Geospatial Analysis of Shoreline Dynamics in the Coastal Areas of Cross River State Nigeria

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Abstract
This study assesses shoreline changes, land use and land cover change, geomorphological changes of the coast as well as analyzes the coastal landforms with a view to generating baseline information for evolving informed decisions and policies for effective flood control and management. The study utilized multi-temporal satellite images namely, Landsat TM 1980, 1990 and Landsat 7 ETM+ 2010. Remote Sensing and Geographic Informtion System techniques were used to analyse the satellite images, shoreline and geomorphological maps were extracted. The land use classes identified from the image include vegetation, outcrops, grassland, water body and settlement. The land use classification indicates a gradual reduction in the grassland, increase in vegetation, water body and also an emergence of settlement in the year 2010. Grassland reduced from 247.65km^2 to 93.6km^{2,} vegetation increased from 6.60km^2 in 1990 to 135.3km^2 in 2010 and waterbody reduced from 98.75km^2 to 97.8km^2. The change detection image also illustrates that areas that witnessed increase are mostly water body and vegetation. Slope of the area also ranges from 0° to 12° with a stream order of 4. The shoreline length for the year 1980 was 71.60 km, 71.43 km in 1990 and 69.70 km in 2010. A gradual reduction of 0.17 km in length was noticed between 1980 and 1990 while a rapid reduction of about 1.724 km was recorded between 1990 and 2010. The shoreline change movement showed that between 1980 and 1990, the net shoreline movement was estimated 259 meters while the net shoreline movement between 1980 and 2010 was about 347 meters. The end-point rate also indicated the rates of erosion (424.96 meters) and accretion (277.5 meters) (loss and gain), suggesting higher increase in erosion over accretion. It implies apparent reduction of the shoreline on yearly basis due to low elevations that range from 0^0 to 6^0. The study advocates continuous monitoring of shoreline changes to reinforce our understanding and establishing the processes driving erosion and accretion in the coastal areas.
Keywords: Shoreline, Remote Sensing, Digital, Coastal dynamics, Accretion & Erosion

Introduction
Coastal zones are considered vital components of the global bio system as well as high biological productive regions that contain wealth of mixed species, genetically diversified habitat and filter pollutants that help to protect shorelines from erosion and storms (Nemani and Running, 1995; Yagoub and Kolan, 2006). These zones serve as major carbon sink and oxygen sources by way of regulating climate and global ecosystem. Coastal zones are found occuring at the interface between the three major natural systems at the earth's surface atmosphere, ocean and land surface. Processes operating in these systems are responsible for the shaping of the coastal zone. The interaction among the three different sets of processes makes the coastal zone an extremely dynamic one. The zone is also a zone of transfer of material from the land surface to the ocean system. The eroded sediments are often moved to the beach and near-shore, some to the ocean floor and accumulated sediments may add to the land mass in some areas (Davidson-Arnott, 2010).

Several studies have shown the effectiveness of remote sensing and GIS techniques in shoreline dynamics assessment. For example, Kumaravel *et al*. (2013) used a remote sensing based approach in shoreline change studies in Cuddalore District, East Coast of Tamil Nadu, India. The rates of shoreline changes were estimated by overlay analysis using GIS The study revealed that most of the study area has been undergoing erosion around 3.21km^2 for the past four decades and that both natural and anthropogenic processes along the coast modify the shoreline configuration and control the erosion, accretion activities of the coastal zones. In a related study, Ogoro (2014) carried out spatio – temporal analysis on changes in the geomorphic shoreline of Bonny Island. The showed that 1,819.4sq km, 4,588.38 sq km and 1,781.96 sq km of land were lost to sea between 1986 and 2001, 2001 and 2006, 2006 and 2011 respectively. In another study, Odunuga *et al*. (2013) conducted a geomorphic mapping and assessment of human activities along the southwestern Nigeria coastline. The paper identified various coastal landforms and anthropogenic activities in relation to ecosystem degradation and stability on the southwestern Nigeria coastline. In a similar study, Pandiaraj *et al*. (2010) utilized remote sensing to perform a study on coastal geomorphological landforms from Coleroon River Mouth to Cuddalore South Arcot, Tamil Nadu, India using aerial photographs and LANDSAT images.

Tomar and Singh (2010) utilized remote sensing as a tool in geomorphological mapping in land use planning around Shivpuri city, India. Landforms were interpreted on the basis of interpretation element keys namely such as- tone, texture, size, shape, color etc. and extract the specific information from the false color composites LISS-III sensor images. Geomorphological units were classified on the basis of differential erosion processes. Vinayaraj *et al*. (2011) assessed quantitative estimation of coastal changes along selected locations of Karnataka, India using GIS and Remote Sensing approach. Qualitative and quantitative studies on changes of coastal geomorphology and shoreline of Karnataka, India were carried out using topo sheets of Survey of India and satellite imageries (IRS-P6 and IRS-1D). Changes during 30 years period are studied at each station and observed significant morphological changes in landforms like spit, channel Island, coastal plain, tidal flat, lateritic plain, alluvial plain and sand bar within and adjacent to estuarine river mouths of Kali, Sharavathi, Kollur-Chakkara—Haladi and Udyavara Rivers.

Given consideration to environment changes, global warming, and issues regarding human activities, studies and quantitative measurements from periodic changes are beneficial for the environmental management of shores. Shoreline change is one of the most common natural processes that prevail upon coastal areas. The most important aspect of managing coastal areas is identifying the location and change of shoreline over time. This requires frequent monitoring of the shoreline using satellite imagery over time (Tamassoki *et al.*, 2014). In view of the non-existent of this kind of study on shoreline dynamics in the study area, this study therefore attempts to carry out an assessment of the shoreline changes, an identification of geomorphological features along the coast, land use and land cover change as well as analysis of the coastal landform of Cross river State in Nigeria. The study also scrutinizes the environmental consequences of the shoreline changes with a view to generating baseline information for evolving informed decisions and policies for monitoring and managing anthropogenic activities in the coastal zone.

Study Area

Cross River State is one of the 36 states of the Federal Republic of Nigeria. Cross River State is made up of parts of old Calabar and Ogoja Provinces divided into 18Local Government Areas. Its capital city is Calabar. It is located between longitudes $8^0$17'00 E and 8^0 20'00''E latitudes 4^0 50'00''N and $5^0$10'00''N (Figure 1). The state has a total area of 21,287.8km^2 and ranked19th of the 36 states of Nigeria (Bassey, et al, 2013). The state is home to approximately 2.9 million people (NPC, 2006), predominantly of Efik, Ejagham and Bekwarra background. One of the fastest growing states in Nigeria, Cross River is endowed with vast mineral resources, plentiful arable land, and a growing number of tourist attractions (Funds for Peace, 2015). It is a coastal state bordering Cameroon to the east.

It covers the Oban Massif, Ikom-Mamfe embayment and Obudu plateau southern Nigeria with a humid tropical environment which experiences alternation of wet and dry seasons. The Oban Massif is composed of Precambrian basement, which is overlain by Cretaceous-Tertiary sediments of the Calabar Flank. It has an interesting geology which includes metamorphic rocks such as phyllites, schist, gneiss, amphibolites and charnockites with igneous intrusions such as dolerite, granite, granodiorite, diorite, tonalite and monzonite. The most prominent fracture set in Oban Massif is the NNW-SSE, with a trend of 150º -160º from the north. Others are NNE-SSW, E-W and NW-SE sets (Oden et al., 2013). The Ikom-Mamfe embayment is a 130 Km long by 60Km wide Cretaceous sedimentary basin extending east from the Lower Benue Trough, Nigeria, into Cameroon where it narrows and terminates beneath the Tertiary to Recent volcanic cover of the Cameroon volcanic line (Fairhead *et al*., 1991). It resulted from the rotation of the Obudu basement with respect to the Oban Massif (Oden *et al*., 2013), and is predominantly a sedimentary environment in which Albian sandstones and limestone are overlain by a sequence of Lower Turonian sandstones, shales and limestone, all of these being intruded by a series of post- Turonian basic to intermediate intrusive (Hossain, 1981). The Obudu plateau consists dominantly of basement migmatitic gneisses, schist and a few amphibolites, all of which have been intruded by acidic, basic and ultra-basic igneous rocks (Odein, 2013). This area has a rugged topography with a series of elevated ridges separated by lowlands. Structural data (Oden *et al*., 2013), show that the most prominent fracture set in Obudu basement area is the NW-SE which trends 140º - 150º from north. Minor sets occur in the NNE-SSW, E-W and ESE-WNW directions (Oden et al, 2013). The state is covered by a body of water from the tributary of the river cross and the Atlantic Ocean. This renders the land very fertile and provides abundant aquatic resources for exploitation. About two third of the state is covered by tropical rain forest. This makes it one of the biodiversity hotspots. This covers about 32% of the entire state, making it the world's second largest preserved rain forest. The vegetation ranges from mangrove swamp, through rain forest, derived savannah and montane parkland. Cross River State falls within tropical equatorial climate with high temperature, high relative humidity and abundant annual rainfall. Two major air masses affect the climate of Calabar as well as other contiguous locations in the West African region. The Tropical Maritime (mT) and the tropical continental (cT) air masses affect the climate in two distinct seasons. mT air prevails and influences its moisture characteristic while the cT air influences the dry season condition due to is desert source across the two air masses at the upper troposphere from east to west. This is called the Equatorial Esterlies (EE). The two air masses meet at the pressure front called Inter Tropical Discontinuity (ITD). There have been a massive development and urban expansion in the area over the last 10 years. Humid tropical climate (1300-3000mm rainfall, 30°C mean annual temperature) prevails over Cross river state except Obudu Plateau where the climate is sub-temperate with temperatures of about 15°C-23°C.

About 3 local governments out of 18 cover the coastal part of the study area. They include Calabar South, Bakassi and Akpabuyo Local governments. This is illustrated in Figure 2.

Materials and Methods

The study used Landsat images TM 1980, 1990 and ETM+ 2010 acquired Global Landcover Facility website and earth explorer in United States Geological Survey interface. Landsat 7 image which had scan line errors was corrected using Landsat toolbox in Arcmap and Focal Analysis tool in Erdas Imagine 9.3. In addition, Digital Elevation Model of the study area was used to delineate the drainage pattern. Bands 432 within the visible region of the electromagnetic spectrum (green, red and near infrared bands) were used to create a false composite image to make features distinct from each other. ArcGIS 10.1 and Erdas 9.1 GIS softwares were used for image restoration. Creation of coastline region was done by creating shapefile for digitizing using the Local Government Area as input. Land use classes were identified and mapped in the images, which include grassland, settlement, outcrops, vegetation and water body using Maximum likelihood (ML) classification algorithm in supervised classification method.

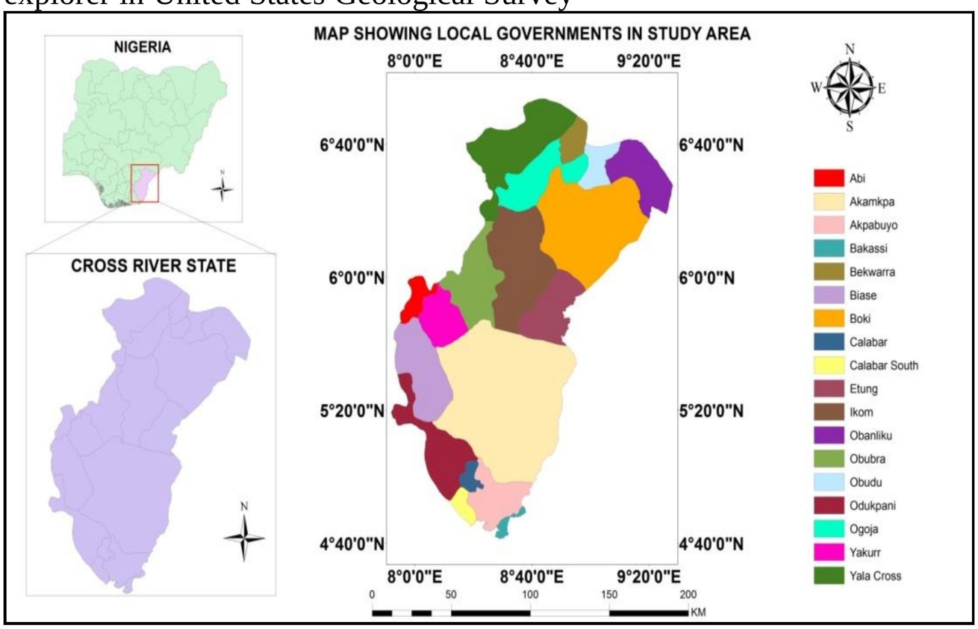

Figure 1: Map Showing Local Government Areas of Cross River State
Source: Oden et.al. (2013)

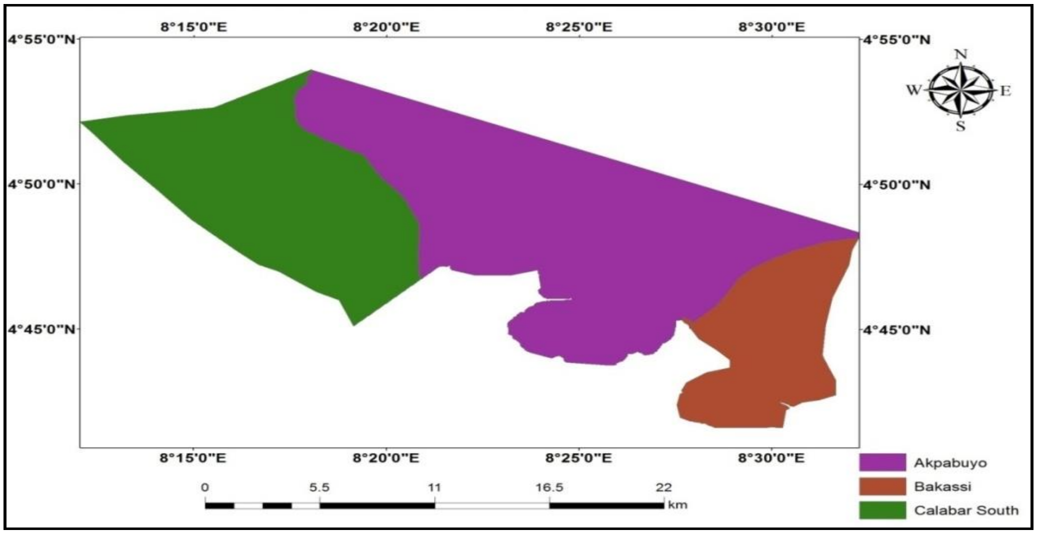

Figure 2: Local Government Areas along the Shoreline

This classifier considers not only the cluster centres but also the shape, size and orientation of the clusters, which is achieved by calculating a statistical distance based on mean values and the covariance matrix of the clusters. The statistical distance expresses a probability value: an unknown pixel is assigned to a cluster to which it has the highest probability. The assumption of ML classifiers is that the statistics of the clusters has a normal distribution. So called equi-probability contours are drawn around the centre of each cluster and this allows the operator to specify a threshold distance by defining a maximum probability value. By choosing a small threshold value, a small ellipse centered on the mean defines the values with the highest probability of membership of a class.

The calculated parameters for the shoreline change include shoreline change envelope (SCE), net shoreline movement (NSM), and end point rate (EPR). The change envelope describes the distance between the shoreline farthest from and closest to the baseline at each transect. The shoreline change envelope reports a distance. This represents the total change in shoreline movement for all available shoreline positions and is not related to their dates. It is the greatest shoreline distance between two periods. The study revealed that the distance (SCE) between the 1980 shoreline and 1990 shoreline was 259 meters (reduction in line distance) while SCE between 1990 and 2010 shoreline was about 800 meters.

Furthermore, the net shoreline movement (NSM) is associated with the dates of only two shorelines. It reports the distance between the oldest and youngest shorelines. This represents the total distance between the oldest and youngest shorelines. If this distance is divided by the number of years elapsed between the two shoreline positions, the result is the End Point Rate (EPR). The net shoreline movement between 1980 and 2010 was about 347 meters. This indicates the extent distance movement of the oldest and youngest shoreline.

DEM was re-projected from geographic coordinate system (GCS WGS 1984) to projected system (WGS 1984 UTM Zone 32N). Drainage network was delineated using a stream threshold of 500 cells in the conditioning of the elevation raster in the hydrology tools of the ArcGIS software.

File geo-database was created in order to create a shapefile which houses the shoreline for each year using on-screen digitizing. Digital Shoreline Analysis System (DSAS) uses a measurement baseline method (Leatherman and Clow, 1983) to calculate rate-of-change statistics for a time series of shorelines. The baseline is constructed by the user and it serves as the starting point for all transects cast by the DSAS application. The transect intersects each shoreline at the measurement points used to calculate shoreline-change rates. Each shoreline vector represents a specific position in time and must be assigned a date in the shoreline feature-class attribute table. The measurement transects that are cast by DSAS from the baseline will intersect the shoreline vectors. Identification of landforms was achieved by visual interpretation using remote sensing techniques as well as methodologies from existing literatures. Change detection analysis was done by calculating areas cover by each land cover classes for the years in view. The characteristics of the images used the year, resolution and source of each image is given in Table 1.

Shoreline geometry remains one of the key parameters in the detection of coastal erosion and deposition and the study of coastal morpho-dynamics. DSAS as a software extension within ArcGIS has been used by many researchers in measuring, quantifying, calculating and monitoring shoreline rate-of-change statistics from multiple historic shoreline positions and sources. The main application of DSAS is in utilization of polyline layers as representation of a specific shoreline feature (e.g. mean high water mark, cliff top) at a particular point in time. A range of statistical change measures are derived within DSAS, based on the comparison of shoreline positions through time. These include Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE), End Point Rate (EPR), Linear Regression Rate (LRR) and Weighted Linear Regression Rate (WLR). Despite the inability of this tool to determine the forcing of morpho-dynamics, it has been shown to be effective in facilitating an in-depth analysis of temporal and historical movement of shoreline positions and cliff geometry.

Change detection studies was carried using Erdas Imagine 9.1 using the classified as input to generate a difference file and a highlight file. Areas that have undergone change are shown while areas that unchanged are presented.

Results and Discussion

Land Use and Land Cover Change

Figures 3, 4, 5 and Table 2 showed a drastic reduction in the area covered by grassland in the area and a rapid increase in the area covered by vegetation. This may be due to presence of good soil condition as well as lush amount of tropical rain forest in the area. Also, gradual reduction of grassland between 1990 and 2010 may be attributed to the emergence of settlement in the coastal part of the study area. Outcrops area coverage in 1990 was 0.03 km^2 and was increased to 68.7 km^2 with an introduction to a small percentage of settlement in places laden with outcrops. The total area ocuppied by water body in 1980 was 35% of the coastal area but was increased to 36% with an increment of about 1.1% due to closeness to the ocean.. Vegetation increased from 14.5% in 1980 to 34.13% in 2010 with an increment of 19.5% while outcrop increment in acreage ranged from 0.009% to 17.3%. The result of the research carried out by Odunnuga *et al.* (2013) supports the results of this research as it establishes that human activities along the southwestern coastline have affected the coastal features along the coast.

Table 1: Summary of some satellites (LANDSAT) missions used.

Data	Resolution	Source
Landsat Tm (1980)	Visible To NIR- 30 Meters Thermal Band-60 Meters	Landcover.Org
Landsat Tm (1990)	Visible To NIR- 30 Meters Thermal Band-60 Meters	Landcover.Org
Landsat Etm Plus (2010)	Visible To NIR- 30 Meters Thermal Band-60 Meters Panchromatic Band- 15 Meters	Earthexplorer.Usgs.Gov
Dem	1 Arc (30 Meters)	Earthexplorer.Usgs.Gov

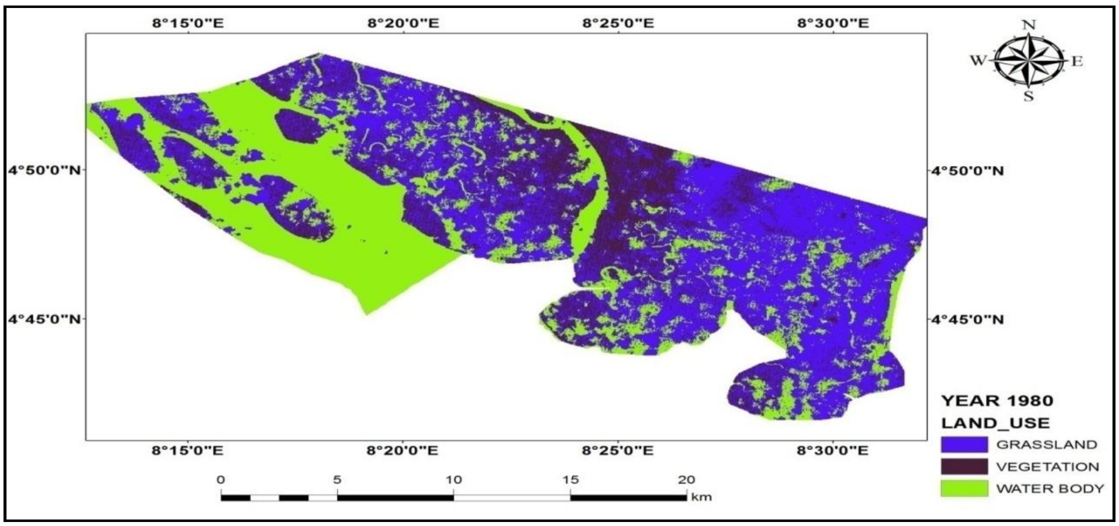

Figure 3: Land cover map of 1980

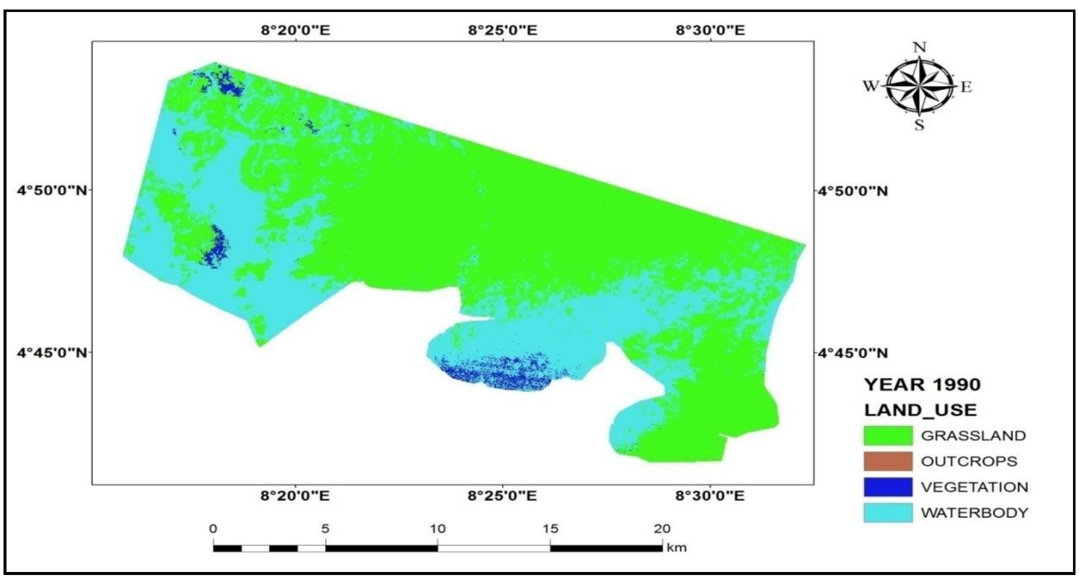

Figure 4: Land cover map of 1990

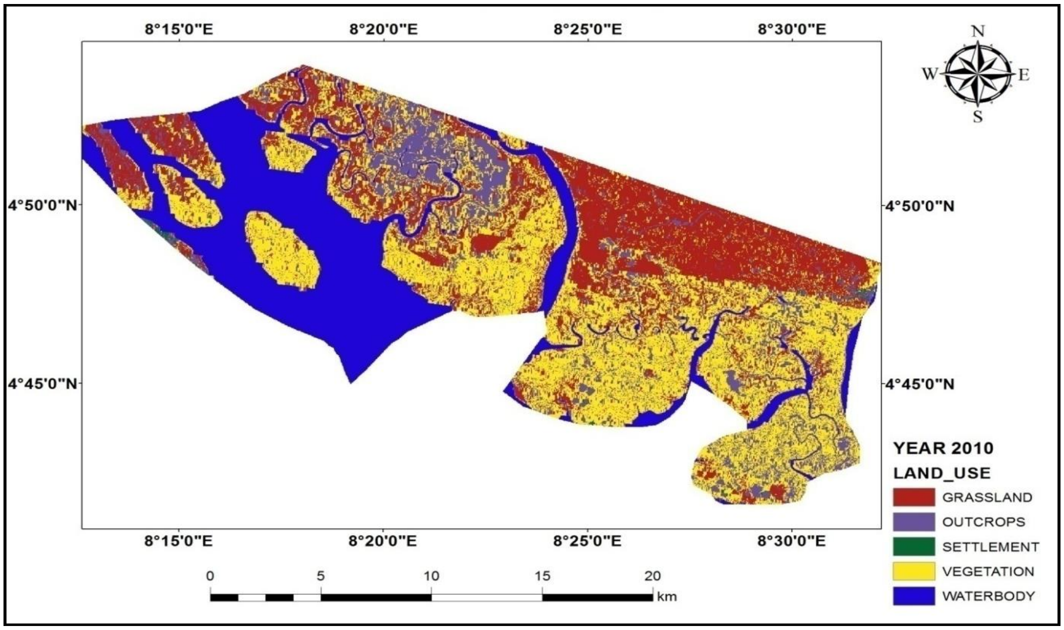

Figure 5: Land cover map of 2010

Table 2a: Land Use Change Statistics

	1980		1990 (%)		2010 (%)	
Landuse	**Km²**	**(%)**	**Km²**	**(%)**	**Km²**	**(%)**
Vegetation	58.2	14.5567	6.60	1.6504	135.3	33.8
Water Body	141.32	35.3338	98.75	24.6879	97.8	26.4269
Grassland	200.43	50.1095	247.65	61.9132	93.6	23.6202
Outcrops		-	0.04	0.009549	68.8	17.3549
Settlement		-		-	4.5	0.202779

Table 2b: Land Use Change Statistics

Landuse	Change betw1980 & 1990		Change betw1990 & 2010		Change betw 1980 &2010		Average rate of Change per yr	
	Km²	(%)	Km²	(%)	Km²	(%)	Km²	(%)
Vegetation	-51.2	-88.0	128.7	1950	77.1	132.5	2.57	4.42
Water Body	-42,57	-30.12	-0.95	-0.96	-43.52	-30.8	-1.45	-1.03
Grassland	47.22	23.56	-154.05	-62.20	-106.83	-53.3	-3.56	-0.12
Outcrops	0.04	-	68.76	171900	-	-	3.44	8595
Settlement/ Built Up	-		4.5	-	-	-	0.225	-

Vegetation along the coastline in Cross River State has increased over the 30 years study period by 2.57km^2, the relationship between the rate of urbanization and human activities along the coast is inversely proportional to the rate of vegetation increase [1]ong the coastline. In Bakassi due to the crisis over some portion of land, activities in these areas have reduced considerably which gave vegetation the avenue to spring up.

The dynamics of water body as shown in Figure 2b explains the unstable nature of water, in this case the coastline reduced by 43.52km^2 in 30 years and an average 1.45km^2 per year. Sand mining along the coast has affected the natural flow of water along the coastline. The rate of loss water is directly proportional to the rate of water loss along the coast. Migration of cattle rearers from northern Nigeria to Southern Nigeria in search of pastures for animals has depleted the grassland in the area between 1980 and 2010, grassland reduced 106.83km^2 representing an average of 3.56km^2 per year. Outcrops in 1990 covered 0.04km^2 erosion, flooding in the area between 1990 and 2010 exposed the outcrops that were formally covered by soil. In 2010 outcrops exposed covered 68.76km^2 which is a result of urbanization and erosion.

Hydrology Analysis

The stream analysis showed that there were four stream orders bordering the coastal area. The drainage pattern was dendritic in nature. Also, the slope map also showed that there were steep areas ranged from 5° to 12° along the outcrop areas while river and coastal area showed gentle or relatively flat areas which range from 0° to 5° (Figures 6 and 7). Most of the flat areas were located in the coastal zones with values ranging from 0° - 6° considered to be extremely flat in nature. This accounts for erosion occurrence in the area. Vegetation and grassland in the region showed gradual increment. This also accounts for luxuriant vegetation and supports farming activities in the region. The highest order of the stream (4th order) was located in the coastal region bordering the shoreline.

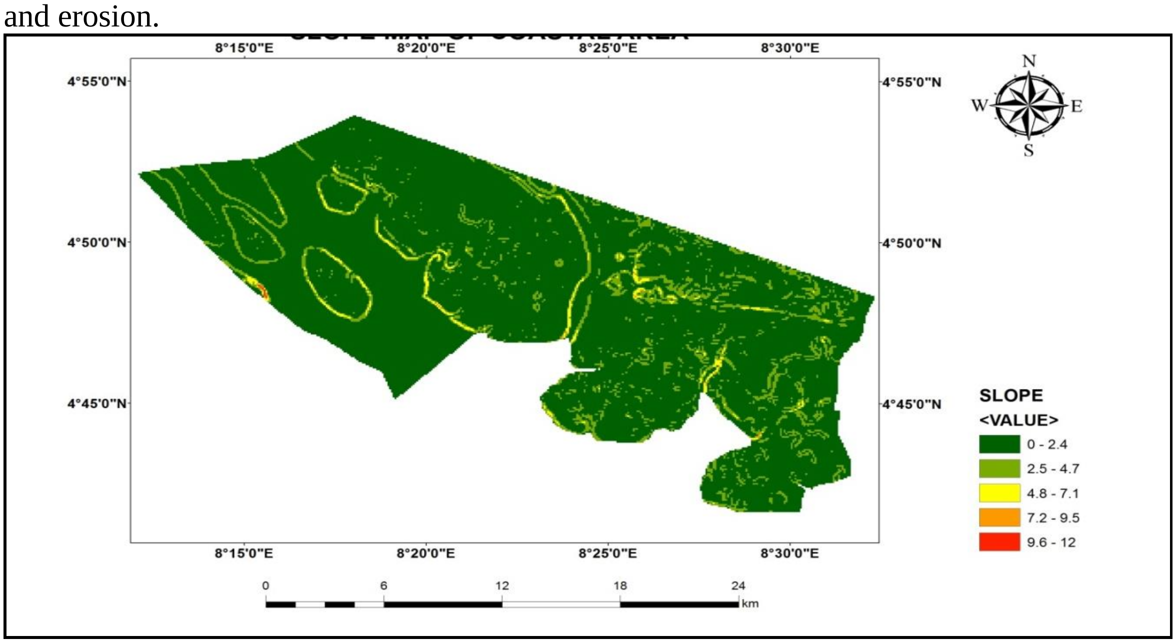

Figure 6: Slope of Study Area

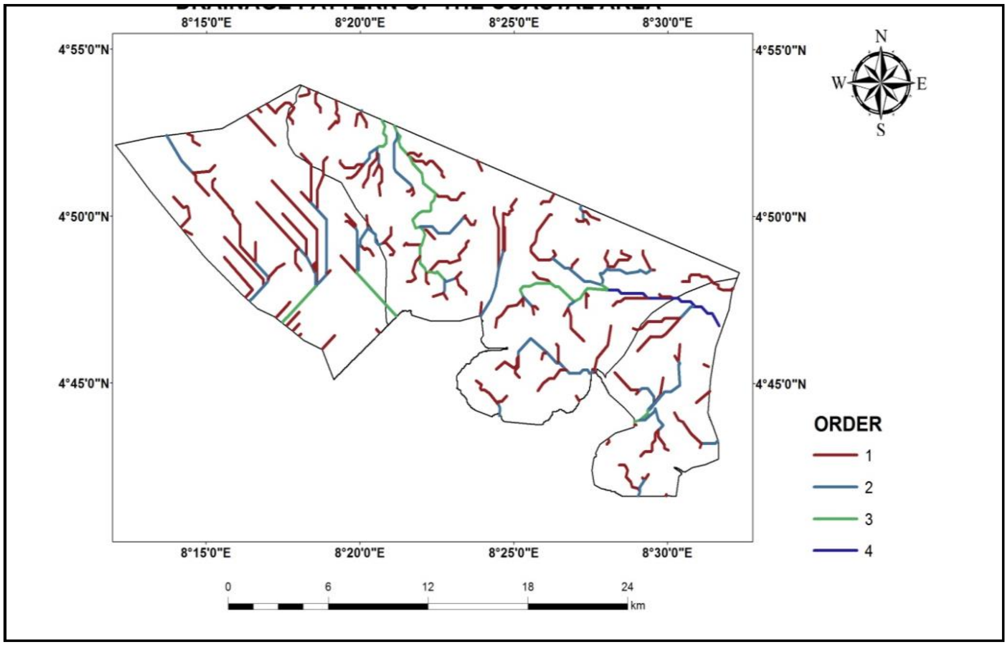

Figure 7: Map Showing Stream Order

Shoreline Change Analysis and Extraction

The shoreline length analysis indicated a gradual decrease between the years in view. The shoreline length for the year 1980 was 71.5962 km, 71.4262 km in 1990 and 69.7015 km in 2010. A gradual reduction of 0.17 km in length was noticed between 1980 and 1990 while a rapid reduction of about 1.724 km was recorded between 1990 and 2010. End point rate is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. In the analysis, it was observed that between 1980 and 2010,

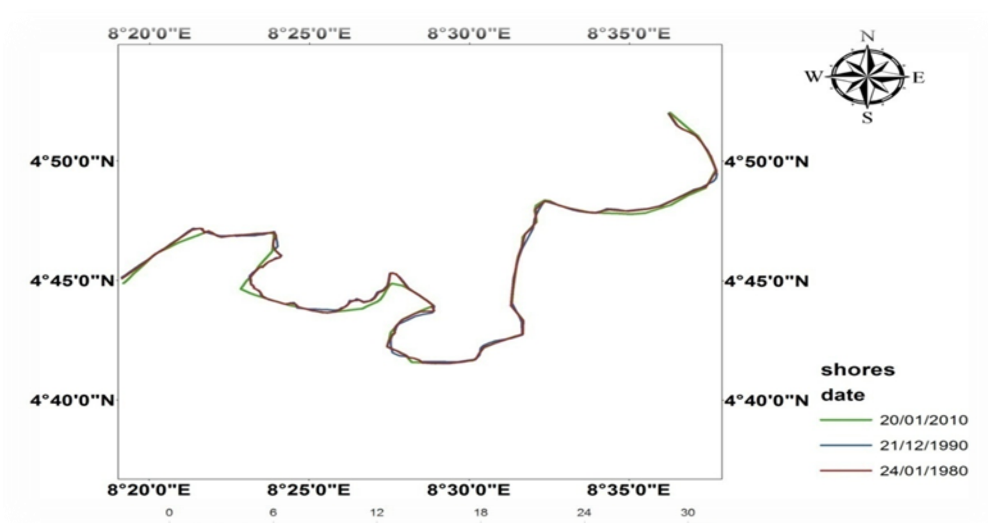

Figure 8: Shoreline from Landsat Images

the EPR was about 11.5m for thirty years. Also, the rate of erosion between 1980 and 1990 was 424.96m while rate of accretion (increase by gradual accumulation) was about 277.59m. The rate of erosion was about 15.4m per year between 1980 and 2010. This indicates that the erosion that occurs per year is higher than rate of accretion. This results in the apparent reduction of the shoreline per year as shown in figure 8.

Conclusion

The study observed a remarkable change in the shoreline with a gradual reduction of 0.17 km in length between 1980 and 1990, and a rapid reduction of about 1.72 km between 1990 and 2010. The study also revealed that shoreline change envelope was 259m between the 1980 shoreline and 1990 shoreline (reduction in line distance) while it was 800m between 1990 and 2010 shoreline. The net shoreline movement between 1980 and 2010 was about 347 meters, representing the extent distance movement of the oldest and youngest shoreline. The study further observed that between 1980 and 2010, the end point rate was about 11.5 meters for thirty years. Also, the rate of erosion between 1980 and 1990 was 424.96 meters while rate of accretion was about 277.59m. The rate of erosion was about 15.4m per year between 1980 and 2010. This indicates that the erosion that occurs per year is higher than rate of accretion.

This results in the apparent reduction of the shoreline per year. This may be attributed to low elevation with values ranging from 0° - 6°, suggesting extremely flat topography and intense farming activities. This trend is similar to other parts of the Niger Delta region of Nigeria. Erosion and accretion processes have been ongoing, outstanding, and very severe in the area. Specifically, it is worthy of note to say that these occurrences are very much peculiar to the coastal region of Cross River State. Therefore, quantitative analysis of shoreline changes at different timescales is very important in understanding and establishing the processes driving erosion and accretion computing sediment budgets, identification of hazard zones as a basis for modelling of dynamics and for coastal management and interventions.

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