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Analysis of Rob Flood Risk on The Coast of East Luwu District Using GIS

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Abstract

Rob floods caused by rising sea levels are a natural disaster that can potentially threaten coastal areas, especially in Indonesia. Tidal floods seriously threaten coastal areas, especially East Luwu Regency. Environmental factors and rapid growth on the coast of East Luwu Regency influence the vulnerability and complexity of the environment. This research aims to identify the spatial distribution of tidal flood risk levels and predict tidal flood inundation in 2050 at the highest tide on the coast of Luwu Timur District. This effort is part of a disaster mitigation strategy due to rising sea levels. The modeling approach involves Geographic Information Systems (GIS) overlaying data and integrating DEM, HHWL, and SLR data for 28 years (1992-2020). The research results show that the coastal areas studied have a high risk related to tidal flooding, with locations closest to the coastline being at the highest risk. In contrast, the risk decreases as you move away from the coastline. Apart from that, the modeling results also estimate that in 2050, inundation will reach a height of 1,570 meters. The area affected by tidal flood inundation has increased in each sub-district. The inundation will spread evenly along the coastline and extend inland due to seawater intrusion. Coastal areas dominated by production land, such as ponds and agricultural areas, are predicted to experience the most extensive impact of inundation compared to other land uses. Emphasizes the need for mitigation efforts to minimize the impacts that may be caused by tidal floods in the future.

Keywords: East Luwu, HHWL, Rob Flood, Sea Level Rise, SIG

1. Introduction

Climate change is one of the reasons for the increase in coastal disasters, such as floods, tidal floods, landslides, and other disasters (Mantika *et al*., 2020). Indonesia is an archipelagic country with a large potential for coastal disasters. Approximately 30% of all rivers in Indonesia are located in densely populated areas prone to flooding, with most of the population having a lower middle income (Sa'diyah *et al*., 2020). The dynamic coastal environment is caused by various commercial land use activities, sometimes causing an imbalance in the natural coastal environment (Pantoh *et al.,* 2021).

The very high dynamics of physical change in coastal areas and the rapid growth of regional development have increased the complexity of coastal disasters. Physical changes such as coastal development, river channel changes, land use, and rapid development growth further increase the potential for tidal floods and complicate managing these disasters. Rapid and unbalanced development in coastal areas has become a significant problem, especially for nearby people (Pasaribu *et al*., 2021).

Tidal floods, which often occur in coastal areas dominated by ponds, can cause water pooling along coastlines experiencing erosion. However, what is more worrying is that settlements located around rivers and coasts also become vulnerable to waterlogging when sea tides reach high levels (Iskandar *et al*., 2020).

Risk is a condition with the potential for losses from the impact of hazards due to disasters. This risk may also occur in the future due to social processes and environmental changes (Hannan & Irawan, 2017) risk is a function of two parameters, namely hazard, and vulnerability, according to *(*Aulia Syam *et al*., 2021) the hazard is the condition of tidal flooding occurring in a specific area and can be influenced by natural factors. Vulnerability reflects how susceptible a region or its population is to the hazard of tidal flooding and can be influenced by human factors. The risk of tidal flooding is the result of the interaction between hazard and vulnerability, depicting the potential losses that may occur.

Geographic Information Systems (GIS) is a technology used to determine areas that may be affected by tidal floods. GIS integrates geographic data and spatial information to collect, analyze, and visualize information to map areas vulnerable to tidal floods' impacts. The geographic and environmental data used in GIS is the basis for improving response to tidal floods and helping to reduce the risk of damage and potential hazards that can affect the environment and coastal communities (Arfiana *et al*., 2016).

The development of the fisheries and agricultural sectors in East Luwu Regency has resulted in pressure on its coastal ecosystem, especially through land-use changes intended to support these sectors. This coastal area, which borders directly on the sea, indirectly increases the risk of disasters, including the impact of global climate change, such as rising sea levels, which can potentially cause inundation in coastal areas.

Currently, no research specifically identifies areas at risk of tidal flooding in East Luwu Regency, and this information is essential as a basis for determining areas that are vulnerable to disasters. Therefore, this research aims to map areas at risk of tidal floods and predict inundation in 2050 in East Luwu using Geographic Information Systems (GIS) in planning disaster mitigation efforts from sea level rise.

2. Research Methodology

2.1 Research Location

Geographically, the East Luwu Regency area is located south of the equator between 2°03'00" - 2°03'25" South Latitude and 119°28'56" - 121°47'27" East Longitude with the coast bordering Bone Bay to the south. The geographical location of the research location can be seen in (Figure 1).

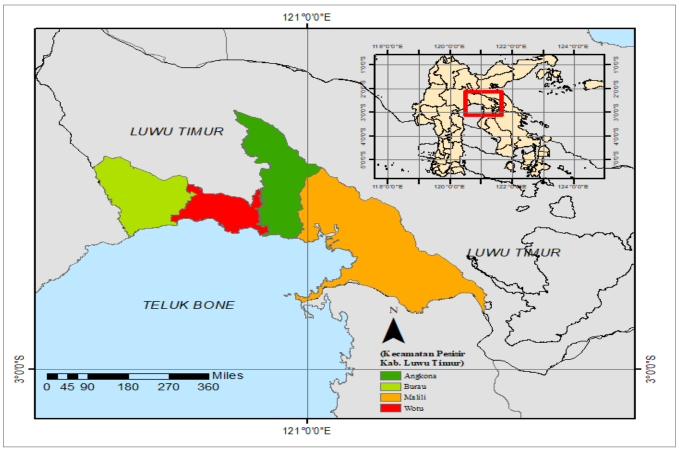


Figure 1. Map of Research Locations

2.2 Tools and Materials

This research relies on two types of data: primary data and secondary data. Primary data in this research includes interview results and ground check data, while secondary data incorporates information obtained from government agencies, journals, and image interpretation outcomes. The study employs hardware in the form of an Intel Core-i3 personal computer with 16 GB RAM, equipped with various software for data processing, analysis, and visualization, such as ArcGIS 10.8, ENVI 5.3, DSAS (Digital Shoreline Analysis System), Microsoft Excel, Microsoft Word, and Matlab R2021a. Field data collection tools like cameras, GPS, and questionnaires are used for ground checks and interviews.

2.3 Data Sources

This research was conducted using descriptive analysis with a quantitative approach, which refers to using data in the form of numbers to describe the tidal flood phenomenon. The initial process involves surveying the research location. Next, data related to tidal floods was collected, and data processing included analysis of tidal data, topography, slope level, geomorphology, abrasion/accretion, land use, mangrove ecosystem data, and creation of tidal flood inundation maps.

Creating a tidal flood risk level on a map in an area necessitates an initial assessment of the potential flood hazard to acquire an estimate of the potential hazard in both spatial (location) and temporal (time) dimensions. Subsequently, a vulnerability assessment is conducted, and vulnerability criteria are determined based on ecological conditions in the study area, as illustrated in the research's flowchart (Figure 2).

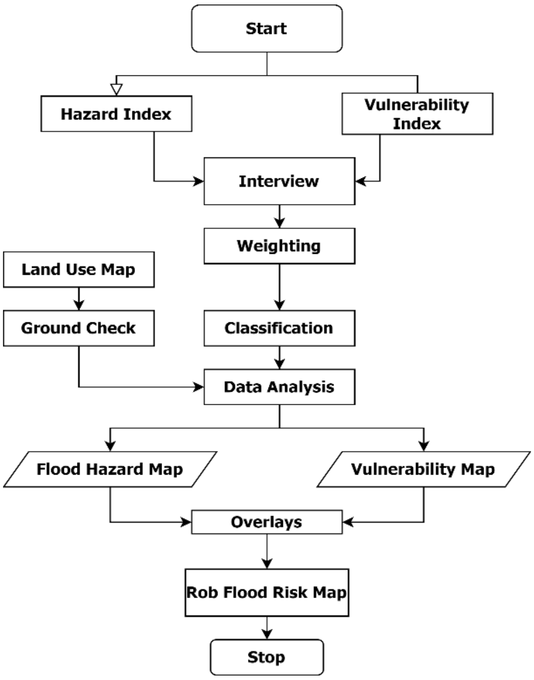


Figure 2. Flowchart

The preparation of tidal flood inundation map in East Luwu Regency was prepared using primary map data in raster data format, namely DEM (Digital Elevation Model), to provide information regarding surface height and land elevation in the research area (Pradana, 2019). The DEM used has a spatial resolution of 0.27 arcseconds sourced from IFSAR (5m), TERRASAR-X, and ALOS PALSAR (11.25m) data added to the mass point data used on the RBI map (Anggraini *et al*., 2012).

Tidal data processing was conducted to determine the type of tide, Mean Sea Level (MSL), and Highest High Water Level (HHWL) in the research area. The tidal data was obtained from the Lampia Station, which was issued by BIG in 2022. MSL values were calculated using the least squares method (Rosida *et al*., 2022). This method employs algorithms in the Matlab 2021 application, as explained in the study by Yoganda *et al*. (2019). The tidal harmonic constant values obtained through this analysis method were used to calculate HHWL, which was determined based on the following formula. (Rosida *et al*., 2022; Ulum & Khomsin, 2013):

$$HHWL = A(So) + A(M2) + A(S2) + A(K1) + A(O1) + A(P1) + A(K2)A(N2) \quad (1)$$

Information:

AK1 = Average daily tidal wave amplitude which is influenced by the declination of the moon and sun

AO1 = The amplitude of a single daily tidal wave that is influenced by the declination of the sun

AM2 = The average double daily tidal wave subsidiary amplitude influenced by the month

AS2 = Average daily tidal wave amplitude influenced by the sun.

Inundation height modeling was carried out using the difference between HHWL and MSL during research in the coastal area of East Luwu Regency with an estimate of the inundation height that will occur until 2050 using the following formula (Iskandar *et al*., 2020):

Inundation height t0 = (High Higher Water Level (HHWL) – Mean Sea Level (MSL)) (2)

Estimated inundation height = Inundation height t0 + (SLR Rate Value x (t1-t0)) (3)

Note:
t0 = starting year
t1 = final year

The value of the rate of sea level rise was obtained from satellite altimetry data at points around Lampia waters obtained from the University of Hawaii Sea Level Center (https://ccar.colorado.edu/altimetry/). The SLR value obtained based on the data site is 0.54 centimeters/year (1992-2020).

The next step involves mapping the extent of tidal flood inundation by using data on the height of the flood and the land surface height (DEM) data. Areas with a land surface height lower than the height of the tidal flood will be flooded. The flood inundation modeling was then conditioned using the Raster Calculator in ArcGIS 10.8 software with the following formulation (Marfai *et al*., 2017):

Con (con([DEM]≤ X, X), con([DEM]≤ X, X) – [DEM], 0) (4)

Note:
X = Predicted figure for inundation height
DEM = Digital Elevation Model
CON = Conditional.

After this process, the area of inundation area calculated using basic data in 2022 with the assumption that areas after the coastline with a surface height less than the resulting inundation height assumption will experience inundation when the highest tide occurs.

The vulnerability index analysis process is carried out by processing ecological data in the form of coastal geomorphological data related to the shape and appearance of the beach/coastal area (Tiraska, 2017). Image data extraction in this research, namely geomorphological landforms, was carried out by referring to the land use by the Ministry of Environment and Forestry in 2020, the Geological Map (https://geologi.esdm.go.id/), and the soil type map by PUPR East Luwu.

The calculation of the rate of change in the coastline in East Luwu Regency was carried out based on the coastline at five different times, namely in 2003, 2008, 2014, 2021, and 2022 through on-screen digitization in Google Earth Pro which was adapted to the technical instructions for determining coastlines by (BIG, 2021), then processed using Digital Shoreline Analysis (DSAS) tools version 5.0 which is integrated with ArcGIS 10.8 software.

The calculation of the distance of change for each coastline is analyzed using the Net Shoreline Movement (NSM) and End Point Rate (EPR) methods. The results of these computational calculations will produce a positive value (+), indicating that the beach is advancing or accretion is occurring, while a negative value (-) means the beach is retreating or experiencing abrasion (Lazuardi *et al*., 2019).

Mangrove ecosystem extraction data processing was carried out using Landsat 8 OLI satellite imagery with data acquisition on July 25, 2022, with a spatial resolution of 30 meters, where several stages carried out pre-processing of satellite images, namely atmospheric correction and geometric correction, then image masking, after which index analysis was carried out. Vegetation to determine the level of mangrove canopy cover based on object reflections with equation (5).

$$MVI = \frac{(NIR - Green)}{(SWIR1 + Green)} \qquad (5)$$

The results of the MVI index analysis classification will produce images with an index value range of (3.47 – 16.95) so that the classification of cover levels can be seen in (Table 1) (Prayudha *et al*., 2021):

Table 1. Mangrove Cover Level

MVI value	Cover Rate
12.45 ≤ MVI ≤ 16.95	Heavy
7.97 ≤ MVI ≤ 12.45	Moderate
3.47 ≤ MVI ≤ 7.97	Rare

Source: Data analysis results.

2.4 Hazard Index

Hazard components are determined through analysis of probability (chance of occurrence) and intensity (magnitude of occurrence). The flood hazard index is determined based on the height of the inundation and the frequency of flooding which can be seen in (Table 2):

Table 2. Flood hazard index

Variable	Weight	Category	Score	Class
Flood Height	0.52	0 – 47.3 centimeters	1	Low
		47.3 – 94.6 centimeters	2	Medium
		94.6 – 141.9 centimeters	3	High
Inundation Frequency	0.48	< 1 time a month	1	Low
		1-3 times a month	2	Medium
		> 3 times a month	3	High

Source: Modification (Arfiana *et al*., 2016; Aulia Syam *et al*., 2021).

The tidal flood hazard level zoning interval is determined by (Table 3):

Table 3. Classification of Tidal Flood Hazards

Class	Index Value
Low	1 – 1.67
Medium	1.67 – 2.34
High	2.34 – 3

Source: Data analysis results.

2.5 Vulnerability Index

Coastal vulnerability analysis begins with an assessment of parameters that are considered capable of representing the ecological conditions of the research area (Nurherdianto, 2018), in the vulnerability analysis process each indicator is given a weight obtained through an expert survey and then grouped into three categories as in (Table 4):

Table 4. Flood Vulnerability Index

No	Variable	Weight	Score		
			Low (1)	Medium (2)	High (3)
1	Topography	0.14	>200 meters	100 – 200 meters	0-100 meters
2	Slope level	0.17	>45 %	15-45 %	0-15 %
3	Geomorphology	0.12	Cliff Beach, Estuary	Mangrove Forest, Rawa Brackish	Beach Buildings, Alluvial Plain, Sandy Beach
4	Abrasion/Accretion	0.14	>2.0 meter/year	(-2) to 2.0 meter/year	<-2 meter/year
5	Land Use	0.14	Savanna, Shrubs, Mangroves	Agricultural land, plantations,	Settlements, Rice Fields, Ponds, Mining
6	Distance from Beach and River	0.14	> 3000 m	1000-3000 m	0 -1000m
7	Mangrove Ecosystem	0.15	Heavy	Moderate	Rare

Source: Modification (Pantjara *et al*. 2006; Hendrawan *et al*. 2018; Aulia Syam et al., 2021; Prayudha *et al*. 2021).

Next, the vulnerability and hazard analysis is spatialized by carrying out an overlay method based on the following equation:

$$V = \sum_{j=1}^{n} (Wj \ x \ I_{Aij}) \qquad (6)$$

Note:
V = Vulnerability;
i = Representing the i-district;
j = j indicator;
W = Weight for each vulnerability parameter;
I = Score for each parameter.

After that, a classification process was carried out into three classes from low, medium to high levels (Table 5):

Table 5. Classification of the level of danger and vulnerability of tidal floods

Class	Index Value
Low	1 – 1.67
Medium	1.67 – 2.34
High	2.34 – 3

Source: 2023 analysis results

2.6 Risk Index

The Risk Index is interrelated with the hazard and vulnerability components. The relationship between these three components can be seen based on the following formula (Wiguna *et al*., 2020):

$$R = H \; x \; V \tag{7}$$

Information:
R = Risk;
H = Hazard;
V = Vulnerability.

Determination of the risk index class for the study area is carried out by classifying it into three classes (Table 6) based on the following equation:

Table 6. Classification of Tidal Flood Risk Index

Class	Index Value
High	5.05 – 6.41
Medium	3.69 – 5.05
Low	2.33 – 3.69

Source: 2023 analysis results

3. Results and Discussion

The coastal area of East Luwu Regency is dominated by the fisheries, agriculture, and tourism sectors. The dominant agricultural sectors include rice fields, oil palms, and mixed plantations. Meanwhile, the tourism areas of beach tourism, snorkeling, and diving are in the Malili, Wotu, and Burau Districts. At the same time, the fisheries sector with fishery products such as seaweed, milkfish, shrimp, and fish is found in all coastal districts but is concentrated in Malili District, namely Lakawali Pantai village and Malili City (East Luwu District Regional Regulation, 2014; Perdinan, 2020).

3.1 Flood Inundation Area Rob

After analyzing tidal data using the least squares method, we calculated a tidal constant value of 0.68. This led to the conclusion that East Luwu waters experience a mixed (semi-diurnal) tidal pattern.

Furthermore, we calculated that the tidal flood inundation height is 1.419 meters, which is quite far from the coast. (Figure 3) shows a map of the tidal flood inundation area, giving an idea of the extent of the inundation during the highest tide.

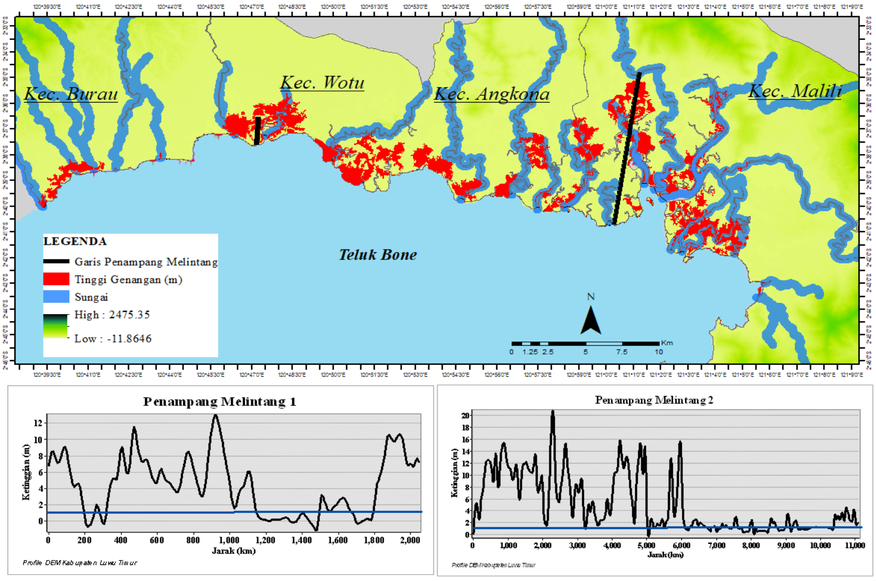


Figure 3. Region flood inundation area

According to the tidal flood inundation map of East Luwu Regency, not all of the coastal areas are affected by the highest tides. This is due to differences in topography. The cross-sectional area graph above shows that the coastal areas that are not affected by flooding have a land height of over 1.5 meters. On the other hand, the flooding that occurs further inland is caused by seawater entering through rivers. The largest tidal flood inundation happened in the Malili District, covering an area of 1,936 hectares. The Wotu District had the second-largest inundation, covering 1,901 hectares, followed by the Angkona District with an area of 636 hectares, and the Burau District with 278 hectares. Therefore, it can be concluded that Malili District is more susceptible to seawater input than other coastal districts.

3.2 Hazard Index

The potential tidal flood hazard index on the coast of East Luwu Regency was obtained based on an overlay of data on inundation height and frequency of inundation on the coast of East Luwu Regency. Based on the visualization of the tidal flood hazard index (Figure 4), it is known that the tidal flood hazard level in East Luwu Regency is in the high category.

Inundation height data is classified into three categories, namely high (94.6 – 141.9 centimeters), medium (47.3 – 94.6 centimeters), and low (0 – 47.3 centimeters). Areas in the high category tend to be close to the coastline, and some small parts are around large rivers. Generally, each sub-district height is medium (2,094 Hectare) and high (1,921 Hectare). Some areas affected by tidal flooding are far from the coastline. This happens because this sloping area is crossed by a large river, which contributes to water rise when high tide occurs. When a tidal flood (tidal flood) occurs, seawater slows down the flow of rivers to the sea. When flooding coincides with high tides, the height of the inundation or flooding becomes higher because there is backwater.

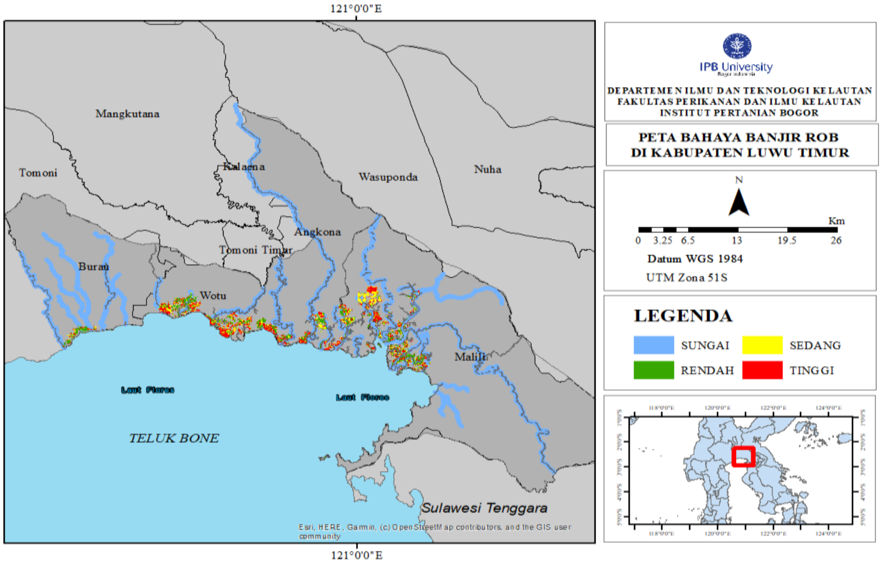
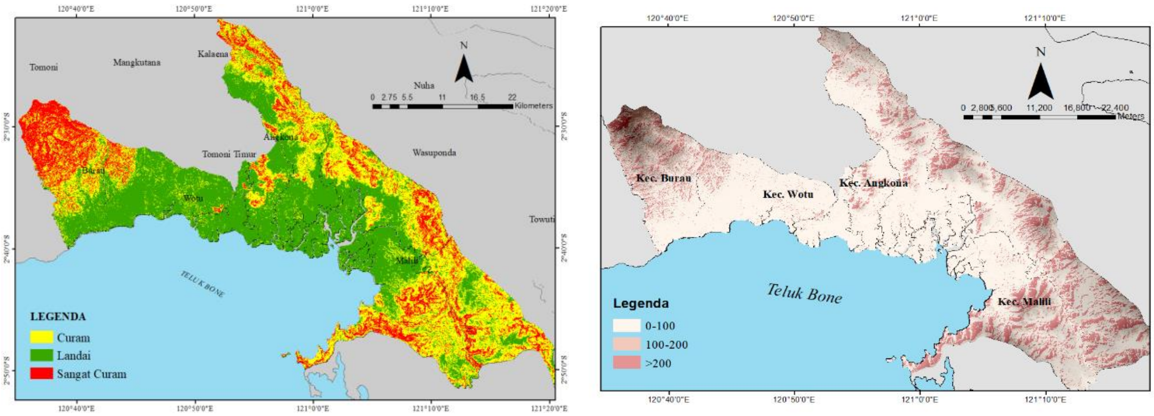


Figure 4. Map of the danger level of tidal floods on the coast of East Luwu Regency

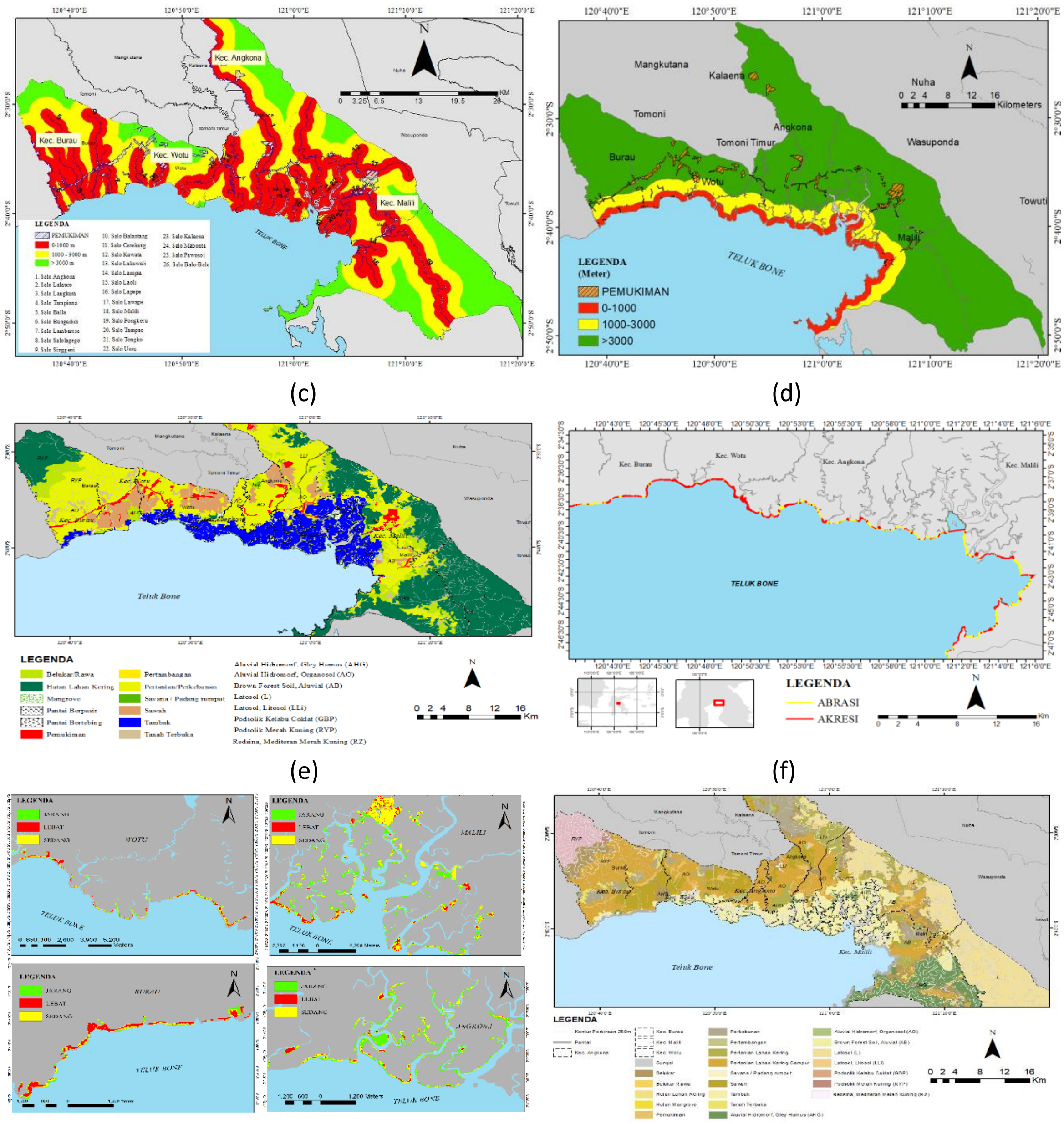
In addition, interviews with residents revealed that the frequency of inundation that occurs on the coast of East Luwu Regency is 1-3 times a month, so it is included in the medium potential hazard category. The frequency of inundation has the impact that the more frequent tidal floods occur in the area, the greater the amount of loss that the environment and society will experience. For example, inundation in agricultural areas or ponds will cause significant losses when the frequency of flooding increases.

3.3 Vulnerability Index

The preparation of physical vulnerability assessment data for tidal floods is carried out by multiplying the weight and score values for each parameter, where the assessment of the level of vulnerability is carried out based on the category of each parameter by looking at the influence of that category on tidal floods. The following is a map of each parameter (Figure 5) overlaid to determine the level of vulnerability to tidal floods.



(a) (b)



(c) (d)

(e) (f)

(g) (h)

Figure 5. (a) Regional Slope; (b) Area Altitude; (c) Distance from River; (d) Distance from Beach; (e) Regional geomorphology; (f) Changes in Coastlines; (g) Mangrove Cover; (h) Land Use.

Based on the analysis of the maps presented above, it can be concluded that the slope and elevation data of Luwu Timur Regency fall under the category of gentle slopes, with slopes ranging from 0 to 15% (Figure 5a). Moreover, the elevation in each district is primarily in the range of 0 to 100 meters (Figure 5b).

The proximity to the sea variable reveals that areas nearest to the coast and rivers have a high risk of being affected by tidal floods (Figures 5c and 5d). Tidal floods are typically caused by river water overflowing due to the increased volume of seawater along the coastal areas and river bodies during high tides, which obstructs the river flow from the upstream during the rainy season, resulting in inundation in residential areas.

Luwu Timur Regency possesses a coastal geomorphology characterized mainly by alluvial plains, with a substantial portion used for fishponds and sandy beaches, which are also utilized as tourist destinations (Figure 5e). This condition also results in the supply of sediment from major rivers that flow into the sea, leading to a tendency of shoreline accretion (Figure 5f).

Moreover, the extent of mangrove ecosystem coverage influences the assessment of vulnerability to tidal floods (Figure 5g). The study conducted by Gunawan *et al.* (2022) demonstrates that the roots in mangrove ecosystems play a vital role in mitigating tidal flood disasters by reducing or blocking incoming tidal waves toward the mainland.

The data processing results for land use in the coastal area of Luwu Timur also reveal that the coastal region is highly productive, with the dominant land use types being fishponds and agricultural areas (Figure 5h).

Based on the results of the vulnerability index overlay above, the results show that the coastal areas in East Luwu Regency are included in the high level of vulnerability to tidal floods. The further away from the coast, the value of the level of vulnerability decreases. This is because the accumulated data on each parameter has a high value in areas close to the coast.

The condition of the vulnerability index provides an overview of the level of vulnerability of the coastal area of East Luwu Regency to tidal floods, which is visualized in the form of a map as in (Figure 6).

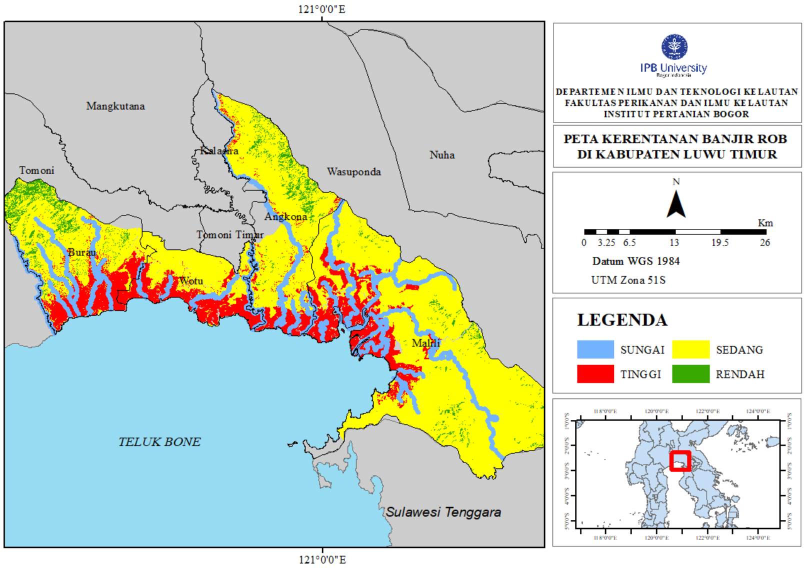


Figure 6. Map of tidal flood vulnerability level on the coast of East Luwu Regency

The increase in coastal vulnerability further inland is influenced by several parameters. Elevation and slope data significantly affect the assessment of coastal vulnerability in Luwu Timur Regency. This region has a low slope category, which, in turn, results in a high level of vulnerability.

Furthermore, the coastal areas in each district are also productive, with activities such as fishponds, agriculture, and some settlements located in the coastal areas. As a result, the land use data generated tends to fall into the high category of vulnerability.

Changes such as mangrove deforestation, inappropriate agricultural practices along the coastline, and other land use changes can also reduce water infiltration and sediment retention, thus reducing the river's capacity, and leading to increased flood flows.

The extent of mangrove ecosystem coverage also influences the assessment of tidal flood vulnerability. The range of mangrove ecosystem coverage values in each district shows a variation from rare to moderate, placing them in the high vulnerability category.

3.3 Flood Risk Analysis

The tidal flood risk analysis results are influenced by the relationship between the hazards on the coast of East Luwu Regency and the level of vulnerability in the area. The hazard and vulnerability data produces a map of tidal flood risk levels in coastal areas based on three categories as in (Figure 7).

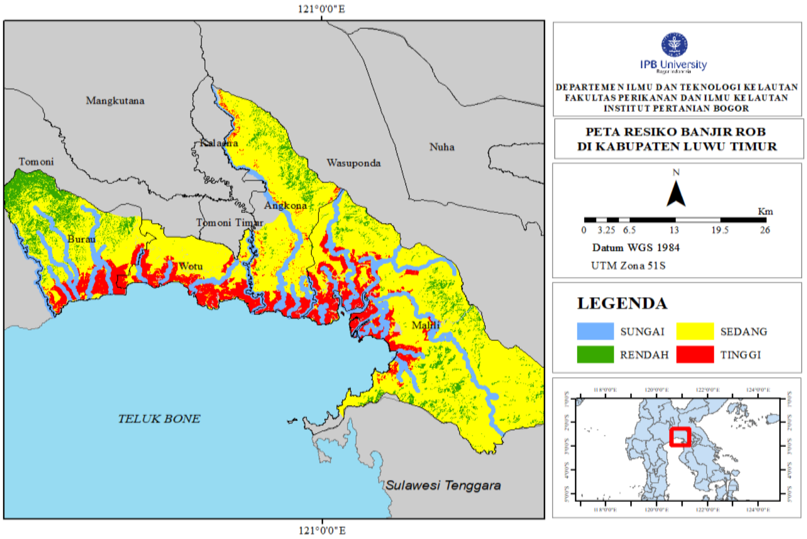


Figure 7. Map of tidal flood risk levels on the coast of East Luwu Regency

The parameters for assessing the potential danger of tidal floods with vulnerability parameter data reflect the level of regional preparedness in facing the threat of tidal floods, resulting in a tidal flood risk level map that indicates the varying levels of risk in each sub-district. The tidal flood risk mapping carried out in East Luwu Regency shows that the area close to the coast is in the high-risk level category, which indicates that the area is in an area with a high level of danger and a high level of vulnerability. This condition predominantly occurs along the coastline.

However, the risk level decreases towards land conditions with a moderate to low-risk level. This indicates the impact of natural protection from the shape of the slope and vegetation. The experts' opinions also align with the analysis results, which state that coastal mangrove vegetation's slope and protective function of coastal mangrove vegetation significantly impact the tidal flood risk level. Thus, areas with a high potential for tidal flood danger with gentle slopes and sparse mangrove vegetation will increase the risk of tidal floods, as is the case in the coastal areas of East Luwu district. (Hannan & Irawan, 2017) explain that high risk in an area does not only depend on the level of danger but is also greatly influenced by the level of vulnerability of the area to disasters.

3.4 Prediction of Rob Flood Inundation in 2050

The inundation prediction for 2050 is based on the inundation height value of 2022 plus the Sea Level Rise (SLR) value in East Luwu waters.

The prediction data for the predicted inundation height for 2050 was carried out using baseline data for the 2022 tidal flood height (t0), namely 1.419 meters. The inundation projection model assumes no protective structures, embankments, dams, etc. So the inundation height (t1) in 2050 is 1.570 meters.

This inundation projection model assumes no protective structures, embankments, dams, etc. The results of this inundation modeling reveal the extent of the impact produced by the inundation event when it reaches the highest tide. This shows that the inundation is temporary, meaning it does not last throughout the year but only occurs when sea tides reach their highest levels.

The predicted map for tidal flood inundation in 2050 in East Luwu Regency can be seen in (Figure 8). The predicted map for inundation in each sub-district can be seen in (Figure 9):

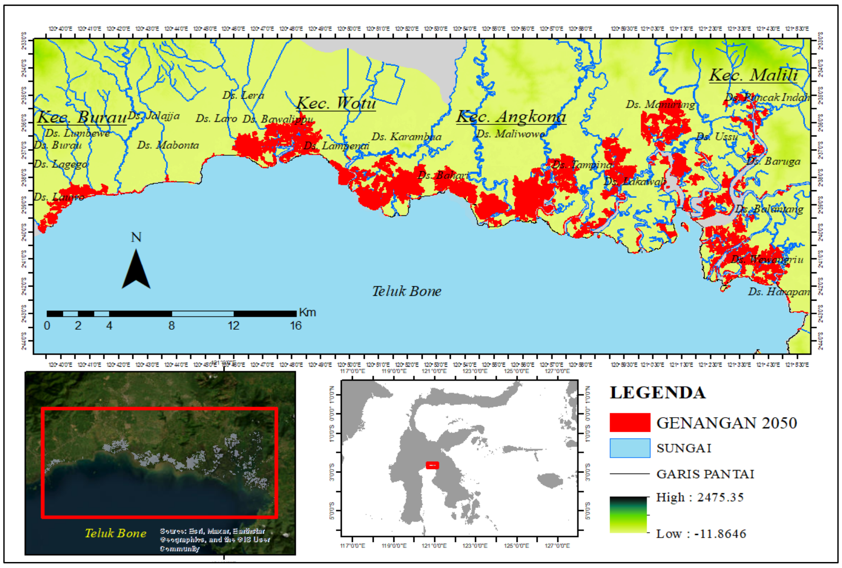


Figure 8 Map of predicted tidal flood inundation in 2050

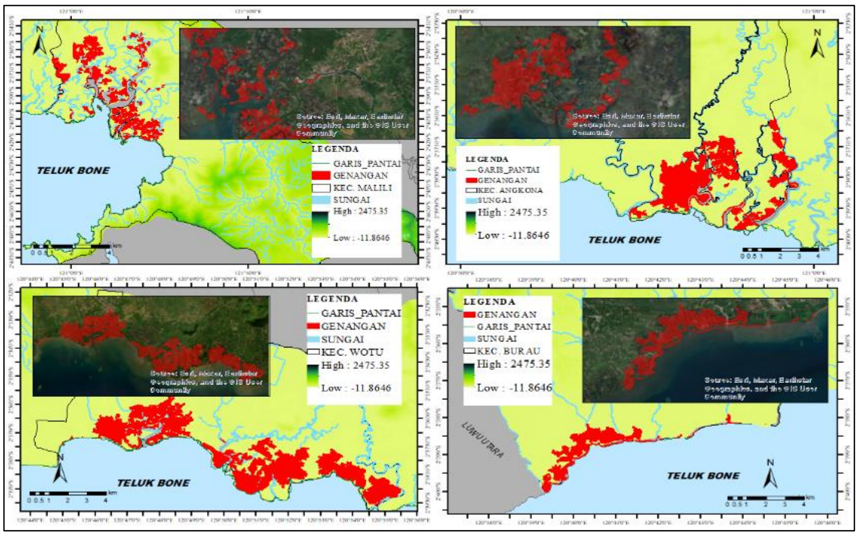


Figure 9. Map of predicted tidal flood inundation in 2050 in each sub-district

Mapping the predicted area for tidal flood inundation shows that water moves far inland. In contrast, coastal regions, the water entry points, are indicated to experience permanent inundation, pushing water input from the sea further toward land. According to (Yuliadi, 2017), negative impacts that can be felt directly from the phenomenon of sea level rise include coastal erosion, inundation of coastal land areas, Increased frequency and intensity of floods, Increased impact of storms in coastal areas, and damage to coastal ecosystems.

The predicted area of tidal flood inundation in 2050 can be seen in (Figure 10) which shows a graph of the predicted figures for the area of tidal flood inundation in 2050 in each sub-district.

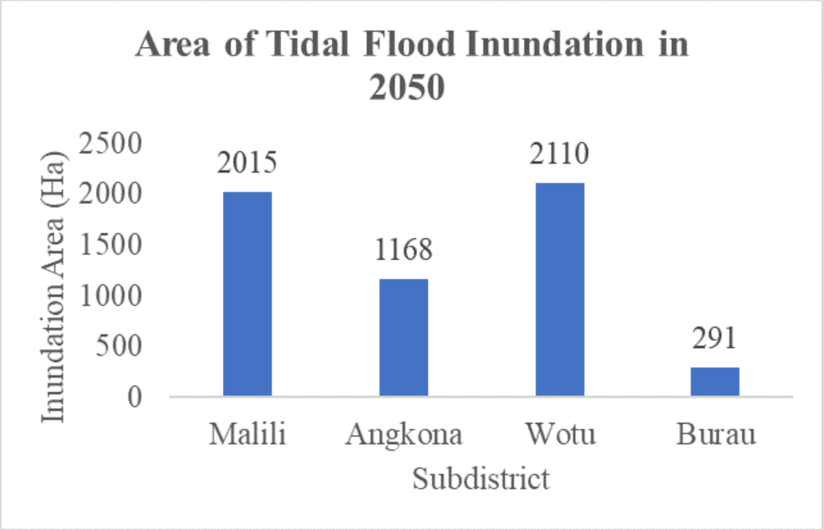


Figure 10. Area of tidal flood inundation in 2050

Based on the data above, it is known that the tidal flood inundation in 2050 in each sub-district will experience tidal flood inundation, which will almost occur along its coastline. In Malili District, the area affected by tidal flooding is 2,015 hectares, Angkona District is 1,168 hectares, Wotu District is 2,110 hectares, and Burau District is 291 hectares. These results are also used to assess the impact of the extent of flood inundation in 2050 on land use with the assumption that there will be no changes in land use within 28 years so that it can be known what types of land use are affected by tidal flooding. The following is a map of the impact of tidal floods on land use in 2050 (Figure 11).

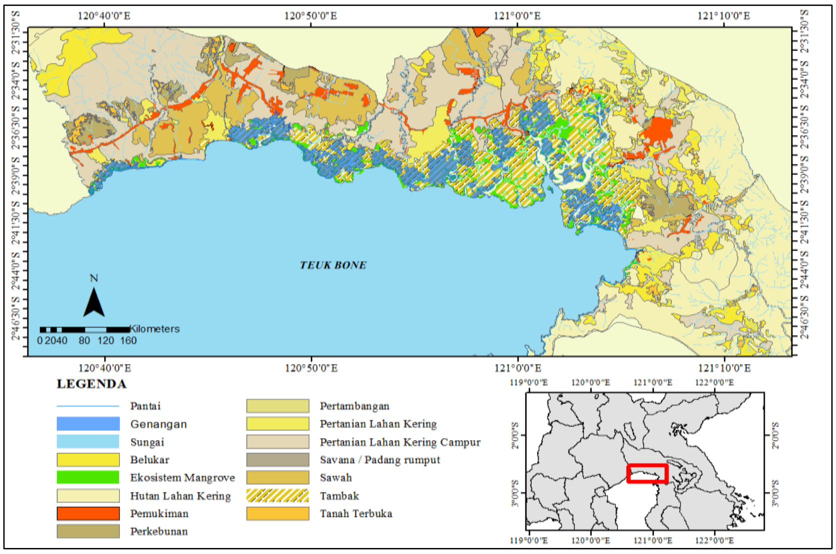


Figure 11. Land use areas affected by tidal flooding

This data shows that land uses predicted to be impacted by tidal flooding in 2050 include ponds, dry land agriculture, mixed dry land agriculture, shrubs, mangrove ecosystems, rice fields, and settlements, assuming there is no change in land use. This shows that in every coastal sub-district of East Luwu Regency, almost all areas that have significant influence are areas of production land, one of which is ponds. Data on land use in each sub-district can be seen in the diagram (Figure 12).

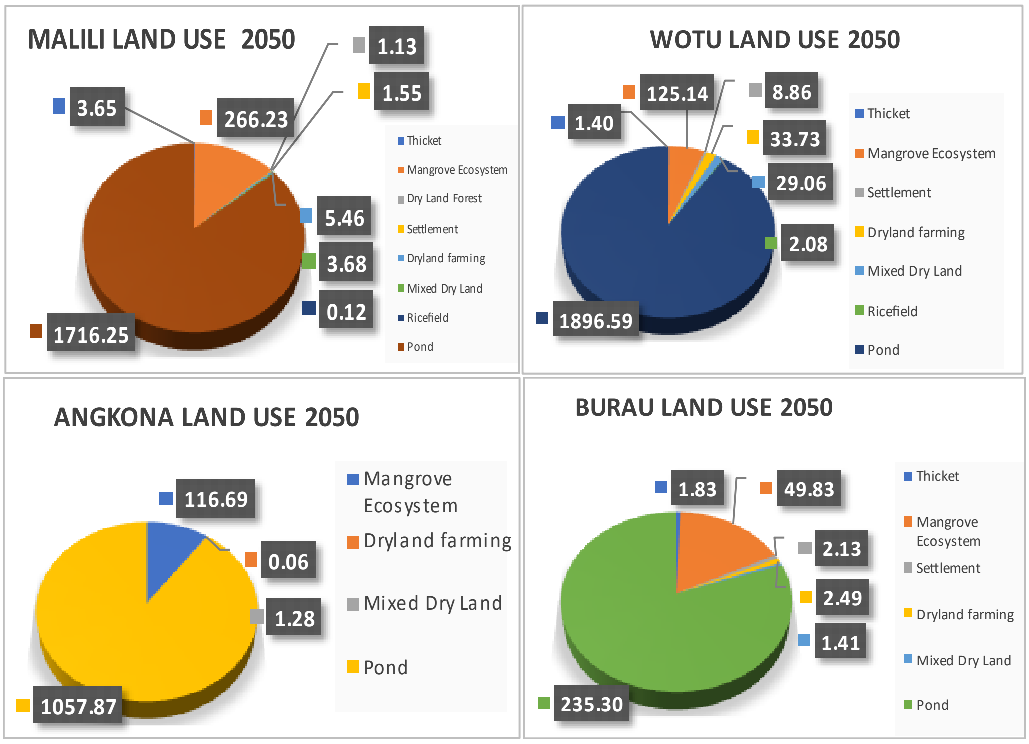


Figure 12. Diagram of land affected by tidal flooding in each sub-district.

Based on the data presented, it is evident that tidal floods in East Luwu Regency will have a significant impact on pond areas and mangrove ecosystems. This has major implications for the future, as the majority of East Luwu Regency's coastal residents rely on the activities of pond farmers for their livelihoods.

In total, four coastal districts have the potential to be flooded by tidal water. However, not all flooded areas will directly affect settlements, such as Harapan Village, Malili District, and Burau Pantai Village. In contrast, several areas in coastal sub-districts, such as Lakawali Village, Angkona Sub-district, and Wotu Sub-district, are more likely to impact community pond areas and agricultural land.

It's worth noting that settlements located farther away from the coastline may not be directly impacted by tidal floods. However, the economic impact on the region remains significant, given that the majority of coastal residents in East Luwu rely on pond farming and agriculture, including oil palm, mixed plantations, and rice fields. To ensure the economic sustainability and well-being of the community, appropriate mitigation measures should be taken in vulnerable areas.

4. Conclusion

Based on the previous analysis, it can be concluded that the coastal areas of Malili, Wotu, Angkona, and Burau districts are at a high risk of tidal flooding. The level of risk decreases as we move away from the coastline and towards the mainland. The area of tidal flood inundation in each sub-district is as follows: Malili District covers an area of 1,936 hectares, Wotu District covers an area of 1,901 hectares, Angkona District covers an area of 636 hectares, and Burau District covers an area of 278 hectares.

By 2050, the coastal sub-district in East Luwu Regency is expected to suffer from inundation with an estimated height of 1,570 meters. The inundation will occur evenly along the coastline, and the affected area will expand further inland due to the inflow of seawater. The tidal flooding will affect the following districts: Malili (2,015 hectares), Angkona (1,168 hectares), Wotu (2,110 hectares), and Burau (291 hectares). Most of this area, including production land, such as ponds, will be significantly impacted by tidal flood inundation.

5. Recommendations

Suggestions for further research are that this modeling will achieve a higher level of accuracy by integrating regional surface height data and land surface change data. This data can help improve the precision of tidal flood inundation modeling in the area and provide more comprehensive insight into the dynamics of the coastal environment of East Luwu Regency.

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