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Using Geospatial Techniques to Assess the Effect of Anthropogenic factor of Urbanization on shoreline Shift in a 22km Coastline section of Bonny Island Rivers State Nigeria

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Abstract
Over the years, coastal population has been on the increase. This is so because of attractions such as tourism, commerce, recreation etc. among others. But these attractions have only exposed the coastal populace to various environmental risks such as flooding, intrusion of saltwater into freshwater and other negative impacts because of shoreline shift. Even though GIS and Remote Sensing have been successfully applied in assessing shoreline changes overtime, the shoreline change trigger factor of urbanization which defines the rise in the coastal population cannot be ignored. Therefore this study was aimed at assessing the effect of the anthropogenic shoreline change trigger factor of urbanization on shoreline shift on the coastline of Bonny Island Rivers State Nigeria using available geospatial techniques. The methods used included GIS and remote sensing, were Landsat imageries were sourced from 2000-2021 at five year intervals (2000, 2005, 2010, 2015 and 2021), and analysed using linear regression in the DSAS V4.5 and ArcGIS 10.5 environment. Furthermore, a Land Use Land Cover (LULC) operation was carried out in the study area to determine how the land use, especially urbanization has been triggering shoreline shift. Results from the linear regression analysis showed that there has been a dominant scenario of 67.2% accretion over the 21year period studied at an annual maximum erosion and annual maximum accretion rate of -7.4m and 7.9m respectively, with a 15,061.11m section of the shoreline being accreted, and 7338.89m section eroded. Furthermore, the result of the LULC showed that from 2000-2021, built up area, has increased from 8.2% to 11.8%, as the increase noticed in the Finima Beach area accounts for the 32.8% eroded 7338.89m shoreline. Therefore this study stated that urbanization is the main shoreline trigger factor in the study area, as areas such as Ifoko and Ngalaka which still had their natural habitat, had experienced accretion over the Finima Beach area which had eroded because of increase in human activities noticed overtime. Therefore, this research provided projected coordinates of shoreline position by the year 2031, and made appropriate recommendations such as; to establish/strengthen sea defences in the Finima Beach area, and for government to provide laws that protect the environment especially in areas such as Ifoko and Ngalaka, which still had their natural habitat.

Keywords: Urbanization, Shoreline Shift, Accretion, Erosion, Coastline, Land Use, Land Cover, Linear Regression

1. Introduction

The coastal area is a highly attractive prospect because of benefits such as commerce, recreation, tourism, and aquaculture among others; According to the UXL 2018 encyclopaedia of Weather and Natural Disasters which states that almost two-thirds of the U.S. population lives in states along the three major coasts; 38% along the Atlantic Ocean, 16% along the Pacific Ocean coast, and 12% along the Gulf of Mexico. While a 2010 United Nations Publication states that about 44% of global population lives within 150km to the sea. Also, Hunt and Watkiss (2011) [9] states that over 50% of the global population and 65% of cities with population of over five million people are in the coastal zone. The attractiveness of these coastal area is one of its major features, also including its highly dynamic environment with many physical processes such as tidal flooding, sea level rise, land subsidence and erosion/sedimentation.

Ekong (2017) [5]; this erosion and sedimentation is evident in coastline (shoreline) changes which is a constant in every coastal area. There has been various renditions for the definition of shoreline/coastline shift, but what has remained constant in these definitions is loss of land area to water and movement of land and water boundary line. Shoreline shift is a major problem globally, especially in coastal areas, with various studies such as (Zuidam *et al*. 1998; Mills *et al*. 2005; Marfai *et al*. 2008; Ryabchuk *et al*. 2012; Mujabar and Chandrasekar 2013) [25, 17, 16, 23, 20] carried out on the landform of coastal areas. A shoreline can either go through the process of erosion or accretion, with negative effects such as; coastal flooding, erosion, intrusion of saltwater in freshwater etc. among other impacts. These effects put the ever increasing coastal populace at risk. It is important to note that Shoreline shift cannot be hindered, but efforts can be made to predict future positions, thereby managing its various effects to protect the environment. This management process is known as Shoreline Management/Monitoring. It is necessary to monitor shoreline shifts and its variation through space and time, because the coastal areas will keep attracting human settlement, and this monitoring process involves an understanding of shoreline change triggers, were studies such as (Mirza, 2002; Carvalho and Wang, 2018; Huong and Pathirana, 2013; Mousavi *et al*, 2009; He *et al*, 2022) [19, 8, 18, 7] attributes Climate Change, Global Warming, Sea Level Rise, Urbanization etc. among others as some shoreline trigger factors. Also, Bamunawala *et al*., 2021 states that the collective impacts of climate change (sea level rise, temperature, and precipitation) and anthropogenic influences (urbanization) will trigger 90% of global shorelines to retreat. From which we can deduce that shoreline trigger factors could be unique for any geographic location. But this study focuses on the anthropogenic factor of urbanization in triggering shoreline shift.

Urbanization describes a conversion; where natural habitats are converted to cities and metropolitan areas through infrastructural development, land reclamation, population increase and migration etc. thereby creating urban areas. Urbanization is usually an attraction and has its benefits especially in the economy (industrialization) of any country. Countries all over the world today, are undergoing rapid urbanization; The United Nations projects that nearly all global population growth from 2017-2030 will be cities, with about 1.1 billion new urbanities over the next ten years (Cohen, 2015). But the downsides of Urbanization is usually its effects to the environment, with flooding one of the major environmental effects of Urbanization. Furthermore, deforestation is a key pathway to Urbanization, were heavy machineries are used to convert forested lands and trees to deforested lands. Common advantages of deforestation include; urbanization, usable land for agriculture, provision of woods etc. while its disadvantages include drought, soil erosion, desertification, exposure to increasing greenhouse gases in the atmosphere etc. among other disadvantages. Shoreline shift is also a major cause of Deforestation, because as the forests are being converted, it makes the soil holding water loose, thereby slowing water movement, and enhancing water collection that inundates any area. As Urbanization increases today, likewise deforestation is also on the increase, and in the same way exposing coastal residents to the effects of shoreline shift. Therefore, this study was aimed at using available geospatial methods to assess the effect of anthropogenic factor of urbanization on shoreline Shift along the coastline section of Bonny Island Rivers State Nigeria from 2000-2021

To achieve this aim, the following objectives were pursued;

1. To determine the progressive movement (erosion and accretion) of the of Bonny Island coastline from 2000-2021.
2. To determine the rate at which the shoreline is changing using Linear Regression.
3. To carry out a Land Use Land Cover assessment from 2000-2021 to determine the effect of urbanization on the Bonny Island coastline
4. To provide appropriate recommendations and a projected shoreline position by the year 2031.

2. Study Area

The study area was focused on the Bonny Island coastline. The coastline of Bonny Island is along and part of the Rivers State coastline which is part of the eight states which make up the Nigerian coastline as can be seen in *Fig 1a*, which includes Lagos, Ondo, Edo, Delta, Bayelsa, AkwaIbom State and Cross River States. Rivers State is located within Latitude 04° 43'N and 5°13'N, Longitude 6° 7°01'E and 06° 44'N with a coastline length of about 143km, and bounded to the North by Imo, Abia and Anambra States, to the East by Akwa Ibom State, to the West by Bayelsa and Delta states and the South by the Atlantic Ocean as can be seen in *Fig 2a*. This Study concentrated on Bonny Island as can be seen in the maps in *Fig 1b* showing Bonny Island relative to Nigeria, Niger Delta and Rivers State which lies within Latitude 04^0 25' 03".98, 04^0 22' 38".04 and Longitudes 007^0 19' 49".53, 007^0 12' 39".63 and is bounded to the West by Bille, to the East by Okirika and to the North by the Atlantic Ocean. From a Google Earth imagery, it was discovered that Bonny Island has a coastline length of up to 22km cutting across four (4) communities including; Ifoko, Finima, Ebongon and Ngalaka as can be seen in the Google Earth Image in *Fig 1c*.

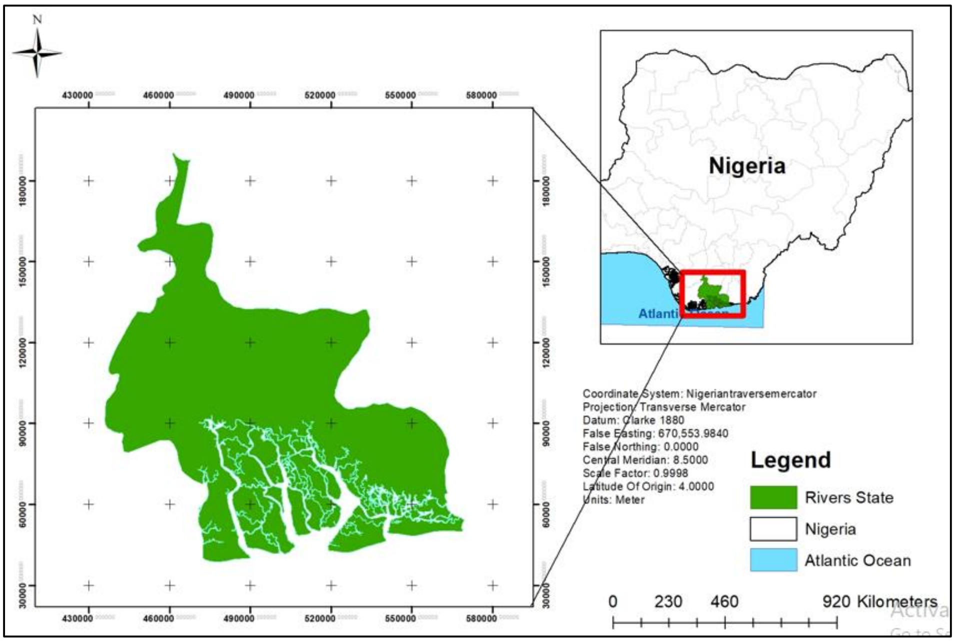

Fig 1a: A Map of Rivers State along the Atlantic Ocean. Source: Adebola *et al*. 2017

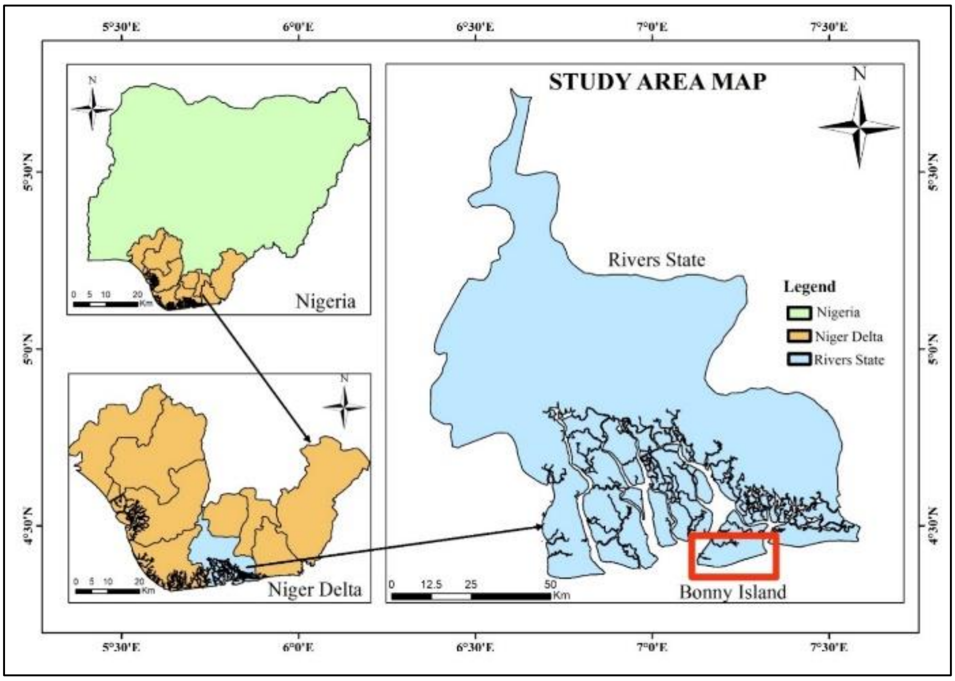

Fig 1b: A Map of Bonny Island relative to Nigeria, Niger Delta and Rivers State

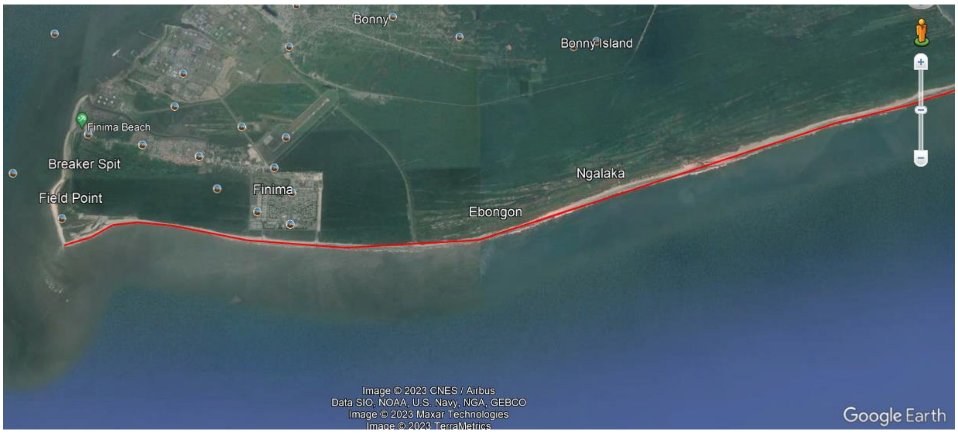

Fig 1c: A Google Earth Imagery showing 22km Bonny Island coastline (in red) and communities along the shoreline

3. Methods

Generally the methods used to achieve this aim employed both remote sensing and statistical methods. This section outlines the process.

3.1. Data Acquisition

Shoreline Data was acquired from remotely sensed Landsat satellite images, which were acquired for five (5) different timelines 2000, 2005, 2010, 2015 and 2021, so as to adequately estimate rate of annual change along the 22km shoreline using Linear Regression Rate. Landsat 7 was used to download for 2000, 2005 and 2010 timelines, while Landsat 8 was used to download 2015 and 2021 timelines. All images acquired from both Landsat 7 and Landsat 8 were all acquired at 30m resolution. All coordinates on the shoreline were acquired in WGS 84 coordinates. Furthermore, a Land Use Land Cover assessment was carried out using the downloaded imageries, so as to assess change over the period of 2000-2021. This was carried out in the ArcGIS 10.5 environment.

3.2. Data Processing

Data was processed using ArcGIS 10.5, QGIS 3.2 DSAS v.4.5 and Microsoft Excel. Digital Image Processing (DIP) operations such as; Band Combination to combine the different bands to one composite band. Scan Line error fix using QGIS 3.2 to de-strip lines which were blocking features on the imagery and Image Enhancement to increase the pictorial peculiarity of the acquired satellite image. The shoreline on the images of the different timelines were extracted and digitized in the ArcGIS 10.5 environment using the High Water Line (HWL) method Ekong, (2017) [5]; Appeaning Addo *et al*. (2011) [2]. *Fig 2a* shows the extracted shorelines for the five different timeline processed in the ArcGIS environment. Furthermore, to determine annual rate of change, Weighted Linear Regression (WLR) and Linear Regression Rate (LRR) statistical methods were applied using DSAS v.4.5 in the ArcGIS 10.5 environment. This involved a baseline with transects cast on the baseline at spacing of 50m in the entire 22km shoreline on the five different shorelines as can be seen in *Fig 2b* for WLR and ***Fig 2c*** for LRR. From the WLR map in *Fig 3.2b*, the numerical rate of erosion or accretion was estimated, while from the LRR map in *Fig 3.2c* the level of erosion/accretion was estimated.

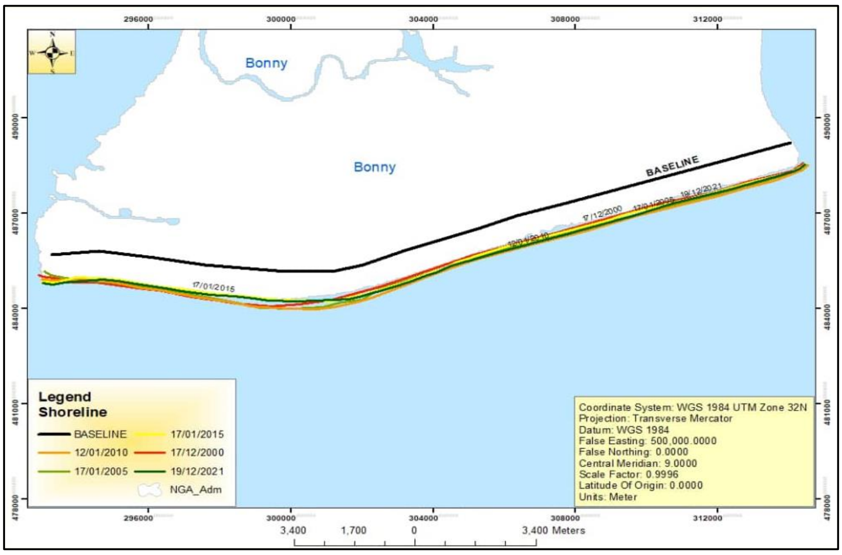

Fig 2a: Extracted shorelines for the 5 timelines in ArcGIS environment

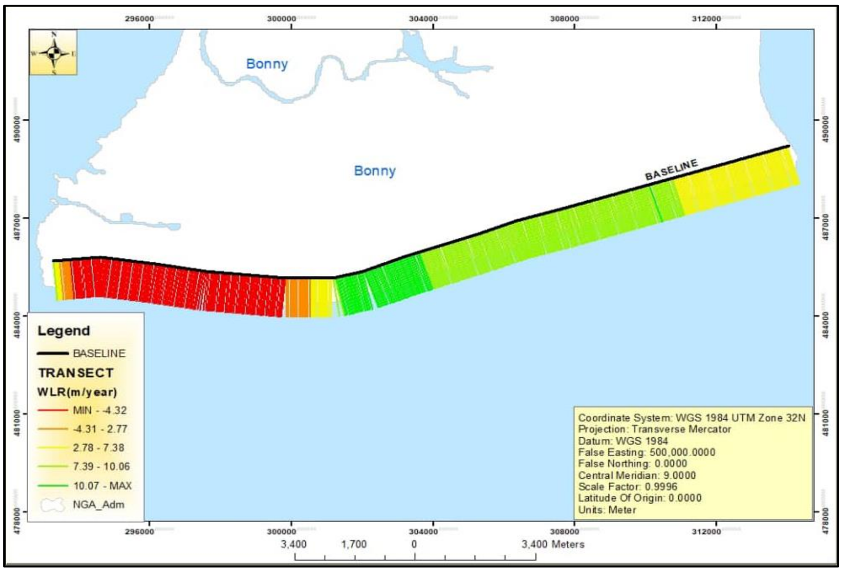

Fig 2b: WLR map showing rate of erosion/accretion along the shoreline for the 5 timelines

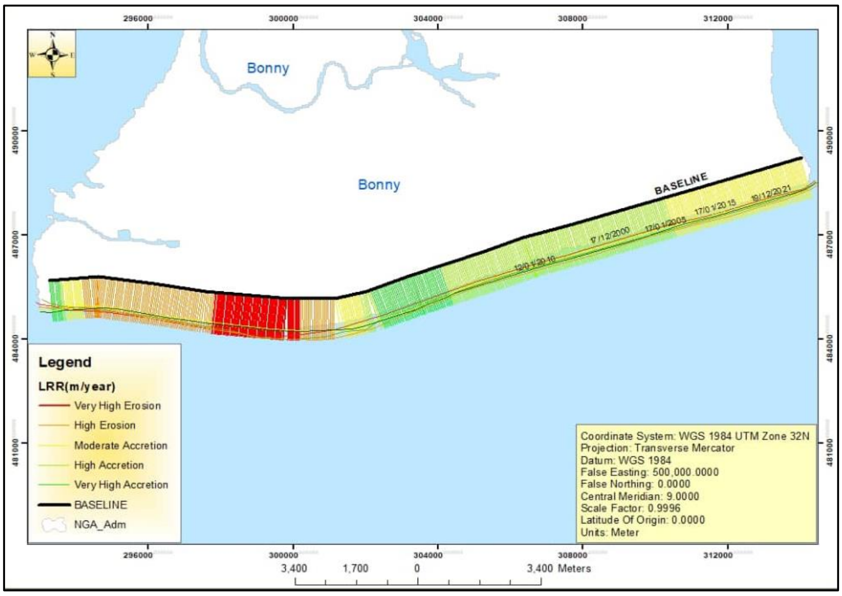

Fig 2c: LRR map showing level of erosion/accretion along the shoreline for the 5 timelines

4. Results and Discussion

4.1. Results

Results showed a total shoreline length of 22,435.049m (22.4km), covering four different communities including Ifoko (7.4km), Ngalaka (5.9km), Ebongon (2.6km) and Finima Beach (6.5km). Furthermore, using Weighted Linear Regression (WLR) and LRR (Linear Regression Rate) statistical, the rate at which the 22.4km shoreline has changed was estimated for Four (4) epochs from 2000-2021, as can be seen in Table 4a and Table 4b. Results showed that there has been a dominant scenario of accretion in the 21year studied; also there has been an annual maximum erosion and annual maximum accretion of -7.4m and 7.9m respectively on the shoreline as seen in *Table 1a*. Also, *Table 1b* showed that a 7338.89m section of the shoreline has eroded, while a 15,061.11m section of the shoreline has accreted with a 32.8% and 67.2% erosion and accretion rate respectively.

Table 1a: Statistical result of shoreline change in the study area

Epoch	Period	Total Distance (m)		Erosion (m/yr)		Accretion (m/yr)		Remark
		Erosion	Accretion	Mean	Max	Mean	Max	
All	2000-2021	-7338.89	15,061.11	-154.9	-7.4	165.9	7.9	Accretive
Epoch 1	2000-2005	-5855.90	16,344.90	-134.9	-26.9	102.2	20.5	Dominantly Accretive
Epoch 2	2005-2010	-3357.01	19,043.03	-10.1	-2.0	106	21.1	Dominantly Accretive
Epoch 3	2010-2015	-21,139.60	740.10	-111.95	-22.4	39.5	7.8	Dominantly Erosional
Epoch 4	2015-2021	-550.05	21,850.04	-13.60	-2.7	62.2	12.4	Dominantly Erosional

Table 1b: Statistical result of shoreline change in the study area

Epoch	Period	Total Distance(m)		Percentage (%)	
		Erosion	Accretion	Erosion	Accretion
All	2000-2021	-7338.89	15,061.11	32.8	67.2
Epoch 1	2000-2005	-5855.90	16,344.90	26.1	73
Epoch 2	2005-2010	-3357.01	19,043.03	15	85
Epoch 3	2010-2015	-21,139.60	740.10	94.4	3.3
Epoch 4	2015-2021	-550.05	21,850.04	2.5	97.5

4.1.1. Land Use Land Cover (LULC)

In the supervised classification carried out on the imageries in the ArcGIS 10.5 environment; the study area was classified into majorly built-up area, vegetation and water body, so as to determine how the land use was causing shoreline shift along the 22.4km Bonny Island coastline. The results showed as can be seen from *Table 2* and the histogram in *Fig 3a* that from 2000-2021 in the study area, Water Body has gone from 37.8% to 30.1%, while Vegetation and Built-up area has increased from 48.7% and 8.2% to 56.4% and 11.8% respectively. *Fig 4b* shows the LULC for year 2021 as produced in the ArcGIS 10.5 environment.

Table 2: Results of LULC in the Study Area

S/N	Land Class	Epoch (%)				
		2000	2005	2010	2015	2021
1.	Water Body	37.8	35.1	36.1	35.2	30.1
2.	Vegetation	48.7	38.6	53.3	54.8	56.4
3.	Built-up Area	8.2	9.9	9.6	11.7	11.8
4.	Others	2.6	3.5	3.5	2.3	2.3

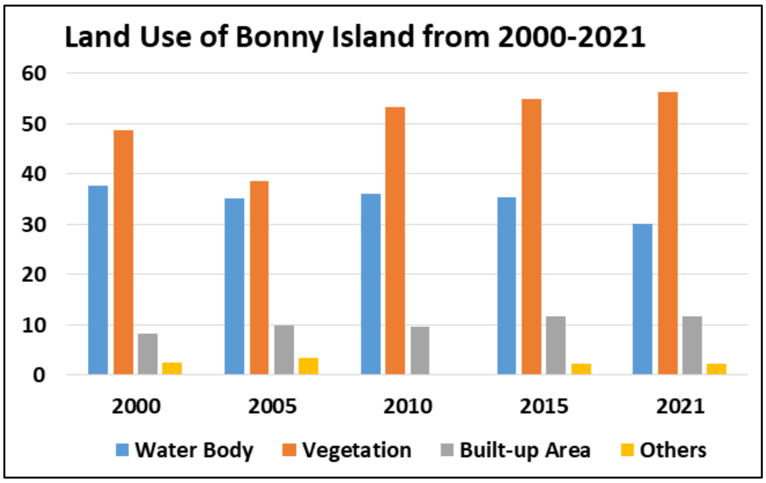

Fig 3a: Histogram of LULC of the Study Area

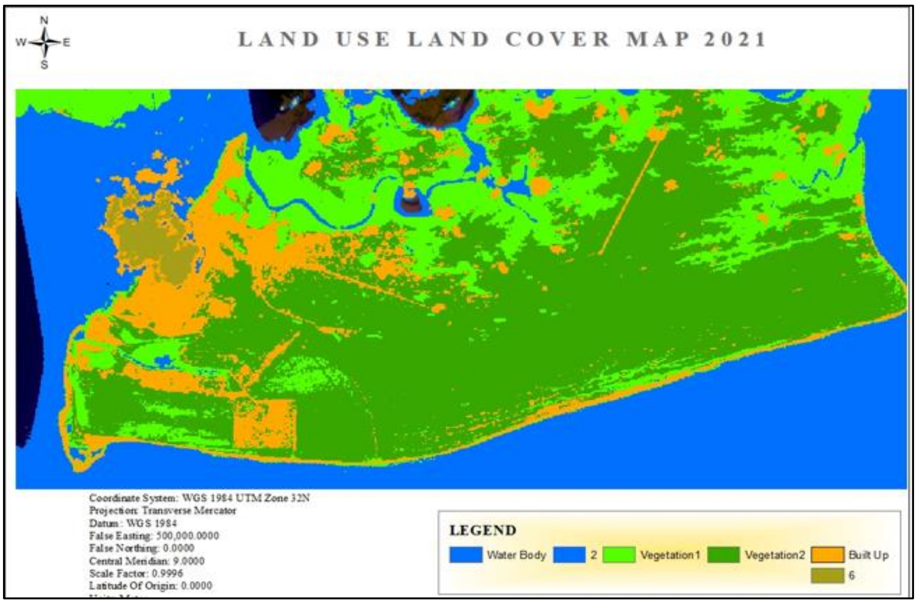

Fig 3b: A 2021 Land Use Land Cover map of the Study Area

4.2. Discussion

Considering the 2021 LULC map in *Fig 3b* and the rate of shoreline change in *Table 4a* and *Table 4b*, we can deduce that the 8.2% to 11.8% increase in built up area has occurred mainly in the Finima Beach area, which had lost over 200m of shoreline within the study period of 2000-2021, with its major area of shoreline loss being the NLNG residential area, covering a total shoreline length of about 7286.323m (7.3km), within Latitude $N04^0$ 22' 48".83, 04^0 23' 03".3 and Longitude $E007^0$ 12' 27".33, 007^0 08' 30".99. Also, the WLR and LRR maps showed that 67.2% accretion had occurred mainly in Ifoko, Ngalaka and Ebongon covering a shoreline length of 15,061.11m. It is important to note that these area which had undergone accretion within the study period from 2000-2021, still had its natural vegetation and little to no human activity was noticed in those area. Therefore, it was deduced that urbanization is the predominant shoreline shift trigger factor in the study area. This is so because deforestation, which is the pathway to urbanization has exposed the soil and made it pervious to water, therefore triggering shoreline shift in the study area especially in the Finima Beach area.

Furthermore, using a WLR and LRR estimated rates of shoreline change in the study area, a prediction of the shoreline position was estimated for the year 2031. Where it is expected that the Ifoko, Ngalaka and Ebongon is expected to accrete more considering the 67.2% accretion rate, the Fininma Beach Area is more at risk, with the NLNG residential area projected to be at a maximum of about 160m and a minimum of about 75m to the shoreline by the year 2031. *Table 4.2* shows Universal Traverse Mercator (UTM) Zone 32N coordinates of the 22.4km shoreline position by the year 2031.

Table 4.2: Coordinates of shoreline position by the year 2031

S/N	Eastings	Northings	Description	Location
1	314456.345	488445.285	Shoreline	Ifoko
2	313060.941	487859.925	Shoreline	Ifoko
3	311126.633	487331.894	Shoreline	Ifoko
4	310201.209	486948.785	Shoreline	Ifoko
5	307900.783	486224.396	Shoreline	Ifoko
6	306702.940	485836.372	Shoreline	Ngalaka
7	304757.244	485231.795	Shoreline	Ngalaka
8	302421.559	484386.597	Shoreline	Ngalaka/Ebongon
9	301782.862	484205.653	Shoreline	Ebongon
10	301626.116	484179.022	Shoreline	Ebongon
11	301128.264	484276.245	Shoreline	Ebongon
12	299867.167	484370.950	Shoreline	Ebongon
13	298885.177	484522.315	Shoreline	Finima Beach
14	298362.399	484610.636	Shoreline	Finima Beach
15	297882.652	484572.143	Shoreline	Finima Beach
16	295883.018	484852.287	Shoreline	Finima Beach
17	295086.444	485079.694	Shoreline	Finima Beach
18	294145.103	484887.905	Shoreline	Finima Beach
19	293891.955	484869.737	Shoreline	Finima Beach
20	293279.206	484563.253	Shoreline	Finima Beach
21	293008.680	484600.700	Shoreline	Finima Beach

5. Conclusion and Recommendation

This situation of human activities triggering shoreline erosion in the Finima Beach area, gives credence to Bamunawala *et al*., 2021 who states that anthropogenic factors such as urbanization among other factors would trigger 90% of global shorelines to retreat. Even though various other studies such as Adebola *et al*, 2017; Okwere *et al*, 2022; Okude and Taiwo, 2006; Fashae and Onafeso, 2011 [1, 22, 21, 6] among others have attributed climate change and global warming to the resultant shifting shorelines to previous land space, this study showed that urbanization has been the major trigger of shifting shorelines into previous land space especially in the Finima Beach Area. This so because areas such as Ifoko, Ngalaka and Ebongon which had experienced more accretion than erosion still had its natural habitat throughout the period (2000-2021) studied. Finally this Study provided coordinates that predicts the position of the 22.4km Bonny Island coastline by the year 2031 as seen in Table 4.2, which could serve as a guide to planners for efficient decision making. Furthermore, the following recommendation has been provided;

1. It is important to establish/strengthen sea defences especially along the shoreline of the Finima Beach area within the years 2023-2025 as the 2031 predicted map suggests that positions of shorelines are going to be at a minimum of 75m to the nearest structure which is the NLNG residential area. This 2031 shoreline position is predicted and does not take into consideration rising sea levels.
2. It is also recommendable to provide a workable environmental plan of the entire study area that monitors and controls human activities, which are yet to be noticed in communities such as Ifoko, Ngalaka and Ebongon, as the movement in shoreline position noticed in the Finima Beach area can be attributed to the human activities in that 7.3km area.
3. It is also recommendable to setup tide gauges which monitors sea levels in the study area, so as to put into consideration the year 2100 1m sea level rise projections by the International Panel on Climate Change (IPCC, 2001; IPCC, 2007; IPCC, 2012; IPCC, 2013) [10- 15].

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