Impact of Sea Level Rise: Barrier Coast, Nigeria

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Abstract:

The length of the coastline of Nigeria is approximately 853km long and composed of four distinct geomorphologic units namely the Barrier, Mud, Delta and Strand Coasts. Much of the Nigerian coast is low lying with the consequence that a 1 to 5 metres rise in sea level, which may result from eustatic or climate change, will have a catastrophic effect on the human activities in these regions. This study examines the consequences of continued sea level rise (SLR), for the Barrier Coast. A Geographic Information System (GIS) has been used to build models and examine the impact scenarios that SLR will have on critical elements, which include land, population, economic activity (GDP), urban extent, agriculture and wetlands with the aid of high quality spatially disaggregated global data on the critical elements. Results show that for SLR of 1 and of 5 metres, between 14% and 34% of the population of the Barrier Coast will be displaced. About 23% to 38% of land area will suffer inundation; 2% to 4% of GDP lost; 51% to 73% of urban extent lost; 44% to 74% of agricultural extent submerged; and 69% to 89% of wetlands will be lost. This study provides information concerning the implications of SLR, which will be useful for coastal planners and managers to develop a framework for Integrated Coastal Zone Management to support sustainable development of the coast in the light of rising sea levels.

Introduction

A major challenge facing the world today is climate change. Various governments in the world are now alert to the challenges and the urgency of the responses needed to mitigate and adapt to climate change (UKCIP, 2007). In the UK for example, these include the Government's draft Climate Change Bill of 2007 and the Communities and Local Government's Planning Policy Statement 25 of 2006 (UKCIP, 2007). One of the effects of climate change is the rise in the level of the sea along major coastlines, which will result in flood damage, erosion, wetland inundation and other ecological losses (Neumann et al., 2010). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) it is projected that global sea level will rise up to 60 cm by 2100 (IPCC, 2007), but with recent accelerated decline of the polar ice sheet, there is the possibility of future sea level rise (SLR) being more than 1m and close to 2m by 2100 (Nicholls and Cazenave, 2010). An assessment of the impact of sea level rise on the coastal environment will be valuable as it gives useful information for coastal planners and managers to adapt and develop the use of the coastal environment in a sustainable manner. This study is focused on the impact of continued sea level rise on the Barrier Coast of Nigeria. Emphasis is on information provision for management of critical elements of this coast.

Barrier Coast

The Nigerian Barrier coastal system is approximately 220 km in length and is characterised by a sandy barrier with width varying from 0.5 to 21km (French et al., 1995). The barrier consists of beach ridges fronted by a very narrow beach with a foreshore gradient of about

1:50 (UNESCO-IOC, 2009). Narrow and sandy beach ridges back the foreshore. The beaches are subjected to high-energy waves, resulting in the formation of characteristically steep beach profiles. This coastal complex is very fragile as it is composed of narrow low lying sandy barrier bars (UNESCO-IOC, 2009). Elevations for most of the coast are less than 3 metres and are vulnerable to increased SLR. The Barrier coast is the most heavily developed and urbanised coast; it is composed of large wetlands which provide habitats for many animal species, and an increase in SLR will result in dire consequences (Ibe, 1990).

Method

A Geographic Information System (GIS) was employed to overlay the critical impact elements (land, population, agriculture, urban extent, wetlands, and GDP) with the inundation zones projected for 1 and 5 m SLR scenarios. Spatially disaggregated data were obtained from various public sources. This is detailed in Table 1. Coastal terrain models were zipped and converted into raster format before importing into ArcGIS. The mosaic function was applied to merge the different elevation models. An overlay analysis was performed within the study area and of the mosaic elevation data. Inundation zones were derived from the terrain models by performing a geoprocessing query, which extracted pixel values of 1 and 5. This was overlaid with the Barrier coast to extract vulnerable regions to scenarios of 1 and 5 metres. Inundation estimates for the critical elements were derived by overlaying the inundation zones with the appropriate exposure surface dataset. The horizontal datum used is the World Geodetic System (WGS 1984) which was projected to a Transverse Mercator and metric grid (WGS_1984_UTM_Zone_31N) for area calculation. For the value of pixels in the population surface (units in population counts), the exposure is calculated by multiplying the grid count value and then summing up. This was overlaid with the inundation zone. For the GDP surface, the same procedure was applied as with the population surface but the grid count value was further multiplied by a coefficient, which was used to code the grid cells for the GDP*mer* (Market Exchange Rate) data. This coefficient represents US$1990 per grid cell. Use of this coefficient is a methodology adopted by IIASA (2007) as an Integrated Assessment Modelling Framework to downscale spatially explicit projections of economic and demographic growth. The other dimensions in Table 1 were measured in square kilometres.

Table 1: Summary of Data Sources

Dimension	Dataset Name	Unit	Resolution	Sources
Elevation	SRTM Version 3	Sq km	90m (Horizontal) 1m (Vertical)	(CIAT, 2005)
Population	GPW-3	Population counts	1km	(CIESIN and CIAT, 2005)
Economic activity	GGI-B2	Million US Dollars	1km	(IIASA, 2007)
Urban extent	GRUMP V-3	Sq km	1km	(CIESIN et al., 2005)
Agricultural extent	PAGE Version 2	Sq km	1km	(WRI and IFPRI, 2005)
Wetlands	GLWD-3	Sq km	1km	(Lehner and Döll, 2004)

Results/Discussion

The implications of a 1 and 5 m rise in sea level were explored and the results are presented in Table 2. Considering the current state of the coast, it was found that the land extent of the Barrier coast is 4247 sq. km, which is about 0.5% of the total area for the country. The population of the coast accounts for 4.4% (approximately 6.4 million) of the total population of the country. It is interesting to note that the average population density per sq km in Nigeria is currently 162 according to United Nations estimates, which would equate to a Barrier coast population of approximately 688,014 but analysis shows that the population for the region is about 6,430,062. This is about 10.5% of the actual outcome. This confirms the widely accepted fact that more people reside near the coast than away from it. Likewise, the country's total GDP is about 129 billion US Dollars according to IIASA (2007) estimates. The country's average equates to about 139.7 thousand US Dollars per sq km and 593.4 million US Dollars for the whole of the Barrier coast. However, the actual outcome is a coastal GDP of 9.1 billion US Dollars GDP, i.e. approximately 7% of the country's total GDP. Thus the average GDP value for the country is just 6.5% of the actual GDP that exists in the Barrier coast. This also confirms claims that economic resources are more concentrated in coastal regions. Urban extent of the Barrier coast covers 6% of the total urban area in the country. Agricultural extent covers 0.4% of the country's area while wetlands cover 0.2%. Table 2 illustrates the extent of the two scenarios of SLR considered in this analysis for the critical elements.

Table 2: Impacts of Sea Level Rise: Barrier Coast

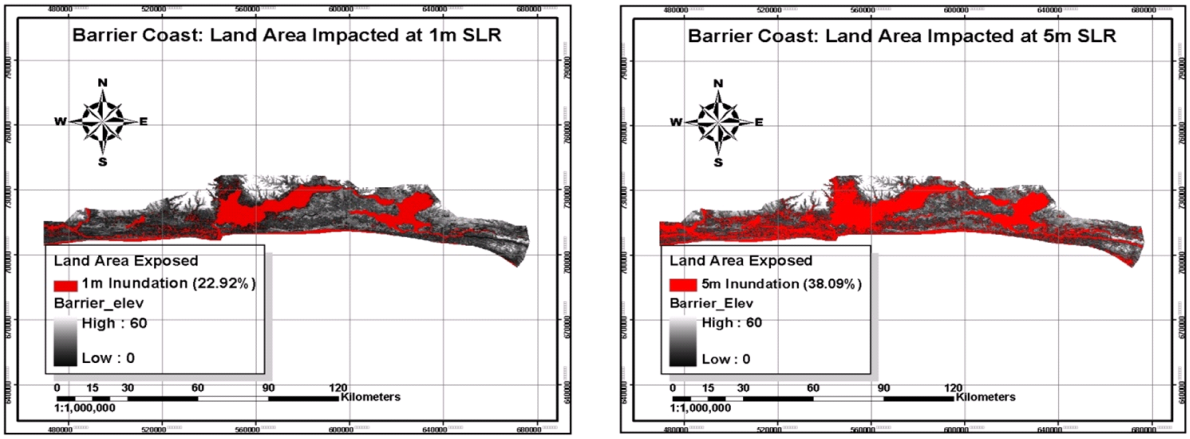
	1m	5m
Area (Total = 4,247 sq km) (0.46%)		
Impacted area	973	1617
% of zone extent	22.92	38.09
Population (Total = 6,430,062) (4.4%)		
Impacted Population	897165	2188372
% of zone extent	13.95	34.03
GDP (Total = 9,106 Millions US$) (7.05%)		
Impacted GDP	224	369
% of zone extent	2.46	4.06
Urban Extent (Total = 1,070 sq km) (6%)		
Impacted area	549	782
% of zone extent	51.32	73.03
Agricultural Extent (Total = 3,411 sq km) (0.37%)		
Impacted area	1497	2527
% of zone extent	43.91	74.09
Wetlands Area (Total = 1,984 sq km) (0.21%)		
Impacted area	1369	1764
% of zone extent	69.02	88.87

Land Extent

Approximately 0.3% and 0.9% of land area in Nigeria would be inundated in a 1m and 5m SLR respectively. With a 1m SLR in the Barrier coast, 22.9% of the land area will be inundated and for 5m 38.1%. Figure 1 show the areas of the Barrier coast that will be

inundated under the scenarios considered. The information regarding the extent of land that will be impacted by SLR is important to be considered, as this land area could include agricultural land and developed urban areas forest, grassland and wetlands. They may be very important for the support of the local population and its ecosystem and so these outputs are useful in informing the various stakeholders involved in managing the coast.

Figure 1: Barrier Coast: Land Area Impacted at 1m and 5m SLR



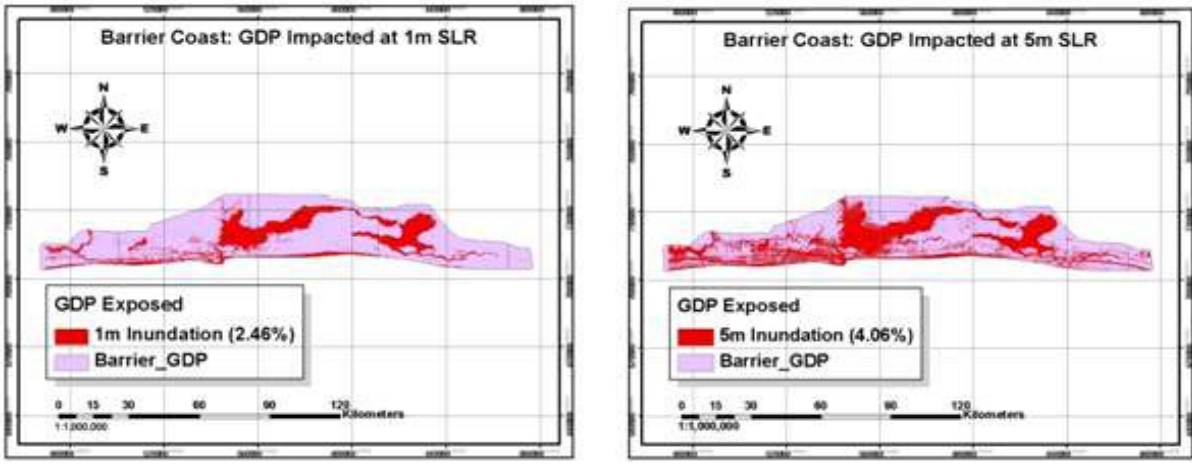
Population

Results indicate that not all the Barrier coastal populace live in a low-lying area and might not be at risk to the effects of SLR. At 1m SLR, 13.9% of population of the Barrier coast will be impacted which will then increase to 34% at 5m SLR.

Economic Activity (Gross Domestic Product)

This segment assessed the impact scenarios of SLR will have on the barrier coast estimating it in terms of GDP lost. At 1m SLR, about 224.1 million US Dollars will be lost in the Barrier coast. This loss amount to about 2.5% of the total GDP generated in the Barrier coast and 0.2% of the country's total GDP. In a 5m SLR, 369.9 (4.1%) million US Dollars will be lost in the Barrier coast. Figure 2 shows specific locations that GDP will be vulnerability to SLR.

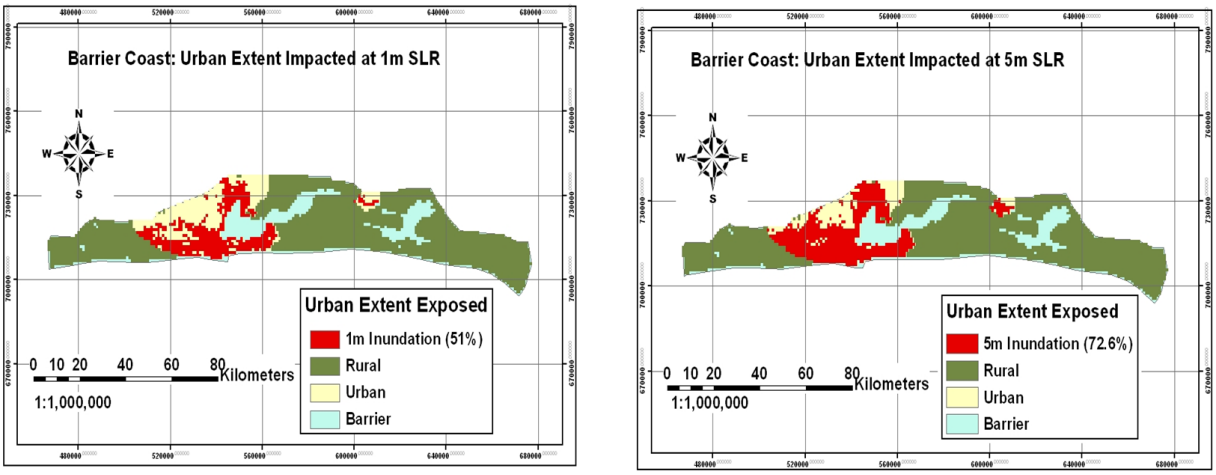
Figure 2: Barrier Coast: GDP Impacted at 1m and 5m SLR



Urban Extent

The urban extent of the Barrier coast covers approximately 1070 sq km. Results indicate that the urban extent is about 25.2% the extent of the Barrier coast. In assessing the impact of SLR, the analysis indicated that 549 sq. km (51.3%) will be exposed at 1m SLR; and 782 sq. km (73.3%) at 5m SLR. This would be devastating and require whole-scale movement of people. Figure 3 shows the extent of vulnerability and the actual areas of the Barrier coast to the scenarios of SLR considered in this analysis.

Figure 3: Barrier Coast: Urban Extent Impacted at 1m and 5m SLR



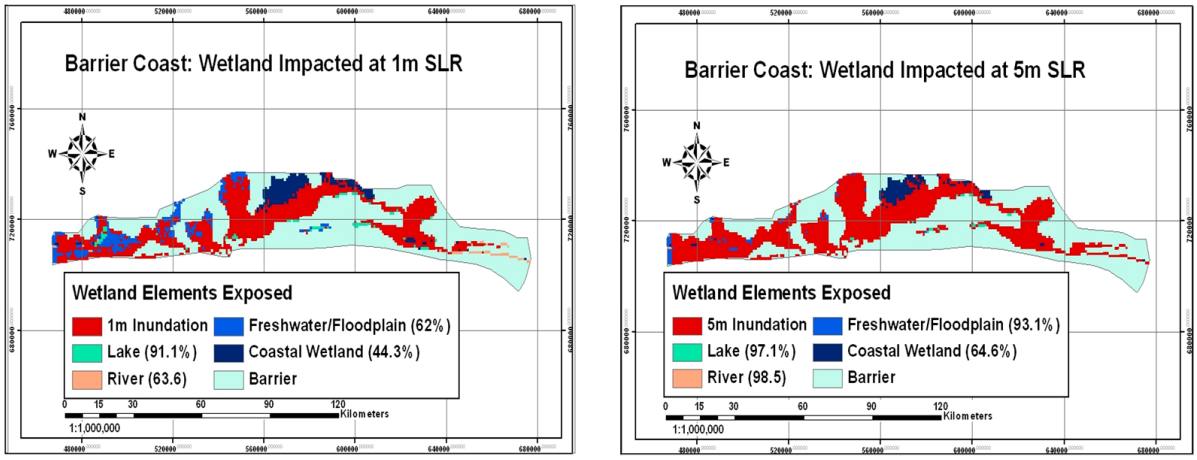
Agricultural Extent

Agriculture will be severely impacted in the event of SLR. Results of this study show that 43.9% of agricultural extent will be inundated at 1m SLR while 74.1% will be inundated at 5m SLR. Based on the classification of the spatial data employed, it was deduced that an agriculture/forest mosaic would be impacted by 0.1% and 36.7% in 1m and 5m SLR respectively. 1% and 3% of agriculture plus other vegetation will go under water in a 1m and 5m SLR scenarios. Forestland will be impacted by about 1.5% and 6.2%. The extent of grassland that will be inundated will be up to 1.5% and 4.2%. Wetlands and mangrove will be inundated to the extent of 4.8% and 21.3%, while sparsely vegetated will lose 0.3% and 0.6% to inundation in a 1m and 5m SLR scenarios respectively.

Wetland

Results show that at 1m and 5m scenarios of SLR, an approximate of 69% and 89% of wetlands will be impacted. Four types of wetland exist in the Barrier coast and they are lake, river, freshwater marsh and floodplain, and coastal wetland. Breaking down the analysis, 27.6% and 30.6% of the lake will be inundated; 1.5% and 3% of river will be inundated; freshwater marsh and floodplain will also experience an impact of 5.9% and 16.8%; while coastal wetland will be inundated up to about 4.5% and 7.3% in a 1m and 5m SLR scenarios. Figure 4 reveals the extent of impact.

Figure 4: Barrier Coast: Wetland Impacted at 1m and 5m SLR



Recommendation and Conclusion

The study was able to ascertain that the wetland element will experience the largest percentage of impacts at 1m SLR while urban extent element will suffer more impact at the scenarios considered which is closely followed by agricultural extent. This paper has been able to showcase the expected consequences of continued SLR in the Barrier coast of Nigeria which is potentially catastrophic. The scenarios we have chosen to explore involve a very substantial sea level rise but the possibility that changes on this scale may occur have been proposed by Dasgupta et al. (2007) in a report for the World Bank. They suggest that a SLR of 1-3 m could be possible in this century and a 5m SLR if the Greenland and West Antarctic ice sheets break up. Changes on this scale call for pre-emptive mitigation and adaptation programmes to be put in place. Dasgupta et al., (2007) noted that adaptation programmes to identify priority activities are in force in some countries. However this is yet to be transferred into most developing countries.

In Nigeria, there have been sectoral approaches to managing the coast. The constraints of the institutional framework in Nigeria include overlap of responsibilities of various institutions and conflicts between the tiers of government where enforcement issues are concerned. There is need to integrate the various sectoral activities into a whole. This can be achieved through Integrated Coastal Zone Management (ICZM). ICZM promotes sustainability and with its tenets - integration, balance, communication, and citizen participation - are best practices to be employed (Gallagher et al., 2004). The Strategic Environmental Assessment (SEA), which takes into consideration sustainability, will be an invaluable tool in assessing the impacts of plans and programmes on the environment including climatic factors (Levett-Therivel Sustainability Consultants, 2007) but it requires information on which to base these studies. In the case of SLR, mitigation and adaptation programmes through the SEA process must be considered at its various stages. This analysis provides a starting point for such assessments. It could help engage the coastal community in reviewing the implications of various options and identifying areas for more detailed research.

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