements. This area is part of Bagan Deli Village, which is very close to the sea. Then, the distance between 1700-3400 meters from the coast is also very affected, and this area is vulnerable to tidal floods. There are 3 villages affected by this distance class, namely Belawan I Subdistrict, Bahari Subdistrict, and Belawan Bahagia Subdistrict. The closer a residential area is to the coast, the more vulnerable the residential area is to flooding. Areas that are close to the coast are areas that are very prone to flooding [15].

3.3. Spearman Correlation

In this study, a Spearman Correlation Test was carried out to see the correlation between biophysical factors and flood vulnerability points in Medan Belawan District. The results of the Spearman correlation test can be seen in Table 3 below.

Table 3. Spearman Correlation of Biophysical Factors with the Distribution of Tidal Flood Points

Class	*Correlation Coefficient*	*Sig. (2-tailed)**
Elevation	-,894*	0,041
Slope	-,900*	0,037
Distance from River	-,1000*	0,000
Distance from Beach	-,900*	0,037

Based on Table 3, it can be seen from the biophysical factors, namely elevation, slope, distance from rivers and beaches tested with tidal flood points in Medan Belawan District, have a negative relationship and significance value ($p<0.05$), which means there is a correlation between biophysical factors and tidal floods in Medan Belawan District [16]. Based on the correlation test results, the one that has the most influence on tidal floods is the distance from the river, with a correlation coefficient value of -0.100, which means it has a perfect relationship. This is because rivers become a medium for water to enter from the sea without any obstructions to water flow, such as vegetation or buildings, so when the river flow has reached its capacity, flood water can immediately overflow into residential areas [17]. This causes many tidal flood points in the middle of residential areas due to the distance from the river.

4. Conclusion

Biophysical factors are related to the spatial distribution of tidal flood distribution points in Medan Belawan District: elevation, slope, distance from the river, and distance from the beach. These four factors are important variables as parameters for the distribution of tidal floods. Distance from the river has the strongest relationship to the point of tidal flooding in Medan Belawan District. Therefore, conserving mangrove vegetation along beaches and rivers is important to minimize damage and economic losses due to tidal floods.

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