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Analysis of Shoreline Change of North Central Timor Regency, Indonesia

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ABSTRACT

Shoreline change is a process that occurs due to the impact of natural factors and human activities. Geographically, the coastal area of North Central Timor Regency (NCT) is in the northern part of the island of Timor, East Nusa Tenggara Province (ENT). Physically, the area is affected by the oceanographic dynamics of the Sawu Sea waters and aquaculture activities, which impact the damage to coastal ecosystems. This study aims to analyze shoreline change in the northern coastal area of NCT Regency. The data used are Landsat 8 images from 2015-20221 to describe current conditions. Meanwhile, Landsat 5 imagery data from 1990 - 2000 was used to describe the initial conditions. The satellite imagery is analyzed to map shoreline changes that experience accretion or abrasion. The results show that the shoreline of the study area has experienced changes in accretion and abrasion. Based on the area of change in the northern coastal area of NCT Regency, the dominant accretion area was 1108.07 m^2 with a rate of change of 20.19 $m.year^{-1}$, as long as 1021 meters, while the abrasion was 845.43 m^2 at a rate of 12.65 $m.year^{-1}$ as long as 36520 meters. The average shoreline change distance in accretion conditions was 11.3 meters, while the abrasion was 7.93 meters. The shoreline shift due to the highest abrasion in Ponu was -16.08, while accretion in North Oepuah was 35.63 meters. The results of this research will contribute to planning the management of the coastal area of NCT Regency.

INTRODUCTION

The Indonesian archipelago is the largest, with the second longest coastline in the world. Such conditions cause most of Indonesia's territory to border the sea (Kurniawan & Marfai 2020). The area that borders the sea with land ecosystems is called the coastal area (Dahuri et al. 2013). The characteristics of the sea and land always influence coastal areas. The characteristics of the sea that affect the land include tides, wind, and sea waves.

In contrast, the characteristics of the land that affect the sea are sedimentation and human activities, which cause deforestation and pollution (Winarso et al. 2001). Geomorphological processes in coastal areas can be divided into destructive and constructive. Destructive processes tend to damage or change existing coastal landforms, while constructive processes can produce new ones (Sugiarta 2018). The occurrence of geomorphological processes causes the coastline to shift. Change in the coastline can be positive due to the sedimentation process, which results in coastal areas having additional land. However, coastline changes can also cause abrasion or land erosion (Winarso et al. 2001).

The coastal area of NCT Regency is in the northern part of the island of Timor, ENT Province, which is directly opposite the Sawu Sea. Physically, this area is affected by oceanographic dynamics (such as tides, waves, and currents) from the waters of the Sawu Sea and the flow of small rivers upstream that changes every season. In general, sea waves in the waters of NCT Regency in the West monsoon propagate from the northwest, west, and southwest, while in the East monsoon originate from the south and southeast. In addition, the utilization and development of the northern coastal area of NCT Regency tend to increase every year, for example, as an aquaculture area (Ledheng et al. 2012).

Utilization of the area for aquaculture has caused the population of mangrove species on the north coast of NCT Regency to decrease or even become extinct. A study of mangrove vegetation in 2009 found that there were as many as 24 types of mangroves (Ledheng et al. 2012), then in 2020, it was only 4 species (Ledheng et al. 2020). The reduced population of the species indicates that there has been damage and disturbance in the coastal area, which has caused abrasion. The loss of most of the vegetation in the northern coastal area of NCT Regency led this area

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to be designated as abrasion-prone by the NCT Regency Government (Timor Tengah Utara Regency 2021). The impacts faced by the northern coastal communities of NCT Regency include damage to settlements, pond areas, and highway infrastructure. One of the causes of damage is tidal flooding. The phenomenon encourages people to open new pond areas (Ledheng et al. 2012). It caused the coastline to shift towards the mainland and salty water to inundate once-dry land. Therefore, studying shoreline changes is an important step to understanding the dynamism and evolution of coastal areas; thus, stakeholders can do better to reduce the risk of coastal abrasion disasters to minimize physical and economic losses (Fuad & Fais 2017).

According to Williams (2013), the study of coastlines plays an important role in coastal management, climate change, and sea level rise. The study of shoreline change on the north coast of NCT Regency applied an *overlay* technique with the help of a *Geographic Information System* (GIS) with ArcGIS software (Nassar et al. 2019). Statistical analysis was performed using the *Digital Shoreline Analysis System* (DSAS). DSAS analysis is useful for knowing the value of *Net Shoreline Movement* (NSM) and *End Point Rate* (EPR) as reports of shoreline changes (Jonah et al. 2016). This study aims to analyze shoreline change along the north coast of NCT Regency over the past 9 years:1990, 2000, 2015, 2016, 2017, 2018, 2019, 2020, and 2021. The results of this study can be used for the formulation of mitigation and regulatory policies as well as giving contribution to the research literature.

MATERIALS AND METHODS

Research Site

The research was conducted on the north coast of NCT Regency, ENT Province. The number of transects at the research location was 4696. They spread across 9 coastal villages divided into 3 sub-districts with 10-meter distances per transect. There were 1354 transects along the coast of the Insana Utara sub-district (Wini and Oekolo Villages), 1112 in Biboki Moenleu sub-district (Oepuah Utara and Oepuah Villages), and 2228 in Biboki Anleu sub-district (Oemanu, Ponu, Tuamese, Nonotbatan, and Motadik villages), as

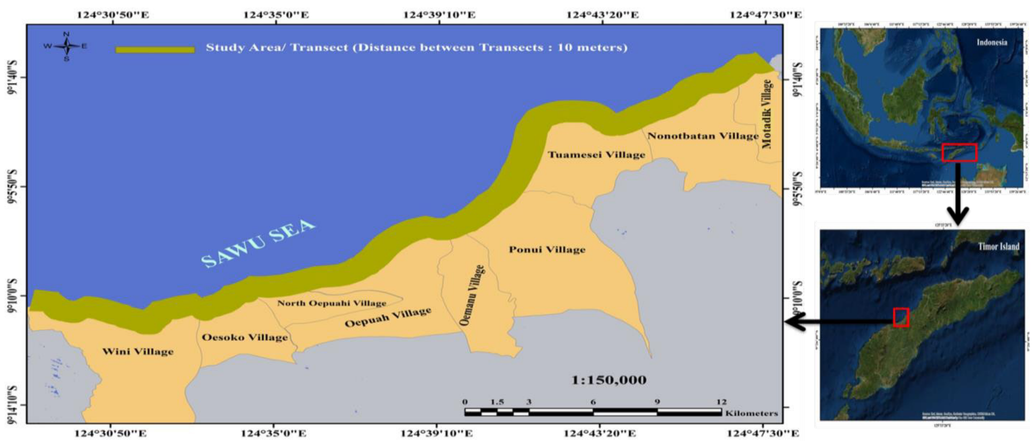

Fig. 1: The research site.

Table 1: Satellite imagery data used in the research.

Satellite Imagery	Resolution	Radiometric	Path/Row	Date
Landsat 5 TM	30	8 bit	110/066	3/31/1990
Landsat 5 TM	30	8 bit	110/066	7/16/2000
Landsat 8 OLI	30	12 bit	110/066	9/28/2015
Landsat 8 OLI	30	12 bit	110/066	8/13/2016
Landsat 8 OLI	30	12 bit	110/066	8/16/2017
Landsat 8 OLI	30	12 bit	110/066	8/19/2018
Landsat 8 OLI	30	12 bit	110/066	7/21/2019
Landsat 8 OLI	30	12 bit	110/066	7/23/2020
Landsat 8 OLI	30	12 bit	110/066	8/11/2021

shown in Fig. 1. The choice of research site, was based on the consideration that the North coast of NCT Regency has a very low mangrove population level which triggers tidal floods that damage settlements, aquaculture areas and roads (Ledheng et al. 2020).

Image Data

The data used in this study are Landsat 5 TM image data for 1990 and 2000 and Landsat 8 OLI from 2015 to 2021, which were compiled from the *United States Geological Survey* (USGS) at https://glovis.usgs.gov/app?fullscreen=0. The satellite images used meet the criteria of less than 10% cloud cover Table 1. Supporting data for this research are tidal prediction from MIKE 21 software and slope data measured from the field.

Data Analysis

Data processing includes several stages, such as image correction and cropping. Image processing is done using the ArcGIS program. The stages of image data processing consist of geometric correction, image cropping, image analysis for shoreline change, and shoreline correction for tides. A geometric correction was carried out on Landsat 5 TM to correct the spatial distortion of objects in the image. Thus, the position of the recorded object matches the coordinates in the field. This action was done because Landsat 5 TM raster data is generally displayed as unprocessed data (raw) and has geometric errors that must be corrected geometrically into the earth's coordinate system.

Image data cutting is done to limit the images to only the research area. Image cropping can be done based on the coordinates, number of pixels, or area magnification results. Image band sharpening uses a *Red-Green-Blue* (RGB) 123 band composite. This band is used because they are the most suitable for detecting shoreline change. After sharpening the image, digitizing the image is also done to get the accuracy of the coastline. Correction of tides is very important to eliminate standing water due to the effect of tides on image recording. Shoreline correction to tides is done by determining the beach bottom's slope and the image shoreline correction to the mean sea level (MSL). The slope of the seabed is obtained by knowing the depth (d) and horizontal distance (m) from the shoreline to depth Fig. 2.

Based on Fig. 2, the beach bottom slope equation is obtained:

$$\text{Tan}\,\beta = \frac{d}{m} \quad \ldots(1)$$

Correction of the imaged coastline to mean sea level (MSL) is carried out by defining the difference in the position of the water level (η) when recording the image to MSL Fig. 3. The MSL is obtained from the tidal constants from the MIKE 21 prediction; therefore the distance to the shoreline shift (r) is obtained through the equation:

$$\text{r} = \frac{\eta}{Tan\,\beta} \quad \ldots(2)$$

If the image recording is done during high tide, the coastline is shifted seaward as far as *r*. Conversely, when the sea water recedes, the coastline is shifted inland as far as *r*. The last process is overlapping, which is carried out to see shoreline change at the research site by calculating the values of abrasion and accretion. To see changes in the shoreline clearly, the site was divided into 9 locations representing each coastal village in NCT Regency. If the shoreline in 1990 shifted further out to sea compared to one in 2021, then the location is determined to have occurred with abrasion or, vice versa, accretion occurred.

RESULTS AND DISCUSSION

Shoreline Extraction

Satellite images obtained from radiometric and atmospheric corrections are used for the shoreline extraction stage. The shoreline extraction process is preceded by transferring band colors to separate land and water colors. Using the Short Wave Infrared 1 (SWIR 1) color band for the Landsat 8 OLI and Near Infrared for the Landsat 5 TM produces the color reflection presented in Fig. 4.

Based on image analysis using ENVI 5.3, the infrared reflectance reflected by the land has a high value compared to the reflectance value from the sea, which is close to zero. According to Alesheikh et al. (2007), the sea absorbs

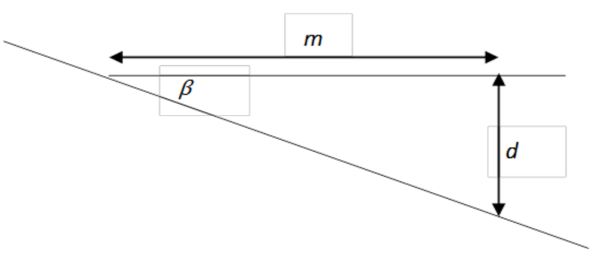

Fig. 2: Scheme for calculating the slope of the coast.

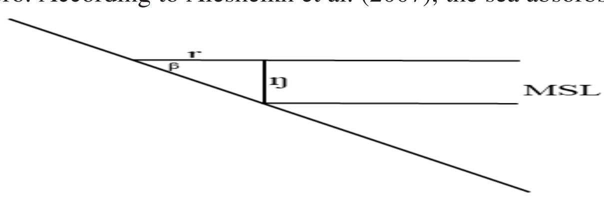

Fig. 3: Schematic drawing of the sea level position at the time of satellite image acquisition.

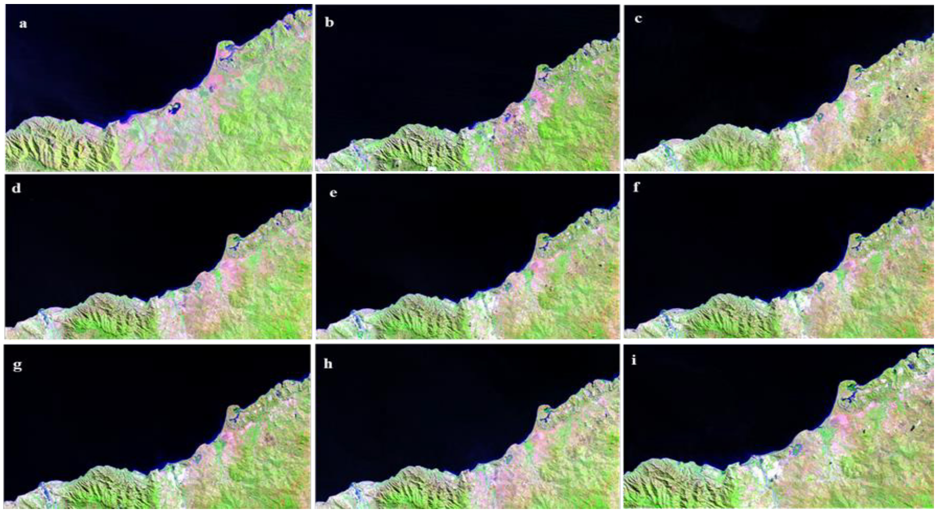

Fig. 4: Land and sea thresholds using Near Infrared for Landsat 5 TM: (a) 1990; (b) 2000, and using SWIR 1 for Landsat 8 OLI: (c) 2015, (d) 2016, (e) 2017, (f) 2018, (g) 2019, (h) 2020 dan (i) 2021.

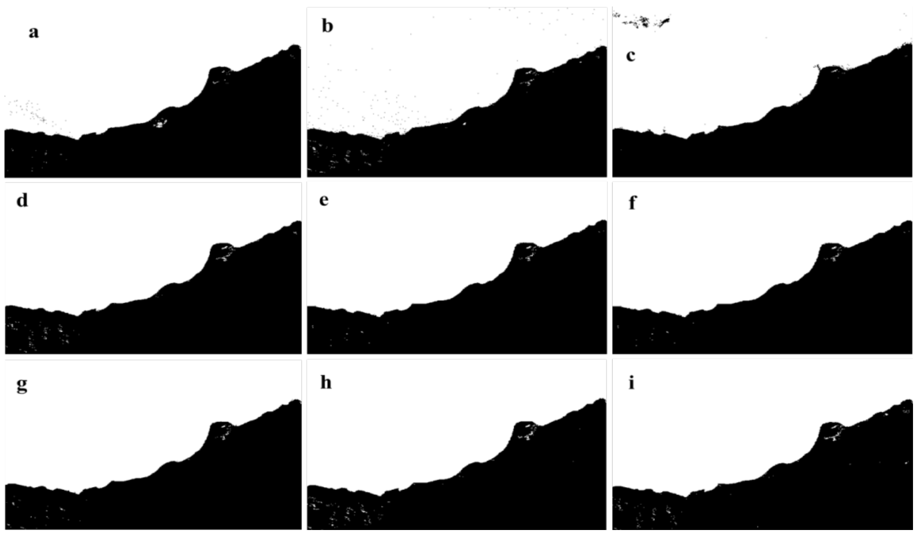

Fig. 5: The results of threshold and band ratio approaches combination images of the year: (a) 1990; (b) 2000, (c) 2015, (d) 2016, (e) 2017, (f) 2018, (g) 2019, (h) 2020 dan (i) 2021.

Table 2. Coastal Slope Calculation Results, Tidal Analysis, and Shoreline Correction Distance to Tide on the North Coast of TTU Regency.

Image Recording Time	MSL [m]	β [°]	Ŋ [m]	Condition	X [m]
3/31/1990 8:00 WITA	2.87	0.8	2.87	Tide	4.25
7/16/2000 8:00 WITA	2.59	0.8	1.85	Recede	2.25
9/28/2015 8:00 WITA	2.68	0.8	1.94	Recede	2.36
8/13/2016 8:00 WITA	2.33	0.8	2.03	Recede	2.46
8/16/2017 8:00 WITA	2.38	0.8	2.38	Tide	2.9
8/19/2018 8:00 WITA	2.33	0.8	2.45	Tide	2.97
7/21/2019 8:00 WITA	2.57	0.8	2.83	Tide	3.43
7/23/2020 8:00 WITA	2.44	0.8	2.45	Tide	2.97
8/11/2021 8:00 WITA	2.72	0.8	1.82	Recede	2.21

Note: Slope classification: < 1 (even), 3-6 (sloping), 9-25 (steep), > 140 (very steep) (Portal Geograf 01 November 2018)

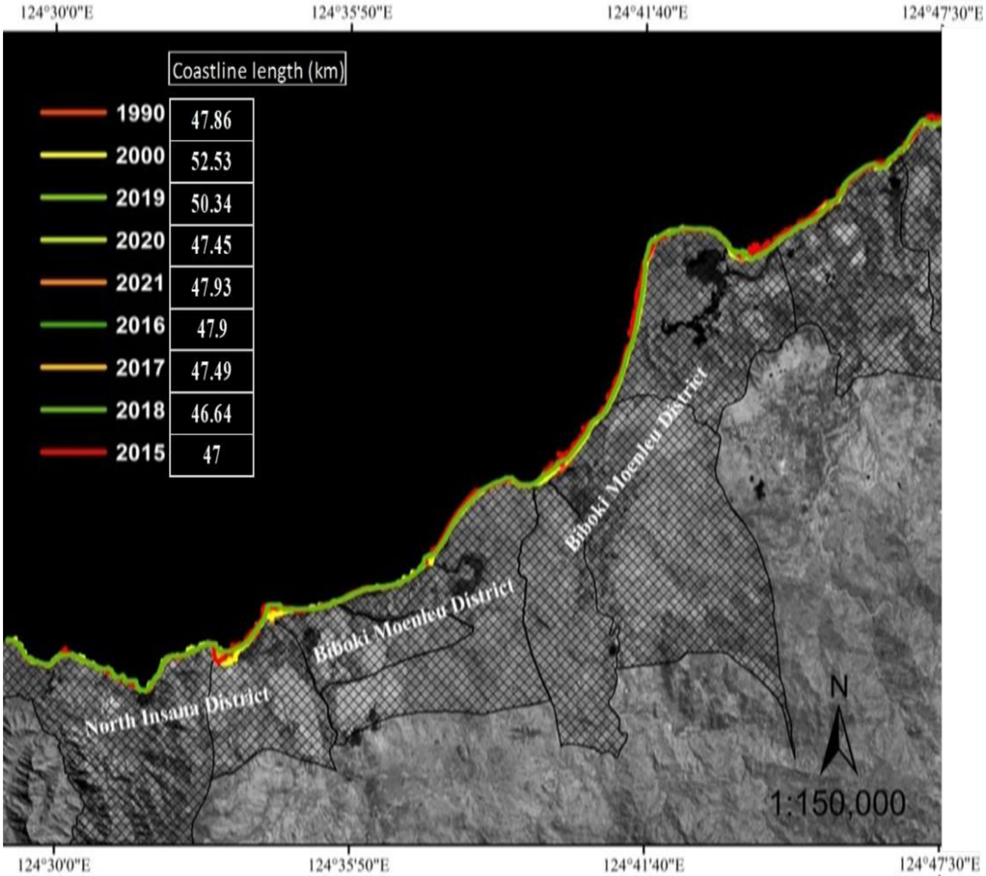

Fig. 6: Landsat imagery from 1990 to 2021 after shoreline correction for tides.

the infrared reflectance value; thus, it is not reflected. In addition, the band ratio used for Landsat 8 is Band 3/6 and Band 3/5. Meanwhile, Landsat 5 uses Band 2/5 and Band 2/4. Combining the threshold and band ratio approaches produces an image converted to a coastline. The results of the band ratio and the combination of the two approaches are shown in Fig. 5.

The combined binary image of the threshold and band ratio is classified between water and land. The results of this classification are vectors, which are conversions from rasters to polygon shapefile formats. The polygon vector is converted into points and then into UTM coordinates for shoreline corrections for tides. Correcting the UTM coordinate value using the line shift (x) obtained from observing the beach slope and tidal analysis using MIKE 21 Table 2.

Landsat 5 imagery recorded on March 31, 1990, was obtained at a sea level elevation of 2.87 m or during high tide conditions. While the recording date of 16 July 2000 was obtained at a sea level elevation of 1.85 m at low tide. Landsat 8 imagery recording dates 28 September 2015, 13 August 2016, 16 August 2017, 19 August 2018, 21 July 2019, 23 July 2020, and 11 August 2021 obtained at elevation altitudes respectively: 1.94 m, 2.03 m, 2.38, 2.33 m, 2.57 m, 2.44 m, and 2.72 m. Based on the elevation value, it is known that the change in coastline distance to the normal position from 1990 to 2021 is successive: 4.25 m, 2.25 m, 2.36 m, 2.46 m, 2.9 m, 2.97 m, 3.43 m, 2.97 m, and 2.21 m. The condition of the coastline of NCT Regency in the landscape images from 1990 to 2021 after correction for tides produces the length of the coastline as shown in Fig. 6.

Shoreline Change Analysis

Based on the analysis of shoreline change in NCT Regency from satellite imagery observations in 1990, 2000, 2015 to 2021, the shoreline has experienced both abrasion and accretion. The average abrasion area is 845.43 m2, as long as 36520 meters, while accretion is 10621 m long with an area of 1108.07 m2. The accretion area is larger than the abrasion, which may be due to a very large supply of sedimentation occurring in the estuary on the north coast of NCT Regency, causing sedimentation to move faster. According to Muryani

Table 3: Analysis of shoreline change of North Central Timor Regency in 2021.

Beach Conditions	Change in coastline			
	The rate of shoreline change [m.tahun^{-1}]	Area [m²]	Length [m]	Percentage [%]
Abrasion	12.65	845.43	36520	77.47
Accretion	20.19	1108.07	10620	22.53
	Total		47140	100

Table 4: The extent and distance of changes in abrasion and accretion in 1990-2021.

Tahun	Width (m^2)		NSM (m)	
	Abrasion	Accretion	Abrasion	Accretion
1990 - 2000	211.35	218.51	-44.68	43.29
2000 - 2015	493.51	547.39	-22.53	105.75
2015 - 2016	449.23	309.88	-72.67	11.75
2016 - 2017	186.27	224.33	-9.60	32.81
2017 - 2018	4963.26	7101.99	-13.73	18.91
2018 - 2019	163.41	143.22	-19.12	8.54
2019 - 2020	189.50	212.61	-24.40	8.35
2020 - 2021	106.90	106.59	-7.93	11.07
Average	845.43	1108.07	-26.83	30.06

(2010), coastal areas near river mouths experience relatively rapid sedimentation, thus forming new land or increasing the existing land area. The analysis results using the *End Point Rate* (EPR) method show an accretion rate of 20.19 m.year^{-1}, higher than the abrasion rate of 12.65 m.year^{-1}. The average change in the northern coastline of NCT Regency from 1990-2021 is presented in Table 3.

Change in the shoreline in 2000 caused abrasion of 211.35 m² with an average change distance of 44.68 m, while accretion covered an area of 218.51 m² and a change distance of 43.29 m. Then in 2015, there was an additional abrasion area of 282.16 m² and 328.88 m² of accretion; thus, the abrasion area reached 493.51 m² and 547.39 m² of accretion with the distance of changes in abrasion and accretion 22.53 m and 105.75 m respectively. In 2016, the area of abrasion and accretion decreased by 44.28 m² and 237.51 m² with a distance of 72.7 m abrasion change and 11.75 accretions. The abrasion area from 2000 continued to decrease until 2017 to 186.27 m² while accretion became 224.33 m². The area of abrasion and accretion increased again in 2018, with 4963.26 m² of abrasion and 7101.99 m² of accretion, with a change in abrasion of 13.73 m while accretion was 18.91 m. Then, there will be a decrease in abrasion and accretion until 2021. They are the abrasion and accretion of 106 m², each with a distance of 7.93 m of abrasion change and 11.1 m of accretion.

Based on the slope level, the north coast of NCT Regency is included in the flat category so that it impacts sea level rise. It is known that the tides in this research area are double-inclined, which can affect shoreline change. The bottom sediments on the north coast of NCT Regency are predominantly very fine to sandy (Ledheng et al. 2012). According to Tarigan (2010), flat beach conditions with a fine sediment substrate will easily experience abrasion when the waves come. The dynamics of changes in line shift distance and beach area due to abrasion and accretion on the north coast of NCT Regency are presented in Table 4.

Based on the observation, the dominant abrasion occurred in 2017 - 2018 on the North Oepuah coast, covering an area of 10001.85 m² along 8090 m with an average shoreline shift of 15.23 m. Ponu beach covers an area of 9778.69 m² along 8090 m with an average shoreline shift of 27.56 m.

Table 5: Changes in abrasion and accretion in 2017-2018.

Village	Abrasion			Accretion		
	Area [m^2]	NSM [m]	EPR [m]	Area [m^2]	NSM [m]	EPR [m]
Wini	1144.90	-7.17	-7.11	1159.57	8.16	8.09
Oesoko	2439.78	-19.64	-19.48	2477.8495	7.78	7.71
Oepuah Utara	10001.85	-15.23	-15.10	9300.83	24.20	31.17
Oepuah	2666.75	-4.98	-4.94	2636.81	11.51	11.41
Oemanu	2517.42	-18.86	-18.71	299.80	23.92	23.73
Ponu	9778.69	-27.56	-27.33	31315.61	31.43	24
Tuamese	9035.79	-11.19	-11.10	9165.41	22.08	21.90
Nonatbatan	2703.56	-9.70	-9.62	2764.91	14.28	14.16
Motadik	4380.63	-9.26	-9.19	4797.10	26.82	26.60

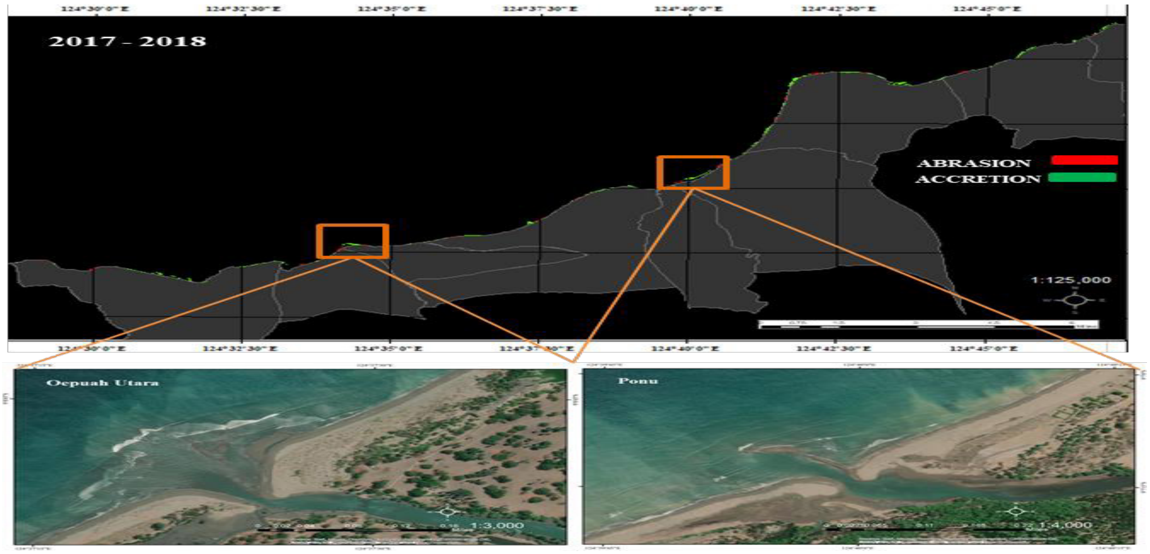

Fig. 7: The condition of North Oepuah beach and Ponu photos from 2017-2018.

Meanwhile, accretion on the North Oepuah coast is still dominant, which is 31315.61 m² and 1110 m long with an average shoreline shift of 24 m, followed by Ponu beach with an area of 31315.61 m² and 790 m long with an average shift of 31.43 m. Ponu Beach has the highest average abrasion rate of 27 $m.year^{-1}$, followed by Oesoko beach at 19.64 $m.year^{-1}$. Meanwhile, the highest accretion rate was on Ponu beach, which was 31 m/ year, followed by North Oepuah beach, which was 24 $m.year^{-1}$ (Table) 5.

River mouths still influence the two coastal areas with muddy beach conditions. The condition of accretion on the coast of North Oepuah and Ponu Beach is thought to be related to the geomorphological shape of the beach in the form of a bulge along the coast area; thus, the sea waves crash more intensively in the west monsoon period. Based on data from the Central Bureau of Statistics for NCT Regency in 2018, there was a very high rain intensity of 148 mm/ day (Statistics of Timor Tengah Utara Regency 2018). This causes the coastal areas, especially the North Oepuah and Ponu areas, to receive floods that carry large particles (Fig. 7).

The accretion that occurred in 2018 is thought to have been caused by particles carried along with the floods due to the low-lying areas of the coastal part of the island of Timor, which always experience floods from upstream that come unexpectedly due to differences in high rainfall upstream. Based on data from the Central Bureau of Statistics for NCT Regency in 2018, there was rain with a high intensity of 148 mm/day (Statistics of Timor Tengah Utara Regency 2018). According to Diposaptono et al. (2009), particle deposition is caused by current energy generated from tides and waves. River currents that enter seawater during high tide conditions will experience a slowdown resulting in reduced material transportability so that the material settles. On the other hand, during low tide, sediment from the river will be carried out to sea. Rising sea levels also cause changes in sedimentation patterns and siltation in river mouths which can interfere with access to and from boats used by fishermen to go to sea. The flat slope and waters that tend to be shallow cause material resuspension which is influenced by wind, waves, and tides, as well as causing expansion and changes in land use that occur in the research site. Hammar-Klose et al. (2003) explained that beaches that are sloping to flat are more susceptible to the movement of sediment particles as the main component forming the beach profile compared to steeper beaches. The dynamics of changes in the coastline from 1990 – 2021 are presented in Table 6 and Fig. 8.

The changes in an abrasion on Nonotbatan and Motadik beaches are 580.73 m² along 5350 m and 877.84 m² along 1620 m, respectively. Meanwhile, the accretion reaches an area of 587.82 m² along 530 m and 877.84 m² along 160 m, respectively. The condition of Nonotbatan beach is dominated by mixed and sandy beaches with settlements in this area, so it is prone to abrasion. The Motadik coastal area includes a flat tidal area with muddy beach conditions; thus, many mangrove plants grow as a coastline. This condition differs from the Tanjung Bastian area on Oesoko beach, which was damaged by abrasion.

The research by Ledheng et al. (2020) showed that the mangrove vegetation in the Bastian Cape area has become extinct. According to Soraya et al. (2012), mangrove damage affects shoreline change. Based on the NSM method, there

Table 6: Changes in the coastline from 1990-2021.

Village	Transect number	Transect length [m]		Total	NSM [m]		Width [m²]		Total
		Abrasi	Akresi		Abrasion	Accretion	Abrasion	Accretion	
Wini	1 - 975	9720	40	9760	-14.06	9.84	248	253.4	501.4
Oesoko	976 - 1354	130	3680	3810	-7.48	16.23	399.05	406.22	805.27
Oepuah Utara	1355 - 1581	8090	790	8880	-7.86	35.63	1536.44	4713.03	3203.89
Oepuah	1582 2467	1380	910	2290	-3.87	6.59	530.88	525.47	1056.35
Oemanu	2468 - 2522		570	570	-2.11	2.28	711.38	399.49	1110.87
Ponu	2523 - 2950	1110	3200	4310	-16.08	9.59	1642.77	1561.12	6249.46
Tuamese	2951 - 3934	9120	740	9860	-7.73	8.47	1268.46	1265.2	2533.66
Nonotbatan	3935 - 4520	5350	530	5880	-6.09	4.49	580.73	587.82	1168.55
Motadik	4521 - 4696	1620	160	1780	-6.06	6.49	846.51	877.84	1724.35
Total		36520	10620	47140			7764.24	10589.57	18353.81
Average					-7.93	11.07			

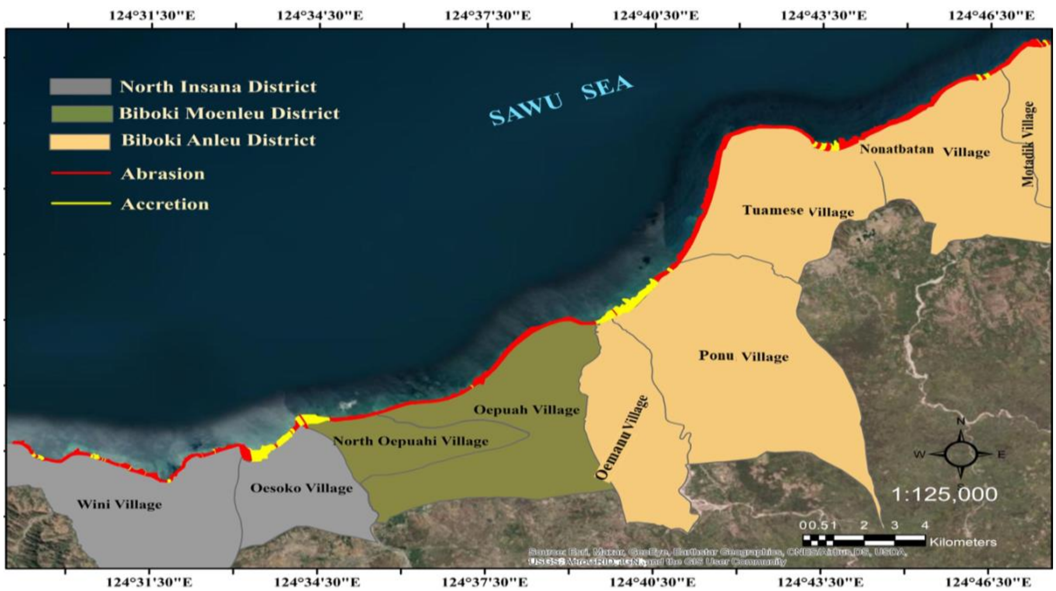

Fig. 8: Conditions of abrasion and accretion on the north coast of TTU Regency in 1990-2021.

was a line shift of 549.97 meters from 1990 to 2021 at Tanjung Bastian at the transect number 2996 Fig. 9. The dynamics of changes in the coastline causing accretion and abrasion in 2021 are also the impact of tropical cyclone storms which cause tidal waves and floods.

Three coastal villages were significantly affected by the tidal wave and flooding: Wini, Oesoko, Oepuah Utara, Motadik, and Ponu (Timor Tengah Utara Regency 2021). Sediment from erosion in the Tanjung Bastian, which has experienced the impact of abrasion, is distributed towards the coast of North Oepuah. Sediment runoff from the watershed on the coast of Oesoko is then driven by a similar current heading east towards North Oepuah at a speed of 3.60 to 11.10 $m.s^{-1}$. This condition was confirmed by windrose from recording results at the BMKG database from January to December 2021 on the north coast of Timor Island Fig. 10. Sediments carried by tidal waves accumulated with those sent by floods from land during tropical cyclone storms so that around the estuary of North Oepuah village there was a shift of the long coastline towards the sea. On transect number 3976, there was the highest change in distance, 467 meters Fig. 11.

According to Darmiati et al. (2020), coastal accretion occurs due to transporting sediment from other areas that

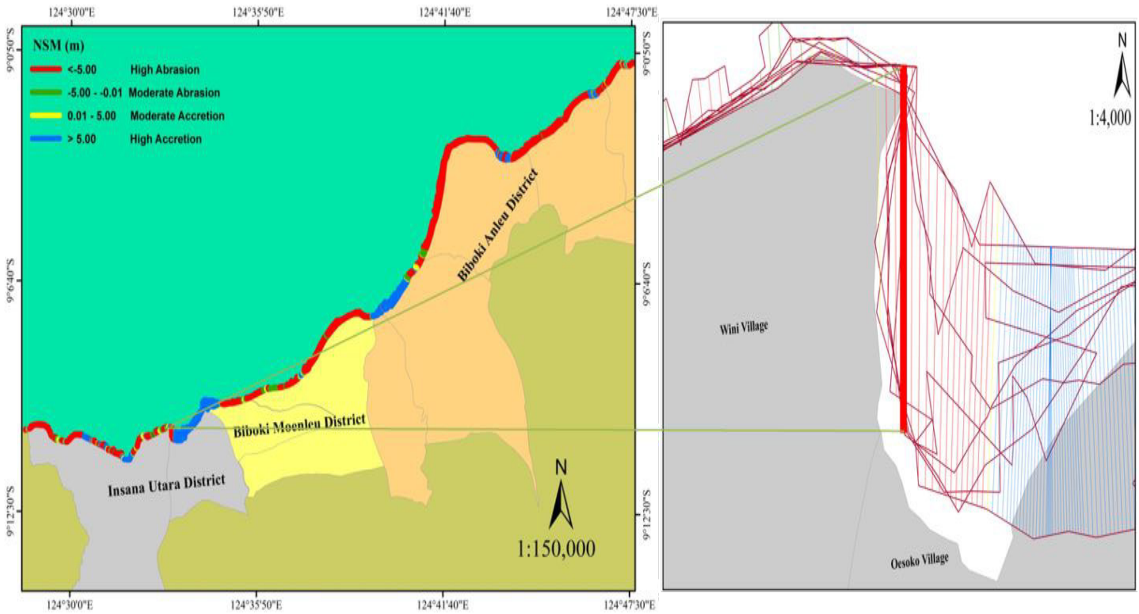

Fig. 9: Changes in the maximum abrasion distance in the Tanjung Bastian area of Oesoko Village.

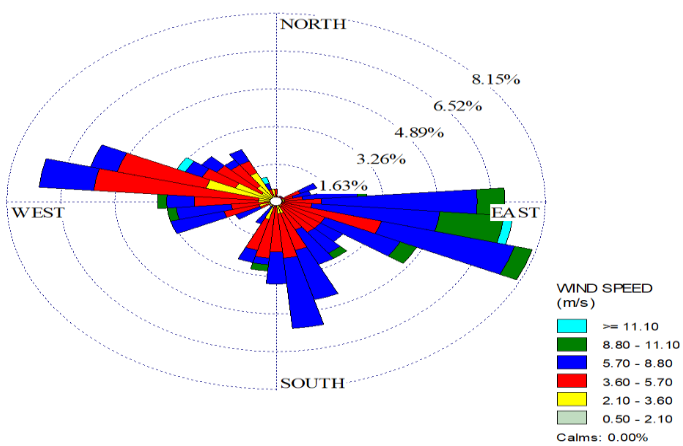

Fig. 10: Windrose area on the north coast of Timor Island.

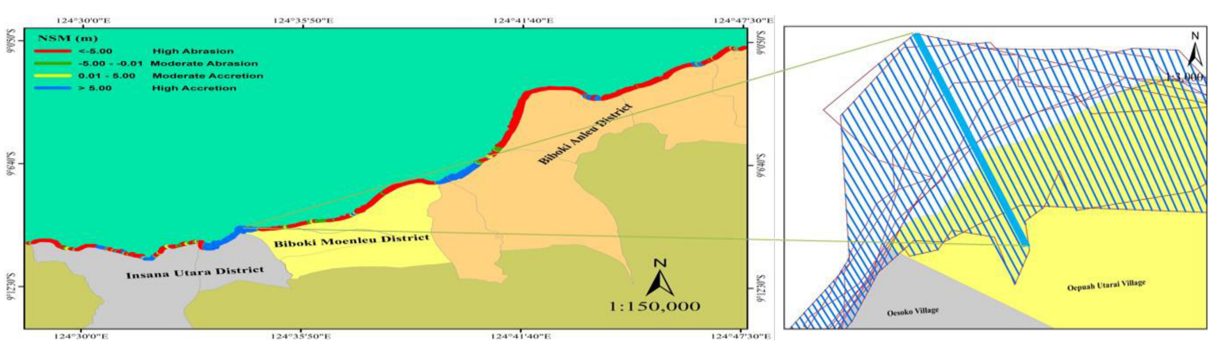

Fig. 11: Changes in the maximum distance of accretion on the coast of North Oepuah.

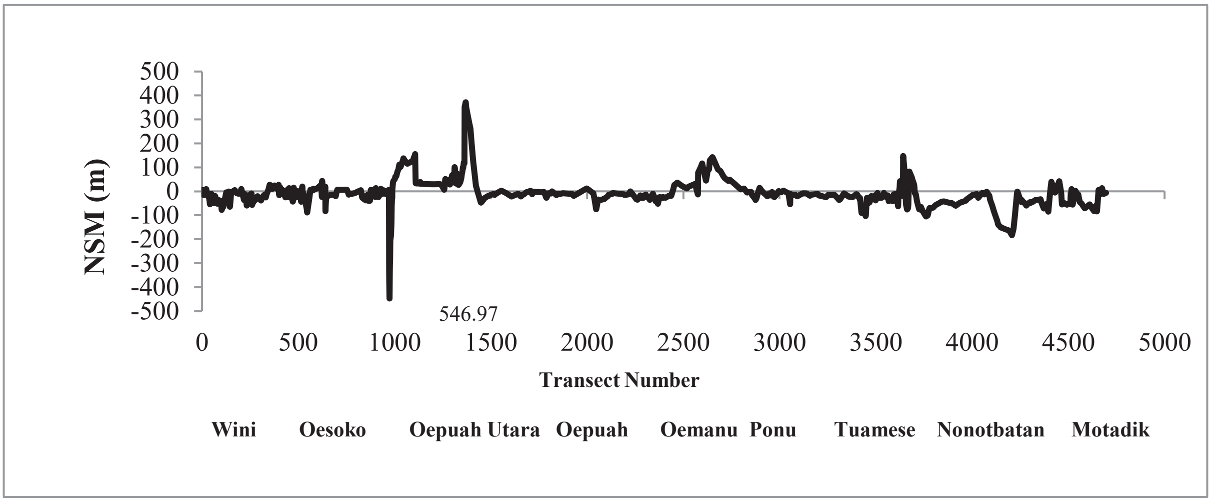

Fig. 12: Dynamics of change in shoreline distance observation 1990-2021.

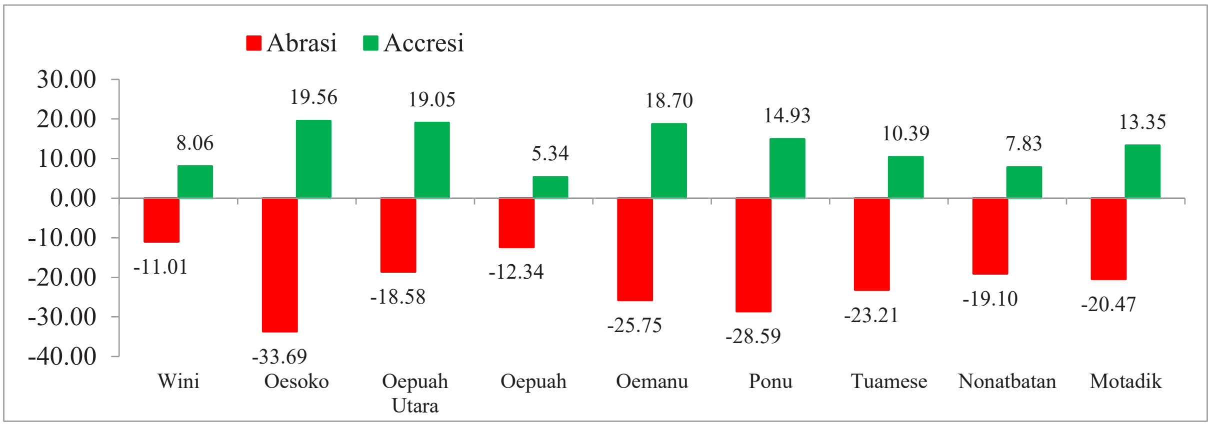

Fig. 13: Average rate of change for 1990-2021.

experience abrasion, which allows sediment to enter due to the force of currents generated from tides and waves. The dynamics of changes in shoreline distance using the NSM method are presented in Fig. 12.

The shoreline distance due to abrasion on the coast of Oesoko underwent a very extreme change of 546.97 meters (Fig. 8). This is due to the high rate of change at that location. The EPR method analysis shows that the maximum average rate of abrasion changes occurs on the Oesoko coast, which is 33.69 m/ year, followed by the Ponu coast, 28.59 m.year^{-1} Fig. 13.

CONCLUSION

Based on the observations of satellite imagery during 1990 - 2021, the north coast of NCT Regency generally experiences the dynamics of change, both abrasion and accretion. The average area of accretion is 1108.07 m² with a rate of change of 20.19 m.year^{-1} occurring along 1021 m, while the average abrasion area is 845.43 m² with a rate of change of 12.65 m.year^{-1} occurring along 36520 m. The average distance of the shoreline change in accretion conditions is 11.3 m, while abrasion is 7.93 m. The distance to the shoreline changed due to the highest abrasion that occurred in Ponu, namely -16.08 m resulting in an area of 1642.77 m² with a rate of change of 27.33 m.year^{-1}, while the shift in distance due to abrasion of 35.63 m resulted in an area of 4713.3 m² with a rate of change of 31.17 m.year^{-1}.

In general, the area that experienced the greatest change in abrasion distance was Oesoko Beach, especially in the Bastian Cape area, with a shift reaching 549.97 m. The maximum accretion shift of 467 m was found on the North Oepuah beach. This research indicates that the north coast of NCT Regency has experienced a significant increase in land area in the estuary. However, there is still the potential for an increase in abrasion area as, in general, the overall flat topography of the North Coast still influences it. The results of the research will contribute to decision-making for coastal management planning for NCT Regency.

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