Ethiopian Journal of Environmental Studies and Management EJESM Vol. 5 No. 2 2012

SPATIO-TEMPORAL ANALYSIS OF SHORELINE CHANGES IN BONNY ISLAND, NIGERIA

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DOI: http://dx.doi.org/10.4314/ejesm.v5i2.2

Received 5th December 2011; accepted 28th February 2011

Abstract

The study examined the shoreline changes over time in Bonny Island of Rivers State, Nigeria. Satellite images comprising of Landsat TM of 30m by 30m of 1986, 2001, 2003 and 2006; and Nigersat image of 30m by 30m of 2004 were used as the sources of data. The satellite images underwent series of geo-processing. The bands (red, blue and green) of each image were combined using Erdas Imagine 9.0. The images were imported to ArcGIS 9.2 whereby the shoreline from each image was digitized as polylines. The shoreline of 1986 was overlaid on that of 2001, shoreline of 2001 was overlaid on 2003, 2003 on 2004 and that of 2004 on 2006. Thereafter, overlaid maps were converted to polygons using Features to Polygon module of ArcGIS 9.2. The polygons were grouped to advanced (land gained) or retreat (land lost) with which spatial query was done. The result revealed that Bonny Island lost about 1793.24 km^2 of land while 419.31 km^2 was gained between 1986 and 2001 whereas between 2001 and 2003; 1246.46 km^2 was lost while 1200.43 km^2 of land was gained. During the period between 2003 and 2004, the analysis showed that 858.47 km^2 was gained while 3408.68 km^2 was lost whereas between 2004 and 2006, the 2460.30 km^2 of land advanced seaward while 2450.03 km^2 of land was lost. The percentage change was highest between 1986 and 2001 with 76.62% of land loss. The study recommended periodic monitoring of the coastal area on monthly and yearly bases.

Keywords: *Shoreline, GIS, Remote sensing, Bonny Island, Water transport, ArcGIS 9.2, Erdas Imagine*

Introduction

A shoreline is a dynamic system with sediment moving continually, being deposited here and eroded there, as the shoreline attempts to establish an equilibrium with respect to available sediment budget and prevailing near-shore marine processes (Poulos and Chronis, 2001). Shoreline change monitoring is an issue of concern in coastal management because of the tendency of the ecosystems to support many population (Moran, 2003) in which the Niger Delta area is not exceptional. Traditional approaches to the study of shoreline dynamics are based on temporal scales either addressing long-term or short-term coastal changes. Moran (2003) submitted that long-term changes occur over periods such as decades or centuries, while short-term changes refer to movements occurring from over a season to a few years. Meanwhile, Braatz *et al.,* (2006) believed that shoreline changes may occur in response to smaller-scale (short-term) events such as storms, regular wave action, tides and winds, or in response to large-scale (long-term) events such as glaciations or orogenic cycles that may significantly alter sea levels (rise and fall) and tectonic activities that cause coastal land subsidence or emergence.

Braatz *et al.,* (2006) observed that shoreline changes induced by coastal erosion and accretion are natural processes. However, they have become anomalous and widespread in the coastal zone of African countries owing to combinations of various natural forces, population growth and unmanaged economic development along the coast, within river catchments and offshore. According to Griffiths (1988), the coastal zone is increasingly under pressure from human activities such as fishing, coral and sand mining, mangrove harvesting, seaweed farming, sewage disposal, urban expansion and tourism. Of particular note are dynamite fishing, over-harvesting of mangroves, coral and sand mining, all of which have profound negative impacts on coastal stability and are thought to lead to coastal erosion and shoreline

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change. Among other human activities that impact coastline include dredging and physical development, mineral exploration, and construction of ports and removal of vegetation. The intensity of coastal erosion has been reported in Tanzania (Makota *et al.,* 2004), Nigeria (Adegoke *et al.,* 2010) and Asian countries like China, Japan, India, Indonesia and Vietnam (Braatz *et al.,* 2006).

Moran (2003) concluded that studies of long-term variations are better suited for large-scale coastal planning and management, since the decision makers' goal is to identify major trends over larger areas. Historical data are used to identify the segments along the coast where the shoreline has changed in order to give general trend of coastal advance or retreat over time, and the erosion or accretion rates which can be used to forecast future shoreline positions. The modeling of shoreline changes may be derived from the historical data that include topographical maps, aerial photographs and satellite images. These data can easily be combined and processed with the use of geographical information system (GIS) suggesting that shoreline change is best studied using GIS because of the its ability of combining and comparing satellite images of different time (years) of the same area. GIS is a unique integration or system of computer hardware, software, peripherals, procedural techniques, organizational structure, people and institutions for capturing, manipulating, storing, analyzing, modulating, modeling, and displaying of geographically referenced data for solving complex human-related problems (Fabiyi, 2002). Burroughs (1987) also viewed GIS as a tool for storing, manipulating and displaying large quantities of geographic information in a micro computer. There were traditional methods that incorporate local observations and basic surveying techniques have been used to monitor shoreline changes (Adegoke *et al*., 2010) and the use of mathematical models (Thach *et al*., 2007). The use of remote sensing and GIS for mapping and analyzing shoreline changes over a period of time has gained prominence in recent years as high resolution satellite data have become more readily available (Adegoke *et al.,* 2010). Yet in Nigeria, studies of shoreline changes over time and space are still very few especially with the use remote sensing and GIS. Monitoring and managing shoreline is very important especially with recent effects of climate change on sea level rise. This study therefore examines the spatio-temporal analysis of shoreline changes in Bonny Island with a view to highlighting the implications on the coastal transport.

Study Area

The study was carried out in Bonny Island of Rivers State, Nigeria. The area is located in the Niger Delta of Nigeria (Fig. 1a and 1b) and it is located on the latitudes between 8°22'N and 8°31'N and longitudes between 5°3'E and 5°19'E. The study area enjoys tropical hot monsoon climate due to its latitudinal position. The tropical monsoon climate is characterized by heavy rainfall from April to October ranging from 2000mm to 2500 mm with high temperature all the year round and a relatively constant high humidity. The relief is generally lowland which has an average of elevation between 0m and 20m above sea level. The geology of the area comprises basically of alluvial sedimentary basin and basement complex. The vegetation found in this area includes raffia palms, thick mangrove forest and light rain forest. The soil is usually sandy or sandy loam underlain by a layer of impervious pan and is always leached due to the heavy rainfall experienced in this area. The study area is well drained with both fresh and salt water. Due to continuous heavy rainfall and river flow, the study area experiences severe flooding almost every year.

Material and Methods

This study made use of satellite images of the study area. Landsat TM of 30m by 30m of 1986, 2001, 2003 and 2006; and 2001 and Nigersat image of 30m by 30m of 2004 were acquired for the study from National Space Research and Development Agency in Abuja (NASRDA). The satellite images underwent series of geo-processing in order to make them suitable for further analysis. The bands (red, blue and green) of each image were combined using ERDAS IMAGINE 9.0. The colour composite facilitates the interpretation of multi-channel image data by human eye. The images were then imported to ArcGIS 9.2 and geo-referenced to geographic coordinates of Universal Traverse Mercator (UTM) of Minna Datum (Zone 32N), using the same control points. Geo-referencing is important to prepare two or more satellite images for an accurate change detection comparison, it is imperative to geometrically rectify the imagery (Tardie and Congalton, 2001; Eludoyin *et al.,* 2011). This made it possible for all the images to align and overlay perfectly. The images were later imported to Arcview GIS 3.3 for enhancement and smoothening using the IMAGE ANALYST- an extension in ArcView GIS 3.3. This made it possible to obtain a sharp boundary between the land and ocean which served as the shoreline. Thereafter, the digitization of the shorelines in the images of each year was done in ArcGIS 9.2 as POLYLINES (Vector Data). The digitized shorelines of each year were subjected to spatial analyses.

The shoreline of 1986 was overlaid on that of 2001, shoreline of 2001 was overlaid on 2003, 2003 on 2004 and that of 2004 on 2006. This is called overlay analysis. Thereafter, overlaid maps were converted to polygons using FEATURES TO POLYGON module of ArcGIS 9.2. The result of the map then revealed those areas that were advanced or gained into the sea and retreated or lost to the sea. However, the area in square kilometers of either advanced or retreat of overlaid map was calculated and inputted into the relational database. The database was then queried using QUERY BUILDER (SQL) of ArcGIS 9.2 in order to group the polygons into advanced and retreat and the total sum of the area in square kilometers of the advanced (gain) and retreat (loss) were determined. Thereafter the percentage gain or loss of land was calculated for the overlaid maps (1986 and 2001; 2001 and 2003; 2003 and 2004; and 2004 and 2006). The results of the analysis were presented in tables, maps and charts.

Results and Discussion

The shoreline captured as line feature from satellite imageries were subjected to geographic analysis. The shorelines of 1986 and 2001; 2001 and 2003; 2003 and 2004 and that of 2001 and 2004 were overlaid. With this analysis, the path at which each shoreline passes gives a quick assessment of the advancement of land into water or retreated of water into the land. The two lines were converted to polygon using FEATURE TO POLYGON MODULE (Figs. 2, 3, 4 and 5). These polygons were formed at interceptions in the advanced land into the ocean and retreat into the land. The area of each polygon either advanced or retreat was calculated in square kilometer in each period under consideration. SPATIAL QUERY analysis was also carried out whereby the polygons belonging to either advanced or retreat were selected and grouped together and their area in square kilometers were summed together for each period (Table 1). This is done for the four periods under consideration and thus it is possible to monitor the changes that occurred between these periods and thus the rate of percentage loss and gain was calculated for the periods.

Table 1 above shows shoreline changes and change rate for each period. During the period between 1986 and 2001 the shoreline shifted seaward (advanced) with 419.31 km^2 while the shoreline shifted landward (retreated) with about 1793.24 km^2. As a result, 81.04% of land was lost. During the period between 2001 and 2003 the shoreline shifted seaward with 1200.43 km^2 while the shoreline shifted with about 1246.46 km^2, thus 1.88% of land was lost. Between 2003 and 2004, the shoreline shifted landward with 3408.68 km^2 while 858.46 km^2 shifted seaward. Finally, between 2004 and 2006, the shoreline shifted landward with 2450.03km^2 while the shoreline shifted seaward with 2460.30 km^2. Assessing the shoreline situation in the periods of consideration, it was observed that much landmass was lost within periods of 1986-2001 and 2003-2004 while very insignificant landmass was gained between 2004 and 2006.

It is therefore evident from the result of analysis that both coastal erosion and accretion are revealed in Bonny Island coastline. The coastline has been subjected to erosion over the years in Nigeria, scientist from the Nigerian Institute for Oceanography and Marine Research (NIOMR) have reported widespread erosion and flooding of the Barrier Islands and the Niger Delta (Ibe *et al.,* 1984; Awosika 1993) created erosion resulting from deficit of sand due to natural and anthropogenic activities varies in intensifies from area to area along the coastline. Notable among the natural causes of coastal erosion are vulnerable soil characteristically topography and occurrence of off shore canyons. Anthropogenic cause includes destruction of coastline dredging and dams of rivers. The impact of the intensity of wave affects the sedimentation level along the coast. The sedimentation transport makes shoreline to protrude and erode (Li and Chen, 2003). The issue of human activities was evident in the study area as the Western part of Bonny Island was greatly found to be retreating inland in all the periods considered. Locating Nigeria Liquefied Gas Company in this area is responsible for the erosion. In addition, this western part of Bonny Island may be exposed more to wave action. No wonder European Commission (2004) concluded that coastal erosion induced by human activities have surpassed in Europe coastal erosion driven by natural factors. Human-induced coastal erosion mainly proceeds from the cumulative and indirect impacts of small and medium size projects, as well as from river damming. The Bonny Island coastline undergoes erosion greatly and this shows that there is sediment loss in the area. Hart *et al*., (2008) submitted that sediment loss caused by erosion may eventually breach causing loss of another lagoon environment. Thus, if absolute care is not taken the seaport in the area will soon be flooded and rendered unusable and less functional. The net effect of shoreline changes in Bonny Island is to cause a high level of frustration and misery because people and businesses would need to relocate and new infrastructure would need to be provided.

Conclusion and Recommendations

The shoreline change in Bonny Island has been analyzed using the integrative approach of satellite imageries and GIS tools and it is revealed that the shoreline of the study area is being eroded due to natural cause and human interference. The study therefore recommends that dredging should be discouraged in the area, mangrove vegetation should be restored and protected, coastal and marine processes should be monitored for integrated management of degraded ecosystems and public enlightenment programmes should be organized periodically for the residents of Bonny Island to make them aware of the vulnerability of the area to sea level rise and adaptation measures that should be put in place.

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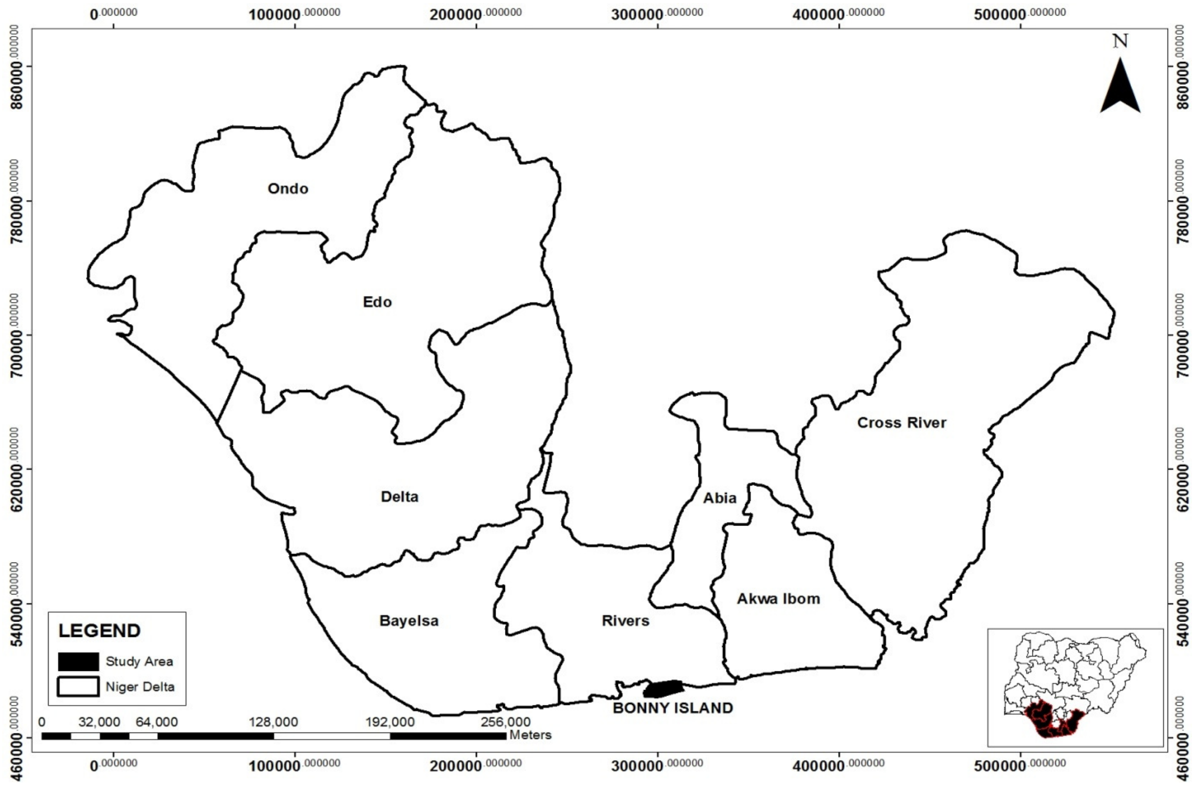

Figure1a Map of Niger Delta showing the Study Area

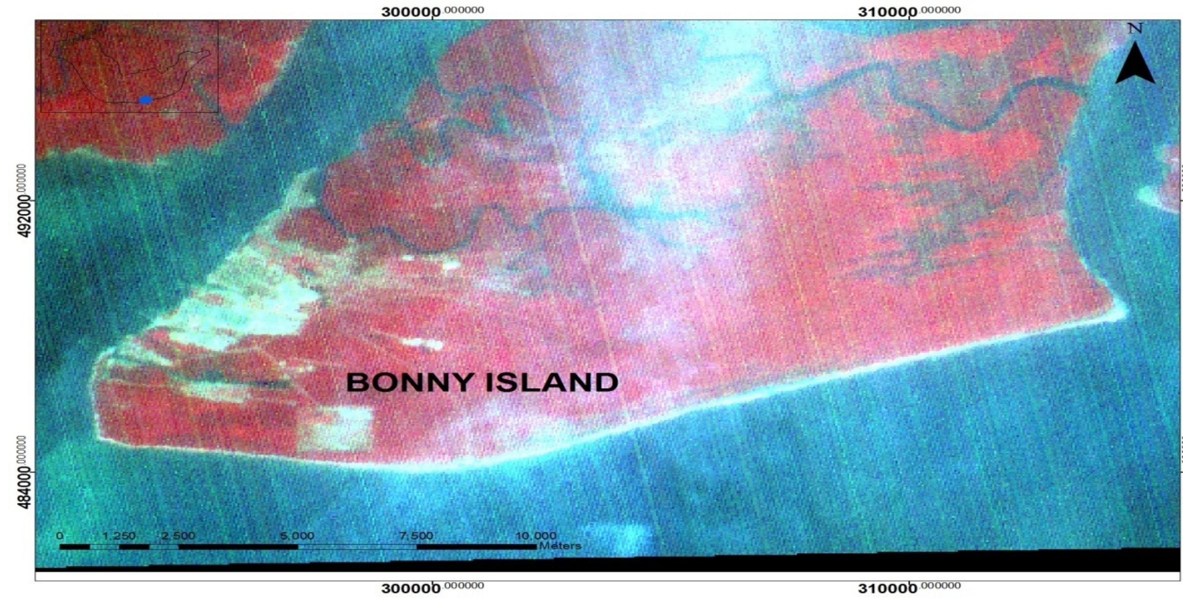

Figure1b Imagery showing the study area

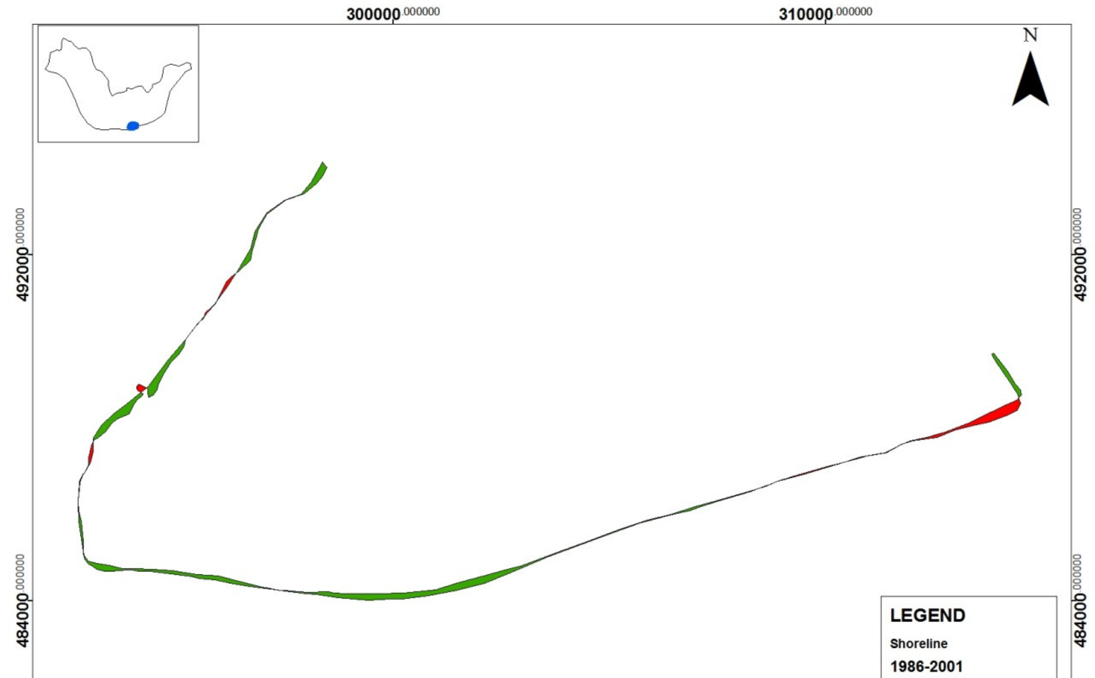

Figure 2 Shoreline changes between 1986 and 2001

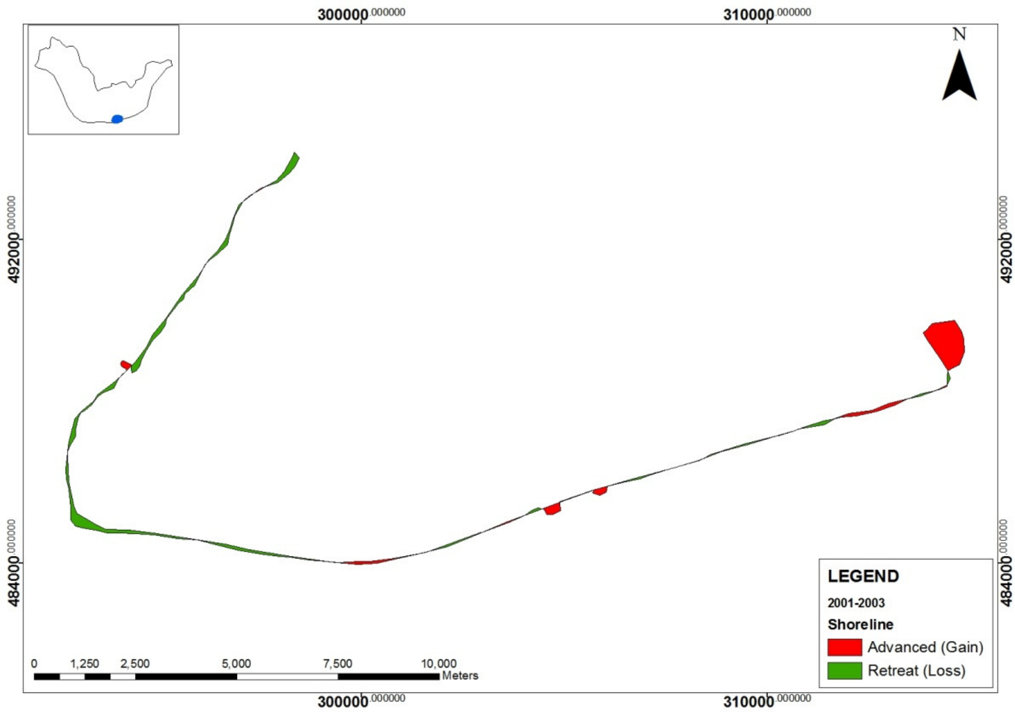

Figure 3 Shoreline changes between 2001 and 2003

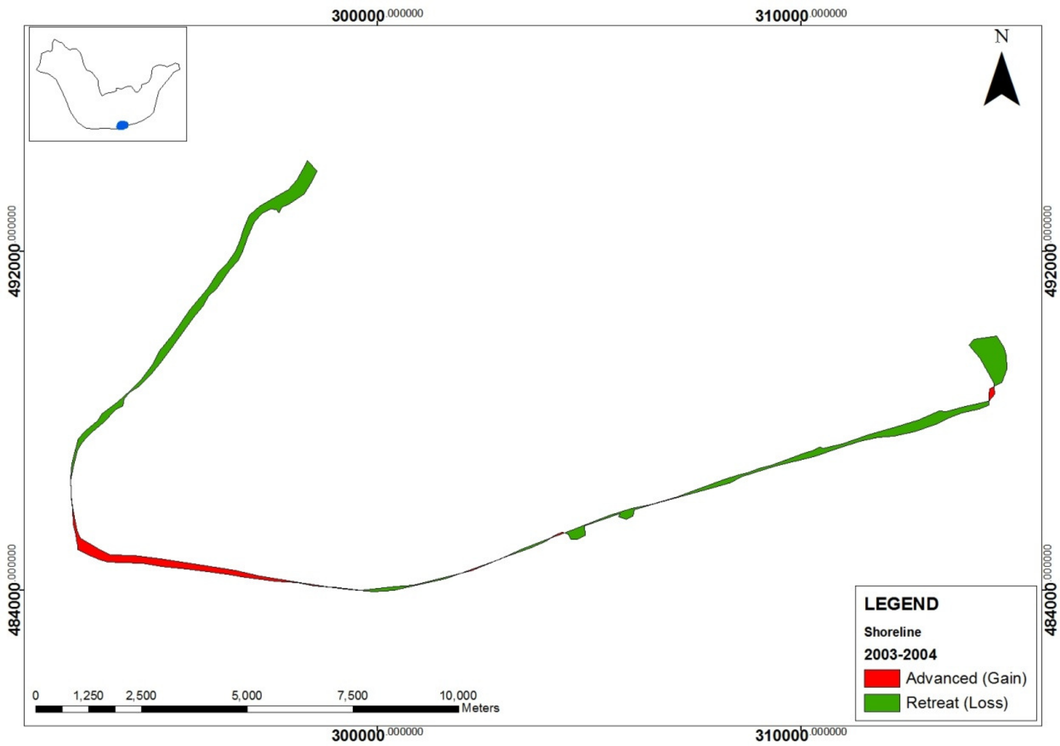

Figure 4 Shoreline changes between 2003 and 2004

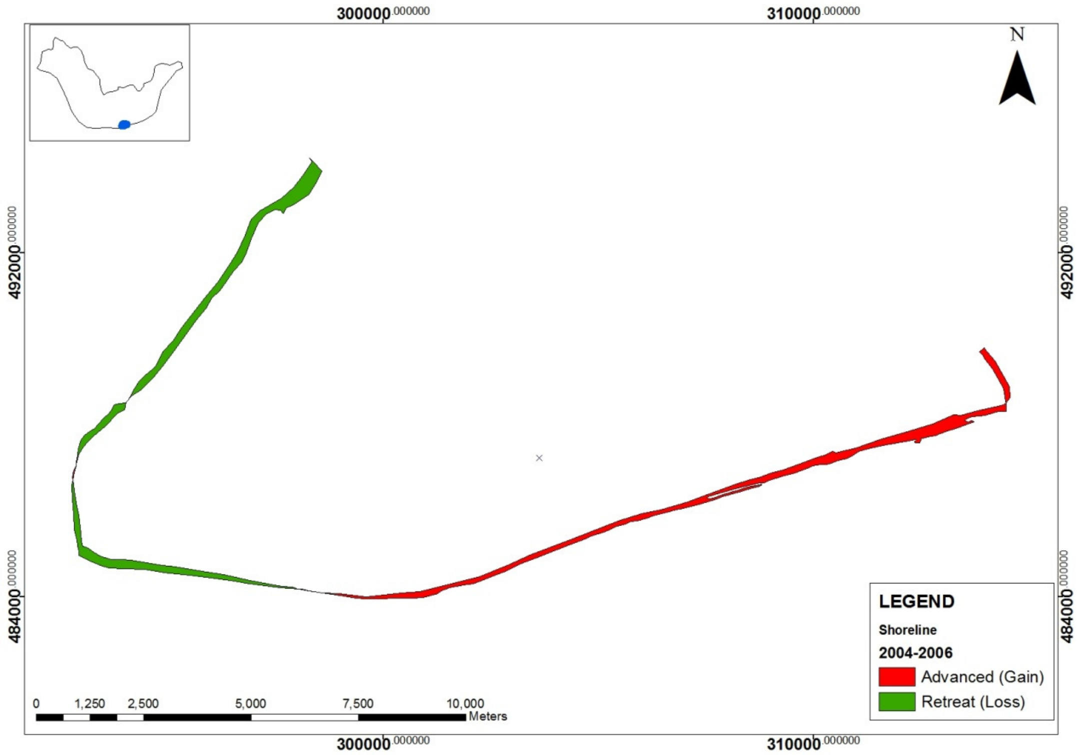

Figure 5 Shoreline changes between 2004 and 2006

Table 1 Spatio-Temporal Analysis of Shoreline Changes

Period	Advanced (Gain) (sq km)	Retreat (Loss) (Sq Km)	Total (Sq Km)	Shoreline Difference (Sq Km)	Percentage Loss or Gain (%)
1986-2001	419.31	1793.24	2212.55	-1793.24	-81.04
2001-2003	1200.43	1246.46	2446.89	-46.03	-1.88
2003-2004	858.46	3408.68	4267.14	-2548.22	-59.72
2004-2006	2460.30	2450.03	4910.33	10.27	0.21