Climate change, sea level rise and coastal inundation along part of Nigeria Barrier Lagoon Coast

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ABSTRACT: The phenomenon of ocean surges and other morphological processes along the Lagos coastline have generated serious public concern on the vulnerability of infrastructures and coastal services along the entire stretch of the Barrier-Lagoon coastline of Lagos State. This study examines Badagry coastal environment inundations that arise from sea level rise. The study uses an iterative GIS-based simulation that mapped area inundated based on Intergovernmental Panel on Climate Change - Special Report on Emissions Scenarios (IPCC –SRES) classification (A1, A1T, B2, A1B and A2) and Locally Oriented Economic Development Scenarios (LOEDS). The results of IPCC-SRES scenario analysis show that area inundated at the high emission and worse case sea level rise is less than 0.13% of the study area while the LOEDS inundation area starts having significant impacts as from 4 meter rise in sea level. Since it is only environmental catastrophism and anthropogenic activities that can attain such serious dimension at local, regional and global scales in sea level, it is recommended that coastal protection infrastructures should be integrated in any major developmental activities. © JASEM

Climate change has come to be one of the pressing challenges facing our planet Earth in this century as it is increasingly threatening the continuous existence of life on earth. With shifting seasons, climbing temperatures and rising sea levels (IPCC, 2007). Although all countries of the world are susceptible, some have been noted to be more vulnerable than the others. (Nicholls et al. 2007). The coastal areas have been identified to be highly susceptible especially to sea level rise (UN, 2004).The presence of extensive coastal stretches with high concentration of population (Pelling and Blackburn, 2013) especially in Africa has further worsened the situation in the continent as they are often unprepared and usually overwhelmed by the magnitude of climate change impacts (Adebayo, 1998; Odjugo and Ikhuoria, 2003; NEST, 2003; Chindu and Nyelong, 2005; Odjugo, 2005; Adefolalu et al., 2007; Ikhile, 2007).

The coastal areas in Nigeria are endowed with numerous natural and human resources ranging from rich biodiversity mangrove ecosystems of the Niger Delta to the barrier lagoon Coast of the south western Nigeria. The vulnerability of the Nigerian coastline to sea level rise is particularly exacerbated

by its low lying, densely populated nature and the high concentration of GDP generating industries and infrastructures especially along the barrier lagoon Coast of Lagos-Badagry-Seme border of the south-western part of Nigeria. From the Nigeria-Benin border to the beginning of the Mahin mud coastline the entire Barrier Lagoon coastal complex of the south western Nigeria is under threat of sea level rise. The situation is more worrisome considering the level of existing infrastructures, ongoing developmental infrastructures and proposed developmental activities within the complex. The Badagry end of the complex is witnessing rapid changes in infrastructural developments and a category A port complex is also being proposed in the area. Considering the current morphological processes resulting from both natural and anthropogenic factors, coastal gradation resulting from degradation and aggradation processes of erosion and weathering of the materials have continually reshaped the coastal lagoon barrier systems including the biodiversity. The extent, rate and nature of the morphological changes is expected to accelerate as it has been noted that the

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anticipated impact of climate change on the coastal zone would lead to; an accelerated rise in sea level of up to 0.6 meters or more by 2100 (Nicholls et al. 2007).

However, an examination of the cumulative effects of the ongoing and proposed developments in relation to the issue of climate change is imperative as a response to the recent infrastructural development and expansion being carried out along the Nigeria-Benin border of the Barrier – Lagoon coastline stretch, especially the extensive construction of the

road-rail transport system, the proposed Badagry Seaport by the Lagos State Government and other developmental activities along the corridor. Thus, this study investigates the impacts of Badagry coastline (Figure 1) to coastal inundation using Intergovernmental Panel on Climate Change - Special Report on Emissions Scenarios (IPCC–SRES) classification (A1, A1T, B2, A1B and A2) (IPCC-SRES, 2000 and IPCC, 2007) and Locally Oriented Economic Development Scenarios (LOEDS). Figure 1 shows Badagry Coast in Lagos State while figure 2 shows the specific project area.
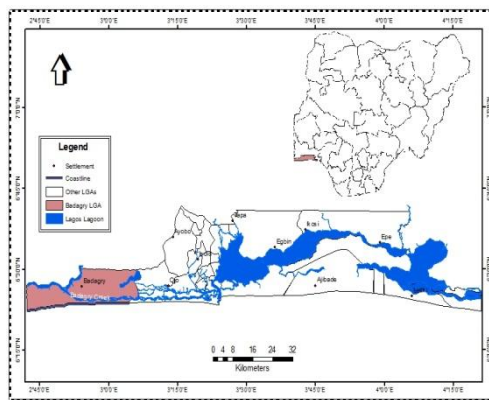

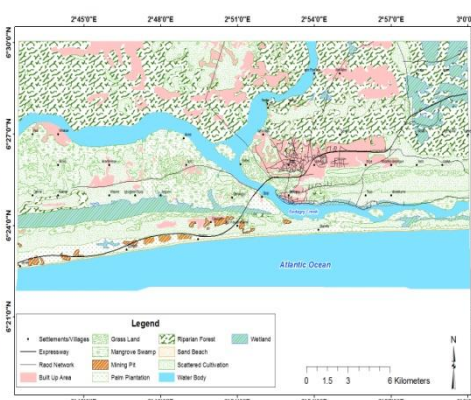**Fig 1**: Badagry Coast in Lagos State
(Insert: Lagos State in Nigeria)

Fig 2: Land Use/Land Cover Map of the Study Area

MATERIALS AND METHODS

This study adopts the GIS-based inundation model to produce both land use and inundation maps for several emission and sea level rise based on IPCC-SRESS and LOEDS. This methodology has been adopted in earlier studies by Nicholls et al (2008), Marfai and King (2008) and Ward et al (2011). Fig 3 shows the flow chat for the study procedure. The spatial data itemized below form the basis for construction of the GIS-models inundation scenarios. The sources and other characteristics of the data are shown in table 1.

The DEM of the study area was downloaded from www.cgiar-csi.org/.../45-srtm-90m-digital-elevation-database, an open data source link. The acquired DEM was updated using spot height data obtained from 1:25,000 topographic sheet in ILWIS GIS 3.3 environment. This becomes necessary due to the fact that several parts near the coastline are under-sampled For the construction of the inundation

model, the neighbourhood function of ILWIS was used. This function works iteratively in such a way that successive repetition of a mathematical operation is done using the result of one calculation as input for the next. The calculation stops when the difference of the output compared to the input is negligible, or if the number of iterations as defined is reached. In this case, several iteration processes based on either IPCC-SRES or LOEDS were made (table 3).The predicted high and low sea level rise (0.18 and 0.59 meters) as given by IPCC-SRES was used as inputs to assess land area that would be inundated if such an event occurs. The input map for iteration is called a start map and contains pixels, which act as the starting point of the calculation. The iteration expression defines a certain condition (based on dual height as in elevation and expected sea level rise) or defines a calculation to be performed. Once the start map has been created, the iteration operation can be done.
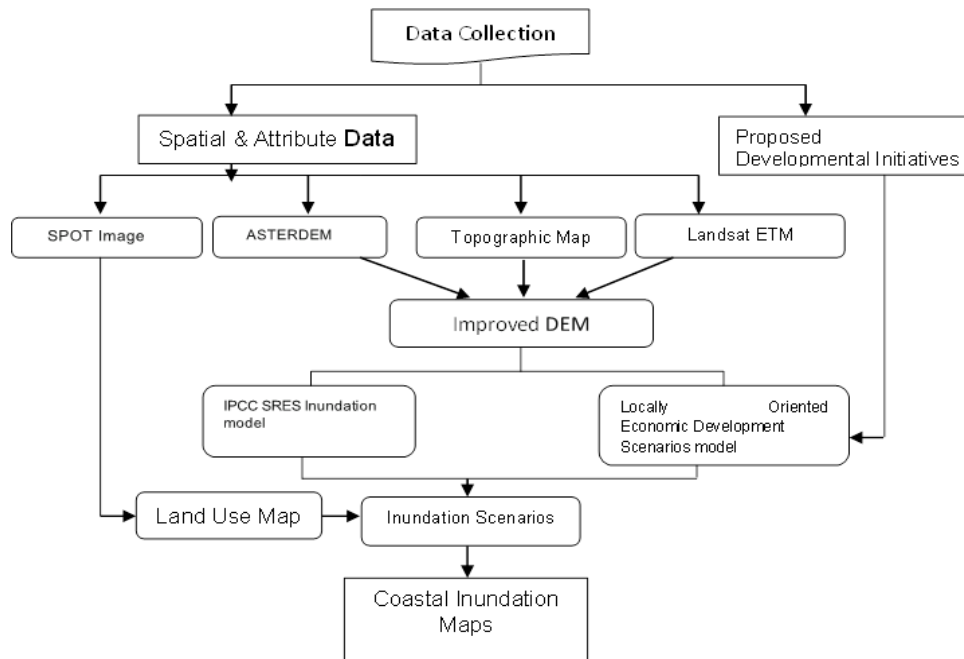
Fig 3: Methodological approach for the study of coastal inundation due to climate change

Table 1: Spatial Data characteristics

S/N	Data type	Scale/Resolution	Source	Date
1	High quality Digital Elevation Model (ASTERDEM)	30 meters	NASA *asterweb.jpl.nasa.gov/gdem.asp*	2011
2	Sea level rise predictions (SRES)	Global	IPCC *http://www.ipcc.ch/publications_and_data/publications_and_data_repor ts.shtml*	2000
3	SPOT image	10 meters	EADS ASTRIUM	2008
4	Landsat ETM r191c056	30 meters	GLCF (Department of Geography, University of Maryland) *http://www.landcover.org*	2000 and 2006
5	Topographic map Badagri NE1, NW1 and NW2	1:25,000	Federal Surveys Department	1985

It has however been noted that the IPCC scenarios do not encompass the full range of possible futures as emissions may change less than the scenarios imply, or they could change more (Karl etal 2009). The scenarios do not also project all the possible future environmental changes (IPCC- SRES, 2000). This study, consequently upon these observation considered other extreme scenarios resulting in local disturbances from unprecedented anthropogenic activities in the area to possible catastrophic tectonic sea level rise. Specifically, the impact of a sea level rise of 3 to 10 meters as a result of Locally Oriented Economic Development (LOED) of the study area was assessed.

Inundation Based on IPCC-SRES Scenarios: The output of the iteration process reveals that in the event of a 0.18 (B1 scenario), 0.59 (A1FI scenario) or 1 meter rise in sea level (excluding future rapid dynamical changes in ice flow) about 9.44 ha (table 3) of land will be inundated within this range of prediction. This is highly insignificant and the land use pattern will only be modified by local anthropogenic activities. In other words, the result shows that climate change and in particular, sea level rise will not have significant impact with respect to coastal inundation on the study area based on IPCC-SRES projection. Even the A1F1 scenario impact is highly negligible. The anthropogenic changes in the area will results from local stressors. Also, the 9.44 ha expected to be inundated under the worse IPCC-SRES prediction falls within the cultivated areas that are currently known to always been flooded during storm rainfalls.

RESULTS AND DISCUSSIONS
Land use: Table 2 shows the present land use distribution along the Badagry coastline and environment. The present status shows that built up area covered about 25.97% (1919.77 ha.) of the total

area. This is followed by scattered cultivation with about 20.09%. (1485.08 ha.). However, the bulk of the areas that are currently scattered cultivation, mining pits, mangrove swamp and wet land have been acquired for developmental purposes including the proposed Badagry Greenfield Port complex. It is expected that these developments will bring additional stress on the coastal biodiversity and might create a totally different morphological dynamics within the micro environment. These new local morphological dynamics may result in coastal accretion and erosion depending on the impacts on local wave and onshore current.

Table 2: The Land Use Land Cover Classification Map of the area reveals that

S/N	Luclass	Area in Hectare	% Covered
1	Built Up Area	1919.77	25.97
2	Grass Land	522.64	7.07
3	Mangrove Swamp	967.26	13.08
4	Mining Pit	896.57	12.13
5	Palm Plantation	634.57	8.58
6	Riparian Forest	58.26	0.79
7	Sand Beach	92	1.24
8	Scattered Cultivation	1485.08	20.09
9	Water Body	214.4	2.90
10	Wetland	603.01	8.16
	Total Area Covered by Land use	7393.56	100.00

However, and as noted earlier, the IPCC-SRES predictions are not totally encompassing as they are likely to be less or more than the predicted value. With the recent upsurge of development on the Lagos Badagry coast, especially with the creation of Eko Atlantic City and the proposed Badagry Greenfield Port, the future behavior and reaction of the Badagry coast to sea level rise may be difficult to decipher. To this end, it becomes imperative that other levels of sea rise predictions have to be considered to cover all possible future scenarios.

Inundation Based on Locally Oriented Economic Development Scenarios (LOEDS): Table 3 shows the statistics of area inundated from different sea level rise scenario. The iteration process for the marginally extreme 3m sea level rise scenario revealed that 18.88 ha of land will be inundated (fig 4) with an average of 9,442.77m^3 volume of water. The expected inundation area for the 3m sea level is about 0.26% of the total study area and is presently occupied by scattered cultivation land use type. Morphologically, it represents areas with the steepest depression.

Table 3: Sea Level Rise inundation area due to locally oriented economic development

Sea level Rise (m)	No of Pixel	Area (ha.)	% from total area	Scenario Type
0-1	1	9.44	0.13	Ipcc Sres
2	2	18.88	0.26	Loeds
3	2	18.88	0.26	Loeds
4	69	654.38	8.85	Loeds
5	74	702.05	9.50	Loeds
6	159	1497.66	20.26	Loeds
7	173	1632.84	22.08	Loeds
8	190	1791.05	24.22	Loeds
9	204	1925.76	26.05	Loeds
10	543	5125.92	69.33	Loeds

For the 5m sea level rise (as shown in table 5), the iteration process revealed that about 702.05 ha occupying 9.50% of the study area will be inundated with 278,535,230.6 m^3 volume of water. Specifically, the areas that will be inundated will start from the coast and extend landward and will include the large expanse of palm plantation, riparian forest, scattered cultivation, wetland, mangrove swamp and built up areas like Seme, Igbogele, Ogungbe, Kweme and Asakpo amongst others. Substantial parts of the expressway (Lagos-Badagry Expressway) which links Nigeria to other West Africa countries like

Benin Republic, Togo and Ghana among others will also be inundated (figure 5).

For the 7m sea level rise scenario (fig 6), the iteration process revealed that about 1632.84 ha of land (representing 22.08 % of the study area) will be inundated with about 713,873,297.57m^3 volume of water. Thus, in addition to the areas that will be submerged in the event of the 5 meters sea level rise, the inundated areas in this case will extend to the Badagry creek and cover land use types like sand beach, palm plantation, wetland, mangrove swamp,

grassland, scattered cultivation and some part of the Badagry creek. Settlements that will be inundated in addition to those already mentioned under 5m sea level rise scenario will include: Akoko, Gbaji, Apa, Wesere, Ganyingbo and Igbogele ropoji amongst others. At this level of salt water intrusion, several other environmental problems, land degradation and aquatic biodiversity loss will be expected. This will have significant impacts on food security, water supply and other ecosystem services.
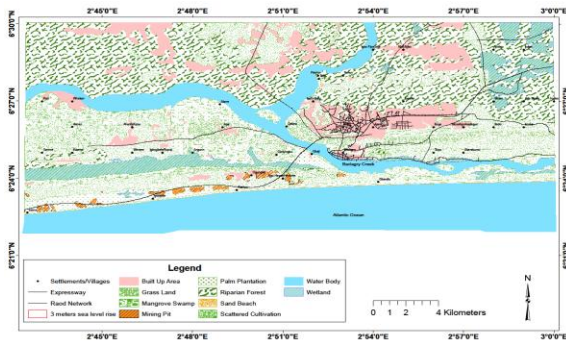

Fig 4: 3 meter marginal sea level rise due to locally oriented **development**
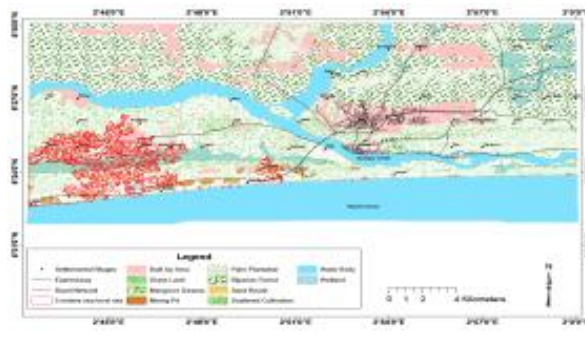

Fig 5: 5m marginal sea level rise due to locally oriented economic development

For the 9m sea level rise scenario (fig 7), the iteration process revealed that 1925.76 ha (representing 26.05% of the study area) will be inundated with 1,187,076,866.18 m^3 volume of water. The inundated areas in this case will have spread across the Badagry creek at the eastern part of the study area into communities like Topo, Akarakumo and some parts of Badagry town. The whole of the road network and all settlements from the border town up to the Yewa Bridge will be inundated with this level of sea rise. At the level, the Administrative Staff College of Nigeria (ASCON) in Topo will be under threat. The environmental problems identified in 7m sea level rise will also apply. For 10 meters sea level rise (fig

8), the iteration process revealed that 5125.92 ha (representing 69.33% of the study area) will be inundated with about 1,540,453,591.23 m^3 volume of water. The area that will be inundated in this case will be extended to the whole of Badagry town, parts of Ajara town and Doforo amongst others. The road network in the area will also be inundated and the fresh water of the Badagry creek will further be polluted with salt water. The creeks fresh water biological life will be totally altered through loss of several organisms and aquatic life. A new kind of aquatic species within the system will also emerge.
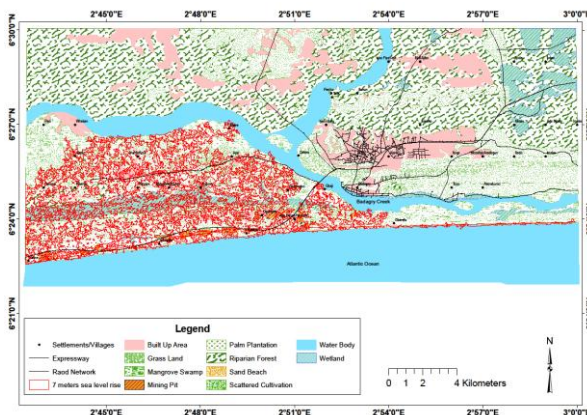

Fig 6: 7m marginal sea level rise due to locally oriented economic development
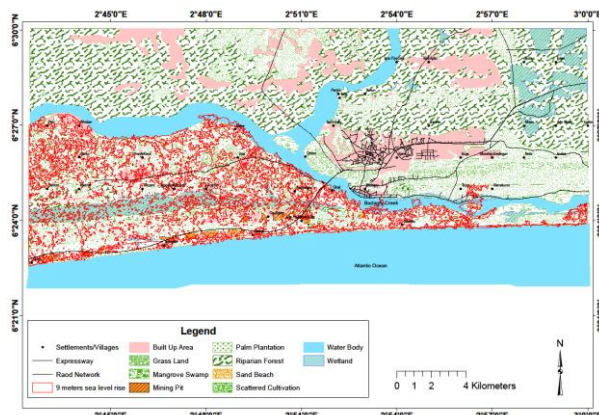

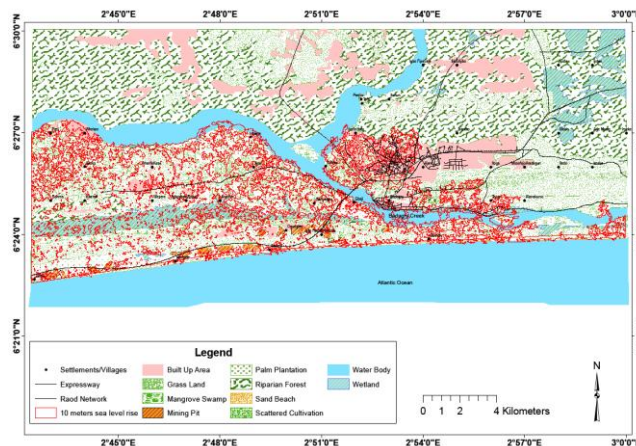Fig 7 9m marginal sea level rise due to locally oriented onomic development

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Fig 8: 10m marginal sea level rise due to locally oriented economic development

*Conclusion and Recommendation:*This study reveals that the impact of anticipated temperature increase and sea level rise under the IPCC – SRES story lines will not have any significant impact on the inundation processes around the Badagry coastal area. However, inundation based on locally oriented economic development scenarios (LOEDS) shows that the current accretion process along the shoreline may be reversed and some level of erosion and shoreline retro-gradation should be expected if LOEDS scenario attain 4 meters and above. Total area expected to be inundated ranges between 8.85% at 4 meters to 69.33% at 10 meters. Since it is environmental catastrophism and anthropogenic activities of high magnitude that can bring about such unusual sea level rise within the study area, it is recommended that coastal protection infrastructures should be integrated in any major developmental activity.

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