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# Simulated sea-level rise under future climate scenarios for the Atlantic Barrier lagoon coast of Nigeria using SimCLIM

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# Simulated sea-level rise under future climate scenarios for the Atlantic Barrier lagoon coast of Nigeria using SimCLIM

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**Abstract**. One of the challenges of climate change in most coastal regions of the world is sea-level rise. This is of serious consequence as the coastal zone plays host to a large human population, abundant natural resources, and several ecosystem services. To alleviate the effect of climate change, proper planning of the coastal area is necessary to enhance the process of adaptation. This study attempts to project an estimate of the rate of sea-level rise along the coastline of Lagos, Nigeria in various time slices, i.e., 2025, 2050, 2075, and 2100 for all 4 RCP scenarios, as recommended by the IPCC using the simCLIM model.  The result obtained shows the median projected sea-level rise values range from 11.86 cm to 49.22cm for RCP 2.6; 11.73 cm to 58.91 cm for RCP 4.5; 11.28 cm to 62.28 cm for RCP 6.0; 11.92 cm to 84.25 cm for RCP 8.0 respectively.  Based on the results of the projections obtained in this study, coastal planning is advisable to provide a means of adaptation for the inhabitants as the consequence of lack of planning could lead to avoidable losses.

**Keywords:** Climate change; sea-level rise; barrier lagoon coast; coastal ecosystems; simCLIM

## 1. Introduction

Historically, sea level has fluctuated considerably at different times throughout Earth's existence. However, the recent observations of global climate change and its consequent rise in sea levels in some regions of the world have been attributed to human activities [1,2,3,4]. A growing number of scientists agree that climate change has led to a global increase in sea level, enhanced ambient temperatures and precipitation, and other extreme events [3,5,6,7]. There are assertions that various processes contribute to this rise. These include expansion of the worlds' oceans due to global warming, melting of land-based glaciers/ice-sheets, and changes in terrestrial water storage. These phenomena have led to an increased volume of water in the ocean and have consequently resulted in the inland movement of the shoreline in most coastal communities, thereby making increasing the vulnerabilities of these communities [5,8].

In recent times, coastal regions have experienced a growth in population due to various reasons. Statistics show that 60% of the population of the world now reside in coastal cities, and the effects of this action will not only be ecological but socio-economic as well with global impact [9]. [10] projected that the population of coastal inhabitants would increase from 1.6 billion people in the 1990s to 5.2 billion people in the 2080s (this includes assumptions based on migration). Any increase in sea level poses a significant risk to these seaside inhabitants, and subsequently lead loss of lives and properties. Although exposure based on physical attributes will affect both humans and the entire ecosystem at large, inadequate

adaptive capacity can exacerbate the extent of vulnerability. Most developing countries suffer more consequences of global warming because of overdependence on climate-related livelihoods. The aggravated effects could also be due to the absence of coping mechanisms [11]. The implication could be far-reaching and lead to unprecedented destruction in these developing regions if left unchecked. The developed nations are not excluded, as climate change increases the occurrences of extreme events, which leads to socio-economic losses even though these countries exhibit a higher level of adaptive capacity.

The Nigerian coastline is low-lying, making it a hotspot of vulnerability to sea-level rise [12,13,14]. This necessitates the need for research about the coastal region to inform policymakers of the magnitude of the possible impacts of accelerated rise in sea level in the region [13]. Integrated assessment modelling incorporates the amount of water gained into the world oceans because of the loss of land ice. This is an advantage over previous methods as they fail to account for this contribution, thereby leading to an underestimation of both global and regional sea-level rise [15]. Most studies along the coastline of Nigeria utilise the index-based/indicator-based approach to assess vulnerability along the coastline. Hence, a deficit in methods that makes use of Integrated Assessment Modelling exist. This study is an attempt to apply the integrated assessment modelling to assess the level of vulnerability of the coastal region of Nigeria to increasing sea levels.

## 2. Materials and Method
### 2.1 Study area

The coastline of Nigeria, located in the Gulf of Guinea, is approximately 853 km. It lies on the West Coast of Africa between Latitude 4°10′ to 6°20′N and Longitude 2°45′ to 8°32′E. It extends from Seme border in Badagry in the West, to Ikang, a community located in Cross River State in Eastern Nigeria, and it descends into the Atlantic Ocean The estimated total land area of Nigeria is 923,773 km$^2$ with an estimated 2020 population of about 206 million [17]. The country's vegetation consists of a variety of ecological habitat that supports the existence and interaction of terrestrial and aquatic life.

The coastline is low-lying and it is endowed with a vulnerable mangrove system, which has depleted over time due to anthropogenic activities such as crude oil exploration, use of wood as fuel, timber, fishing, sand mining, etc. Lack of government policies that protect these vital species has contributed enormously to the destruction of this vital ecosystem. The inland elevations range from 2 to 4 m above mean sea level, stretching through a distance of about 15 km in Lagos, 25 km East of the Niger Delta, and up to 150 Km in the Niger Delta [11]. The Nigerian coastal zone is characterised into four distinct geomorphic zones. These are the Barrier-Lagoon Coastal Complex, the Mahin Transgressive Mud Coast, the Arcuate Delta, and the Strand coast [17,18,19]. The coastline of Nigeria is home to several coastal cities which include Lagos, one of the fastest-growing megacities in the world with a population of about 20 million people and Port Harcourt, a city located in the Niger Delta region, home of the oil and gas sector [20]. The present study was focused on the Lagos lagoon coastline (Figure 1).
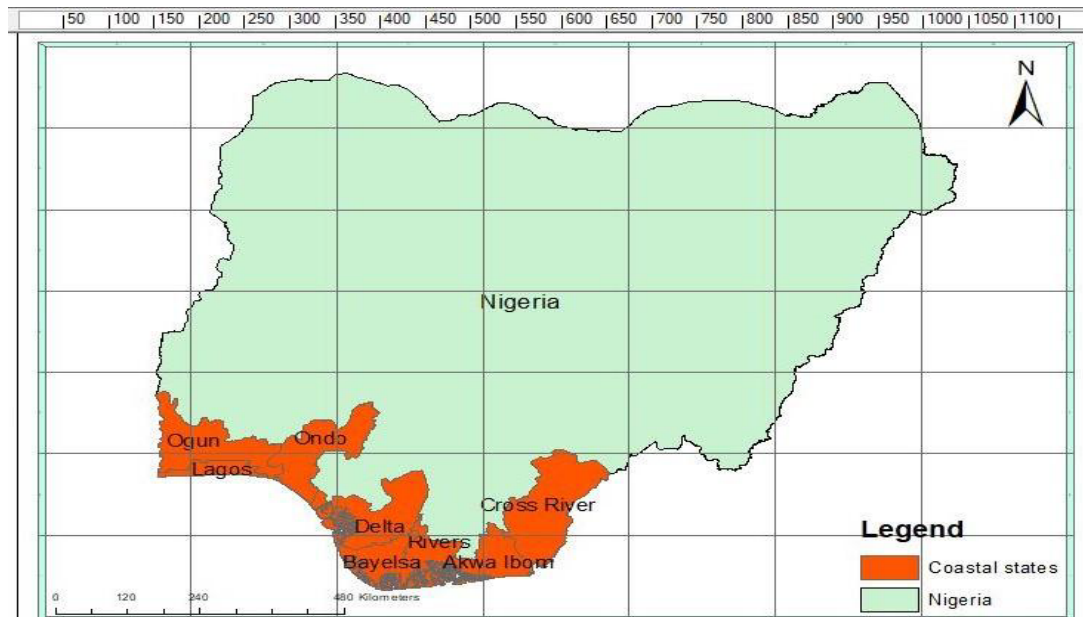
Figure 1: Map of Nigeria showing the coastal states (Source: Esri ArcGIS)

*2.2 Method*
SimCLIM Modelling software was used in this study. SimCLIM is an integrated model system that helps to simulate the effects of climate change and variability, both spatially and temporally. In recent times, most coastal impact studies have neglected the estimation of regional assessments of variations in sea level. This is mainly due to inadequate technical expertise and access to relevant and usable data. The software, SimCLIM, was developed to proffer solutions to this challenge. It makes use of the pattern scaling method that was re-gridded to a 720×360 grid (i.e., 0.5°×0.5°) using a bilinear interpolation method. The General Circulation Model (GCM) data in SimCLIM is from Coupled Model Intercomparison Project Phase 5 (CIMP5), which is also the data source for IPCC Fifth Assessment Report (AR5), and it provides projected values of climate change impacts using the sea level rise generator function [21].

The simCLIM software can be used to give high, medium and low projections for the four different Representative Concentration Pathways (i.e., RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) introduced by IPCC AR5. The Representative Concentration Pathway (RCP) approach supersedes the Special Report on Emissions Scenarios (SRES) scenarios, as indicated in the IPCC Fifth Assessment Report (AR5). The SLR projections from the simCLIM software are obtained from the sea-level rise scenario generator, which gives the predicted values in three (3) sensitivities (low, mid, and high). These values are based on a range of uncertainties of the projected values. The data inputted was obtained from the Coordinated Regional climate Downscaling Experiment (CORDEX), which is a World Climate Research Program (WCRP) supported structure, and its main aim is to generate ensembles of regional climate projections for all continents globally.

## 3. Results and discussion
The projected trends in sea-level rise at interdecadal time scales are shown in Figs. 2 - 5. As indicated in the figures, the median sea-level rise (SLR) projected values for the Nigerian coastline based on the RCP 2.6 for the year 2025, 2050, 2075, 2100 are 11.86, 24.89, 38.09 and 49.22 cm, respectively. According to [22], a 1 m increase in sea level will inundate 75% of the entire Niger Delta region. This could lead to an estimated 6 to 10% loss in the Gross Domestic Product (GDP) of Nigeria by the year 2050, as well as the loss of properties worth about US$100-460 million. The projected SLR for RCP 4.5 for the year 2025 is 8.63 cm, 11.73 cm, 14.69 cm for the low, median and high projections respectively. The values for year 2050 are estimated to be 18.98 cm, 26.05 cm, 33.22 cm, while the median projections for year 2075 and 2100 are 42.62 cm and 58.61 cm, respectively.  The projected values for RCP 6.0 ranged from 11.28 cm in the year 2025 to 25.04 cm in the year 2050, and 42.09 cm

and 62.28 cm in the year 2075 and 2100 respectively. Potential future changes for RCP 8.5 are 11.92 cm and 29.07 cm for the year 2025 and 2050. These values are for the mid projection, given a business-as-usual scenario, i.e. continual emission of greenhouse gases without cutbacks. It is projected to rise to 53.09 cm and 84.25 cm for the year 2075 and 2100, respectively.
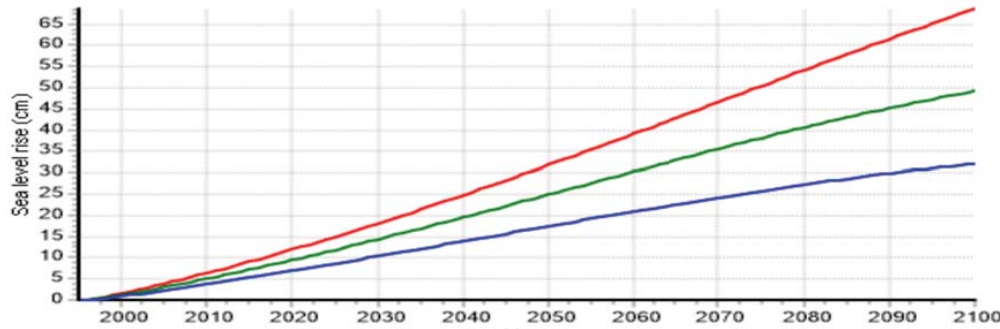
Figure 2: Sea level rise projection for the coastline of Lagos, Nigeria using simCLIM (RCP-2.6)
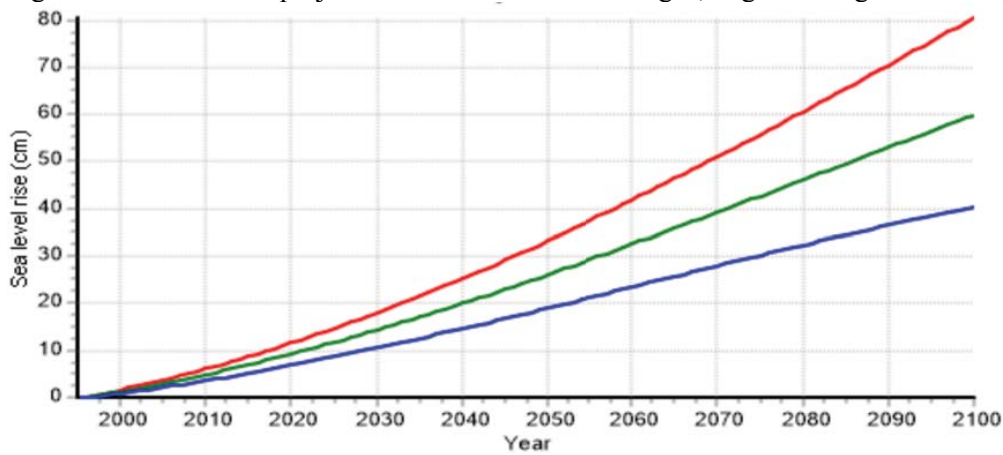
Figure 3: Sea level rise projection for the coastline of Lagos, Nigeria using simCLIM (RCP-4.5)
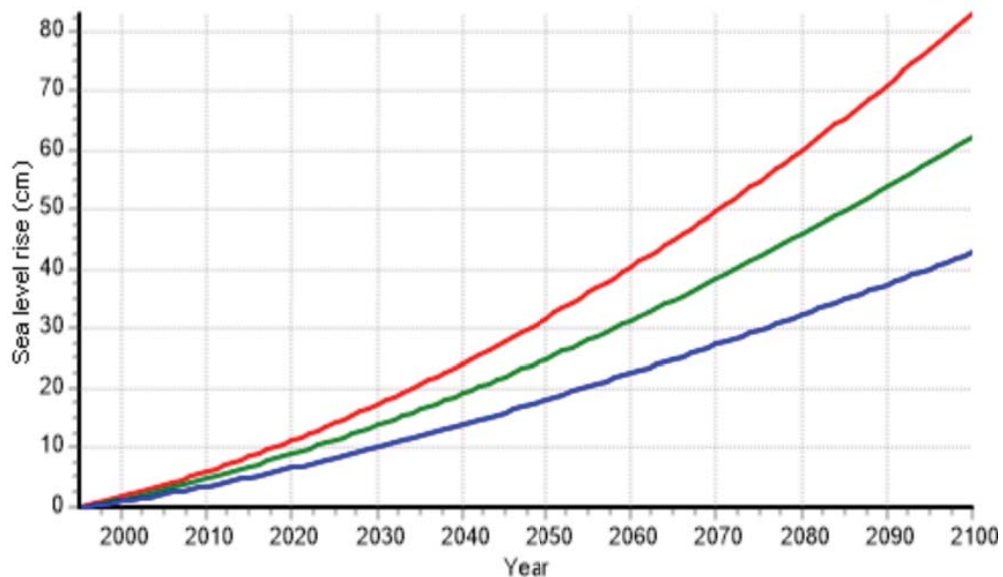
Figure 4: Sea level rise projection for the coastline of Lagos, Nigeria using simCLIM (RCP- 6.0)
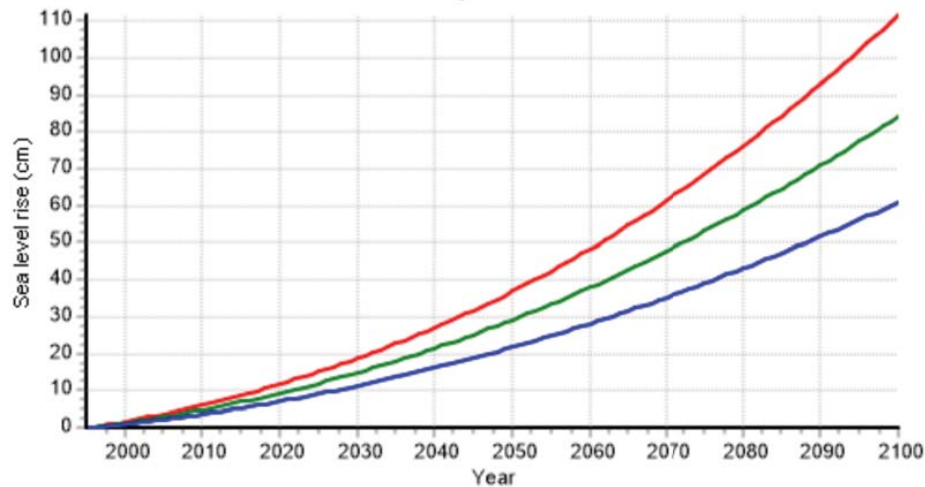
Figure 5: Sea level rise projection for the coastline of Lagos, Nigeria using simCLIM (RCP-8.5)

The result of this study emphasises the need and importance of coastal planning and management to enhance adaptation of the inhabitants of the Nigerian coastal zone. Although the significant occupation of the rural dwellers in the region is mainly fishing, there have been reports of a decline in fishing activities due to various factors such as rising waters and marine pollution, which occurs mainly because of oil spills [23-26]. This has led to a high rate of rural to urban migration as the primary source of livelihood in the rural coastal settlements are being threatened and has led to increased poverty status. A significant issue faced by coastal dwellers in Nigeria is coastal erosion and is being exacerbated by climate change and other anthropogenic activities such as mining. There are some reports about the accretion of sediments around the Niger Delta region. However, coastal cities like Lagos are facing erosion of beaches [8,13]

## 4. Conclusion
This paper has attempted to predict the rise in sea level of the Nigerian coast, under different RCP scenarios using simCLIM. Due to the high level of vulnerability of the Nigerian coast predicted by this study, coastal adaptation strategies need to be executed by environmental agencies as proactive measures to avoid the losses associated with an elevated sea level. This paper serves to provide information to aid coastal planners and create awareness for coastal inhabitants.

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