JENRM, Vol. 4, No. 3, 15-22, 2017
Research Article

# Assessing The Effects Of Climate Change On Sea Level Rise Along The Gulf Of Guinea

Caleb Mensah*, Amos T. Kabo-bah**, Eric Mortey***

**Abstract**
The sea level is rising due to global warming in response, by and large, to anthropogenic activities. Coastal communities along the Gulf of Guinea are low lying which makes them more vulnerable to rising sea level. Due to the topography of the Gulf of Guinea, the coastal belt is a highly erosive sandy barrier system that is susceptible to flooding. In West Africa, highly productive ecosystem like mangroves, estuaries, and deltas, that form the vital socio-economic activities like trade, tourism, fisheries and industrial growth due to the oil and gas development are found in these coastal communities. Therefore, majority of the population in West Africa who live in these mega cities along the coast face possible threats. Thus, climate adaptation is the only option to address these future threats as reduction in the emission of carbon dioxide ($CO_2$) and other green house gases is not enough for now to prevent global warming which leads to sea level rise. Thus, this study seeks to investigate from other research works, how sea level rise has affected these coastal communities along the Gulf of Guinea and how the communities are adapting to these challenges to new ways of living. It concludes with a recommendation on a climate change based framework.

**Keywords**
Coastal Erosion—Sea level rise—Climate Change Effects—Global warming

*Department of Matter and Energy Fluxes, Global Change Research Institute CAS (CzechGlobe), Brno, Czech Republic, Faculty of AgricSciences, Mendel University, Brno, Czech Republic, Earth Observation Research and Innovation Centre, University of Energy and Natural Resources, Sunyani, Ghana.
*E-mail: caleb.mensah@uenr.edu.gh*
**Earth Observation Research and Innovation Centre, University of Energy and Natural Resources, Sunyani,Ghana.
*Email: amos.kabobah@uenr.edu.gh*
***Earth Observation Research and Innovation Centre, University of Energy and Natural Resources, Sunyani, Ghana.
*Email: morteyeric@gmail.com*

## Contents



## 1. Introduction

Sea level over the recent years, caused mainly by climate change has received much attention globally due to its devastating nature. The earth has warmed and cooled many times since its formation over billions of years ago, mainly due to both natural and man- made induced changes within the land and atmosphere system [16]. These natural forcing arise due to solar changes, climate variability and explosive volcanic eruptions. Man-made activities which has also greatly contributed to climate change comes from burning of fossil fuels over this industrial era, which releases carbon dioxide ($CO_2$) gas, water vapour and other reactive gases into the atmosphere. These Green house gases and aerosols affect the climate by changing the incoming solar radiation and out-going infrared (thermal) radiation that are part of the Earth's energy balance, which leads to a warming or cooling of the climate system. The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report in 2007, reported on a global average sea level rise of about 195 mm from 1870 to 2004 and further predicted through the fifth assessment report in 2013, an annual rise of 26cm to 86cm for the 21st Century, due to the increase in green house gas emission and global warming. This report attributed the main cause of sea level rise to two main mechanisms, namely;

1. Thermal expansion, where the ocean water expands and rise as a result of global warming and

2. Melting of major land ice stores like ice sheets and glaciers found in Antarctica and Arctic regions of the world (IPCC, 2007).

Local mean sea level is defined as the height of the sea with response to a land benchmark averaged over a period of time such as a month or year, long enough that

fluctuations caused by waves and tides are smoothed out [17]. Thus, an increase in the height of the sea above the local mean sea level caused by global warming within the 21st Century will worsen inundation, increase coastal erosion and cause more temporal and permanent flooding tides in low lying coastal environments which include the coast of Gulf of Guinea [7]. The Gulf of Guinea, as shown in Figure 1, is the North Easternmost part of the Tropical Atlantic Ocean, between Cape Lopez in Gabon and north and west to Cape Three points in the Western region of Ghana. The Gulf of Guinea's coastal complex mainly consists of a low lying sandy barrier system which is highly erosive and susceptible to flooding [13]. The coastal cities along the West African coast of the Gulf of Guinea are densely populated, and it is continuously becoming an urban megalopolis with the potential of attracting more inhabitants, due to its rapid industrial growth, fisheries, trade and tourism. These coastal areas are the locus of rapid urban and industrial growth, oil and gas development, industrial- scale fisheries and tourism. A report by the United Nations Environment Programme showed how biodiversity of the coastal zone is an important resource [27]. The marine and coastal resources have traditionally supported livelihoods through subsistence fisheries, agriculture and trading [**?**]. The shallow coastal strip attracts bulk of the regional market and has the greatest regional trade potential in West Africa due to its agricultural and mining resources. Thus, there has been a general trend of population increase in the coastal areas, with the coastal cities being the principal growth nodes. It has been estimated that by 2025, the coastal zone from Accra to the Niger delta could be an unbroken chain of cities, with a total population of about 50 million people along 500 km of coastline [15]. Much of the West African region's heavy industry, including most refineries and gas liquefaction plants is sited at these coastal locations, along with terminal facilities for tankers, undersea pipelines and bases for offshore engineering services [29]. The projected sea level rise will definitely have severe impacts on life and the socio- economic activities within the West African region [20]. As such, these coastal cities need to adopt certain measures which will have short and long term benefits of reducing the effect of sea level rise along the coast.

Recent evidence recorded at most cities along the Gulf of Guinea like Lagos, Accra, Dansoman, Keta, Ada and other deltaic areas, have shown accelerated coastal erosion with severe flooding, degradation and modification of the coastal ecosystem. These have all been as a result of the rise in sea level [22]. Other effects also include the more intense and frequent extreme rainfall events in both coastal and inland zones due to the increase in the global surface temperature. Over the past decade, 20 storm surges have been documented along the Victoria beach in Lagos [13]. This is expected to further add to water scarcity and population displacement if not checked. Without Adaptation, large land areas and millions of people will be displaced by sea level rise. Appropriate responses include Climate mitigation and National Adaptation programmes. These adaptation responses could reduce the impacts of sea level rise significantly through the construction of sea walls and other artificial defences to protect roads, buildings and other vital coastal resources. In a meeting organized by the Economic Community of West African States (ECOWAS) on the 18$^{th}$ to 20$^{th}$ of June, 2013 at Accra, Ghana, the United Nations Framework Convention on Climate Change (UNFCCC) recommended to the coastal countries to adopt adaptation programmes that will have a more coherent, systematic approach to climate- resilient coastal planning, rather than a fragmented approach that centres on siloed adaptation activities. The UNFCCC also suggested in its report on a more coordinated research and sharing of data or information between the coastal countries in facilitating the identification and filling of regional climatic data gaps, that could help understand the trans boundary impacts as well as country- to- country learning in addressing similar climate change impacts [28]. This study seeks to assess the impacts of the sea level rise due to climate change on the coast of the Gulf of Guinea and further suggest ways through which these impacts could be reduced in a more climate friendly manner.

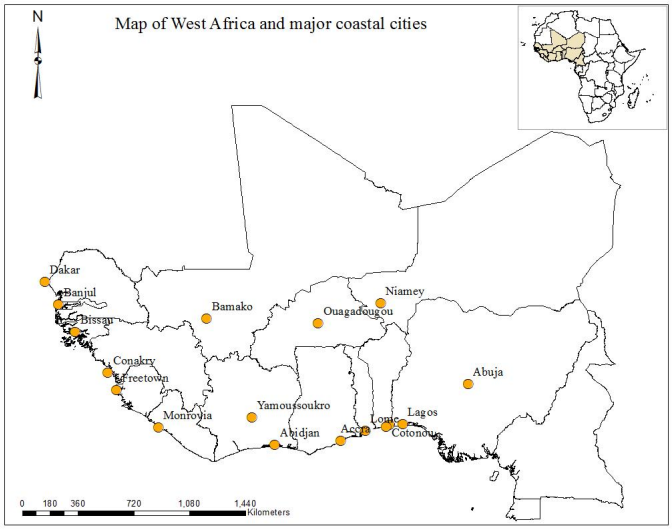


**Figure 1.** The Map Of The Gulf Of Guinea Showing Coastal Cities [7]

## 2. Overview of Related Work

Climate Change is one of the most challenging issues facing the world today. It has led to a rise in the earth's average surface temperature by about 0.7° C over the past 100 years [14]. The resultant thermal expansion of the ocean and the increased melting of the glaciers

have facilitated the sea level rise in the oceanic system. Sea level rise differs from one place to another because of isostatic adjustment of the mantle, nevertheless their impact on the coastal zone is significant. It threatens vulnerable coastal areas with flooding, frequent storm surges and increased erosion as the shoreline moves more inland enabling waves to break and and dissipate more energy nearer to the shore. This enhanced landward movement of the coastline brings about loss of life and properties and the destruction of businesses which leads to loss of revenue to both local and national government, creating a general environmental catastrophe [5].

Economic activities coupled with the complex oceanic processes results in certain morphological changes which affects the coastal environment greatly. Human impacts in the coastal zone worsens the natural stress from wave and tidal forces. [2] identified the ranging geological constituents along the coast as a major driver of erosion. Beach sand gravel mining and general lack of enforcement of laws banning beach sand mining was identified by [4] as a major cause of increased erosion in Accra. He further identified the unplanned physical infrastrucutre development, population increase and increasing tourism development in the coastal zone as a cause of increased erosion. Coastal vegetation is cleared and wetland are drained for infrastructure development [23].

Also, [13] researched extensively on meteorologically induced storm surges in the Gulf of Guinea. This work gives account of how the average of higher high water (HHW) level for the Victoria island near to Lagos, Nigeria has increased from 0.9m above the zero of the tide gauge with tidal range of about 1m to over 2m above the zero of the tide gauge in recent years. These oceanographic conditions were further aggravated when the swells coincided with the high tides and spring tide. Thus, from the studies, it can be shown that while natural oceanic processes results in a cyclic event, human activities from construction along the coast accelerates cyclic behaviour which results in these storm surges and coastal erosion or flooding in most vulnerable areas. The vulnerability of coastal systems to sea level rise and to other drivers of climate change is determined by their sensitivity, exposure and adaptive capacity [23]. Also it must be noted that the prevailing situation of increasing vulnerability on the already high vulnerable coastal areas calls for concerted efforts in addressing the threats, as vulnerability is specific to given location, sector or group [16]. Regions with low reliefs and erodible substrates show histories of subsidence and shoreline retreat with high wave and tidal energies [14]. The Cameroon coastal lowland zone has come under the influence of increased magnitude of global environmental change processes exhibited by flooding, saline water incursions, erosion, wetland loss and the threats of sea level rise due to global warming, and is today focused upon as a disaster zone. In the three consecutive years (2004 - 2007), this area recorded flood related hazards similar to the effect of the December 2004 Tsunami, which flooded South East Asia [10]. Also, Gleefe, a coastal community in Ghana, has over the years experienced frequent flooding due to the increasing occurrence of storm surge and sea-level rise. Gleefe and its environs experience relatively severe erosion due to the presence of unconsolidated as well as poorly consolidated sediment, making the area extremely vulnerable to the impact of sea level rise [7]. Coastal erosion hotspots have been identified along the Accra coast, where about 80% of the shoreline is eroding and the remaining 20% is either stable or accreting as reported in a study by [5] on the detection, measurement and prediction of shoreline change in Accra, Ghana. Below is a picture on how the west coast of Accra has been eroded by the sea over the years.

**Figure 2.** The Map Of The Gulf Of Guinea Showing Coastal Cities

This has affected the social and economic of the local population, threatened cultural heritage and hindered coastal tourism development [26]. According to [11], a substantial amount of houses has been lost to coastal erosion in the past and the trend continues in some areas along the coast. On the western part of Accra, [12] on the sustainability of coconut palms Cocos Nucifera Linnaeus 1753 in coastal Ghana, reported that 17 local inhabitants in two coastal communities lost their buildings to coastal erosion over 26 years. A study by [6] estimates that about 85 houses will be lost to erosion in three communities in the western part of Accra by 2025 under the increasing rise of sea level, which will displace over 2000 coastal inhabitants. The number of buildings which are much likely to be affected by the year 2050 for Dansoman is estimated at 381, whiles by the year 2100, a total of about 926 houses could be destroyed at the coast if not checked. This confirms studies by [4] and [2] that identified the coastal section of Ghana as being erosion prone. Also Keta, another coastal town in the Volta Region of Ghana,

was partly destroyed by the sea erosion at the end of the 20$^{th}$ century. Keta is situated on a sandpit separating the Gulf of Guinea from the Keta lagoon. Due to this double waterfront, the city is highly vulnerable to erosion. It is flooded from the ocean front during high tides and from the lagoon front during heavy runoff, especially in the rainy seasons. During devastating erosion events between 1960 and 1980, more than half of the town area was washed away. Since 1999, more than US$80 million have been invested by the government to protect, restore and stabilize the coast of Keta [9].

## 3. Monitoring Of Sea Level Rise Along The Gulf Of Guinea

Tide gauge measures sea level relative to a crustal reference point, which may be moving vertically at rates comparable to the true sea level signals. Tide gauges have limited spatial distribution and suboptimal coastal locations and thus provide poor sampling of the open ocean. These measure changes in total sea level, but only around the coast and at islands. Satellite altimeters give near- global measurements of the sea level change every repeated period (eg. 10 days). Remote sensing advancement has thus enabled the provision of a continuous monitoring of the shoreline globally. Scientists are now able to measure and monitor closely the world's waters globally in a sustained and comprehensive way using a combination of satellite observations and sensors in the ocean. With satellite measurements, scientists are able to better predict the rate at which sea level is rising and the cause of that rise.

The US's National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) and the EU, have satellite missions devoted to sea level research, which include: the Gravity Recovery And Climate Experiment (GRACE), which maps Earth's gravitational field with precision and resolution, and whose data helps us better understand movement of water throughout the Earth; the Ocean TOPography Experiment (TOPEX/Poseidon), a joint U.S./French satellite that uses radar to map the precise features of the oceans' surface; Jason, which measures ocean height and monitors ocean circulation; and the Ice, Cloud and Land Elevation Satellite (ICESat), whose primary purpose is to study the mass of polar ice sheets and their contributions to global sea level change. Less work has been done along the Gulf of Guinea using satellite altimetry measurements to monitor and predict sea level rise. However, [30] carried out validation studies at Sao Tome Island, Gulf of Guinea, where altimeter data from TOPEX/POSEIDON (T/P) were analyzed and compared with shallow pressure tide gauge. Sea level variations were seen to be consistent with known seasonal mean sea level cycle of the area, due to steric sea level changes.

Figure3 is a recent TOPEX/Poseidon and Jason satel-

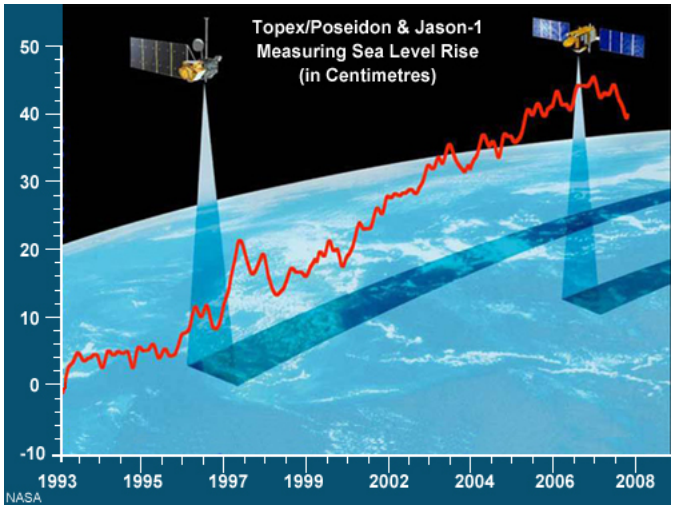


**Figure 3.** The observed rate of sea level increase within 1993 to 2006

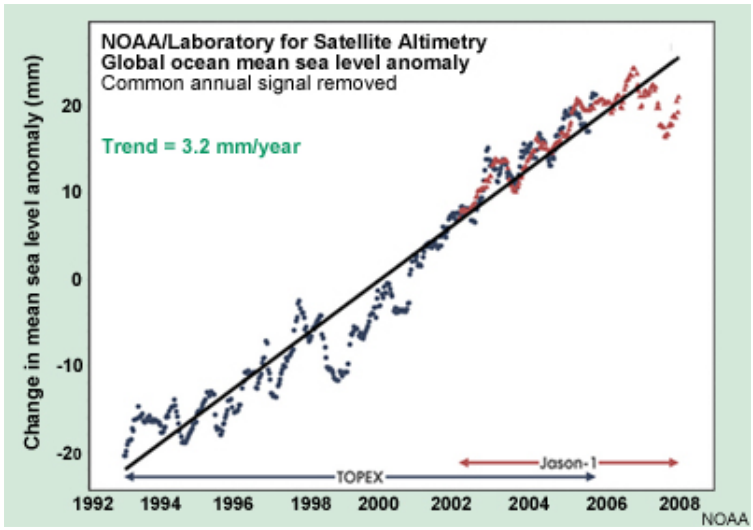


**Figure 4.** Graph showing Global sea level rise

lite observations, which shows an exponential increase in global mean sea level in centimeters from 1993-2008. Figure4 also shows an average increase in global mean sea level of three millimeters a year. It is anticipated that sea level will continue to rise for several centuries, even if greenhouse gas emissions are stabilized, due to long lag times required for the deep oceans to respond. Global warming has also resulted in the continuous melting of ice sheets that contribute mainly to sea level rise. Studies by [4] investigated the impact of sea level rise on future shoreline evolution trend using remote sensing methods coupled with archival shoreline data that enabled future rates of change to be predicted. Ghana as a whole like other countries along the coast of the Gulf of Guinea has few points for recording tidal heights. The use of remote sensing technology will enable a cotinuous monitoring of the shoreline globally to detect, measure and analyze any change. Historic rate of change information and estimated sea level rise will enable the future shoreline positions over time to be estimated and its impact on the coastal environment identified. There has been several investments made by other countries like Tunisia, Morocco, Nigeria and Kenya, with funds allocated for necessary sea level equipment. One disadvantage has been with countries not willing to share with other neighbours or the international community. Takoradi station has been enhanced with radar and pressure system by the National Institute of Oceanography, India in Ghana. This station provides new set of tidal and non-tidal residual information [3]. Satellites images have shown that the extent of Arctic sea ice has declined by about 8.5% per decade from its size in 1979 [14]. According to [21], if the observed increases in ice discharges rates from the Greenland and Antarctic ice sheets were to increase linearly with global mean temperature change, this would add a 0.05 to 0.1m rise in sea level over the century. The effect would vary locally due to prevailing factors such as isostatic adjustment of the mantle and variations in oceanic level change [20].

The vulnerability of the coast of Gulf Guinea needs to be taken seriously and proper measures put in place to reduce the negative effects. Traditionally, global sea level change has been estimated from tide gauge measurements collected over the last century. Tide gauges, usually placed on piers, measure the sea level relative to a nearby geodetic benchmark. In order to measure long term sea level changes accurately, it is important to ensure that tide gauge instrumentation remains stable over time. This process is known as datum control and historically, it has been achieved by careful monitoring of tide gauge elevation relative to local benchmarks and datums. Sensors continuously record the height of the water level with respect to a height reference surface close to the geoid. Water enters the device by the bottom pipe and electronic sensors measure its height and send the data to a tiny computer. The measurements make it possible to derive the mean sea level. Using this method, sea level slopes up to several 0.1 m/1000km and more have been detected. Data collected from tide gauges is also of interest to scientists measuring global weather patterns, the mean sea water level, and trends. Tide gauge technology has advanced considerably over the last few decades and nowadays, many countries have adopted acoustic gauges or radar gauges as their standard means of sea-level measurement [33].

### 3.1 Vulnerability Of The Gulf Of Guinea

Some coastal areas in the world will experience rise above the normal sea level, whilst in other places, sea level will be low. Coasts subsidence due to natural or human induced causes will experience large relative rises in sea level. In some locations like the deltas and coastal cities along the Gulf of Guinea, this effect will be significant. Increases in extreme sea level due to the rise of mean sea level and changes in storm characteristics will hugely affect these coastal nations and local coastal environmental managers [25]. Although [25] suggested relocating some inhabitants in the more erosion and disaster prone areas, as a measure to manage the erosion problem in the coastal sections, the residents are rather resolved to maintain their occupancy due to their strong cultural and social ties to their respective communities. The government as such, has adopted constructing hard engineering structures, such as groynes and revetments, to manage coastal erosion in the critical areas along the coast. This approach is not sustainable as the erosion problem is simply transferred down-drift of the coast.

Future coastal environmental modeling has revealed how both tropical and extra- tropical storm intensity will increase, implying more coastal impacts than attributable to sea level rise alone especially for the Gulf of Guinea [21]. These changes in the storm characteristics include increase in wave height with more intense and erratic storms that would displace millions of people homeless along the coast of West Africa. Human modification of the hydrologic cycle along the coast due to industralization also affects sea level rise greatly. According to [13], the severe storm surges recorded along the Gulf of Guinea coast mostly coincided with the astronomical high tide conditions which exacerbated the flooding of the low lying nature of the coastal system. The storm was also preceeded by a low barometric pressure recorded at the tide gauge station. Whenever storm surges occur which usually last for a day or two, erosion rates are highly aggravated. For example it is reported that in Lagos, about 5-8m of the Victoria beach was lost during the August 1995 storm surge. The high erosion rates and the resultant flooding usually destabilizes socio-economic activities. High rates of erosion also result in uprooting of coastal settlements, decimation of agricultural and recreational grounds, destruction of harbour and navigation structures and damaging of oil producing and export han-

dling facilities [13]. The effect of tectonic activities along the coast was also found to be crucial for sea level rise, for example over places like Accra. Earthquakes that occured in the locality of Accra over the past recent years with major shocks was experienced in 1906, 1939 and 1969. According to [7], the 1939 incidence recorded the most severe earthquake as having a magnitude of 6.5 on the Richter scale. Although most of the shocks was centered in Accra, strong effects were reported along the coast. In 1911, the eastwards effect of the earthquake in Accra resulted in Lome, Togo, experiencing a trough tidal wave.

### 3.2 Effect On Coastal Environment

The warming trend associated with global climate change and sea level rise will affect the zooplankton community structure, especialluy during the major upwelling season. A study by [32] reported a significant decline of 6.33ml per $1000m^3$ per year in Zooplankton biomass in the Gulf of Guinea from the late 1960s to the early 1990s, and attributed the trend to the global warming. Sea level rise may kill forest species at the coastal forest margin through the increase in soil salinity, hydroperiod or through coastal erosion. According to a report by the United States of America, Department of Interior, dying trees at a marsh or forest border have been spotted since 1957 on the Atlantic coast of Florida near the Georgia border and have been interpreted as victims of sea level rise [19].

Near large estuaries, coastal forest often shares border with tidal freshwater marsh. It can therefore be concluded that sea level rise will cause forest retreat through its effect on the flooding regime in these areas, because the conversion of forest to freshwater marsh is generally associated with increased hydroperiod rather than increased salinity. Some coastal forest retreat appears to be linked to increasing salt exposure, rather than increased flooding [23].

However, the effect would vary locally due to prevailing factors such as isostatic adjustment of the mantle and variations in oceanic level change. Some coastal areas in the world will thus experience rise above the normal, whilst in other places sea level [14].

To address these challenges, the United States Agency for International Development (USAID) established the 5-year West Africa Biodiversity and Climate Change (WA BiCC) Program, which will join with West African and international partners to improve coastal resilience to climate change in West Africa. To effectively achieve this goal, WA BiCC is supporting ongoing efforts at national and regional levels to coordinate and integrate climate policy and socio-economic approaches, develop and refine climate- and disaster-related indicators, improve monitoring and early warning systems, and improve techniques for data collection, analysis and communication. WA BiCC will identify effective coastal adaptation practices, barriers to access of information, and experiences and opportunities to foster collaborative action.

## 4. Conclusion

Global forecasts project a 33% area loss in coastal wetlands between 2000 and 2080 with 36cm of sea- level rise [17]. Sea- level rise will also affect urban, developed lands by inundating infrastructure, with 2.4% of the global population forecasted as being displaced in this century [22]. Coastal adaptation is thus, urgently required [**?**], so as to plan for a sustainable future. It is very important to identify the areas that are much vulnerable along the Gulf of Guinea to sea- level rise. Assessing the impacts to urban, developed lands and environmental systems from the sea- level rise could be done by analyzing the land cover and land use. The threat posed by this sea-level rise is critical and devastating. [6] concluded that by the year 2100, the most likely range of the sea- level rise in the Dansoman coastal area, a suburb of Accra in Ghana, from a model projection will be between 21.2cm - 79.7cm, with $0.48km^2$ of the coastal land being lost by the year 2050 to permanent inundation. He concluded on such a statement with reference to the 2005 baseline. This will lead to the displacement of a greater percentage of the local population due to relatively high rate of the population growth in the coastal community.

Sea-level rise will inundate areas and cause wetland migration. For the coastal vegetation, it is projected that a maximum of about 6.0ha of vegetation along the Gulf of Guinea would be lost to permanent inundation by the year 2050. Fish landing sites could also be destroyed. The large scale salt industry in Saltpond, Panbros, the Densu delta and other major salt winning coastal communities along the Gulf of Guinea with their communities will be severely impacted. Thousands of species of animals particularly birds whose habitats are the wetland vegetation and lagoons will be affected. Increased erosion and flooding in the Densu wetlands will affect the habitats of migratory birds and destroy the ecology [7].

Human health and life of the coastal population suffers from inundation and pollution in terms of food, water quality and sanitation. Coastal inundation may aid in the spread of parasitic and enteric diseases in the communities through the stagnant flood waters. The stagnant waters breed mosquitoes which cause malaria. Others have already reported of other strange skin diseases and rashes which affect children rampantly during these seasons of floods. People living in the coastal communities of West Africa are aware that the sea is rising and the beaches are eroding. This study has revealed the fact that inhabitants have no systems in place to help them adapt to the problem of inundation in the communities [7].

This study has reviewed similar works done on the sea-level rise and its significant impact of coastal inundation along the Gulf of Guinea on the socio-economic activities of the people and countries involved. It has also exposed the level of awareness of the region on the coastal flooding

and the mitigation measure which need to be in place. Some sand barriers were built in some local areas to help in adapting to the gradual sea- level rise. Sand from the coastal area were dug and formed mould barriers with stones to protect structures. However, majority of these barriers are ineffective and cannot resist the impacts of the sea as it moves onshore, collapsing the barriers. The government has also intervened by building sea defence walls in most of these coastal towns to resist the risk of flooding in these areas. The high risk state of the coastal area requires pragmatic measures to manage the coastal environment and resources.

## 5. Recommendations

To plan responsibly for future sea- level rise which is inevitable, due to climate change, it is crucial that we jointly plan for human and ecological systems. There should be high awareness on the causes, effect of climate change and sea- level rise amongst the coastal population in areas which are more vulnerable to flooding. In so doing, properties and life could be preserved, as are more cautious.

Key planning decisions for sea level rise should be based on the best available scientific knowledge and based on the best available scientific knowledge, with careful considerations of long- term benefits for a sustainable future. Decisions on adaptation or mitigation measures should also take into consideration economic, social and environmental costs. There is therefore the need to explore the option of using soft engineering measures, such as beach nourishment which facilitate managing with nature, to manage the erosion problems in the coastal section. The measures if adopted would preserve the source of livelihood of the inhabitants as well as their social life and the marine ecosystem.

## References


[1] Allen, J., Somerfield, P., and Gilbert, F. 2007: Quantifying uncertainty in high- resolution coupled hydrodynamic- ecosystem models, Journal of Marine Systems, 64, 3-14.

[2] Anokwa, Y., Martin, N. and Muff, R. 2005: Coastal Stability Map of Greater Accra Metropolitan Area. Environmental and Engineering Geology Map of Greater Accra Metropolitan Area. Accra, Ghana.

[3] Aman, A., Woodworth, P. and Testut, L. 2006: Contribution of ODINAfrica to sea level monitoring in Africa. Presentation at the World Climate Research Programme workshop on Understanding Sea-Level Rise and Variability, Paris, 6-9 June, 2006.

[4] Appeaning Addo K., Walkden M. and Mills J.P. 2008: Detection, measurement and prediction of shoreline recession in Accra, Ghana. J Photogramm Remote Sens 63:543–558.

[5] Appeaning Addo, K. 2009: Detection, Measurement and Prediction of Shoreline Change in Accra, Ghana. Lambert Academic Publishing, Germany. pp 234.

[6] Appeaning Addo, K., Larbi, L., Amisigo, B. and Ofori-Danson, P.K. 2011: Impacts of Coastal Inundation due to Climate Change in a cluster of Urban Coastal Communities in Ghana, West Africa. Remote Sens. 3(5); doi:10.3390/rs3050962.

[7] Appeaning Addo, K. 2012: Shoreline Morphological Changes and the Human Factor: case study of Accra Ghana. Journal of Coastal Conservation and Management, DOI: 10.1007/s11852-012-0220-5.

[8] Armah, A.K., Wiafe, G. and Kpelle, D.G. 2005: Sea-level rise and coastal biodiversity in West Africa: A case study from Ghana. In Climate Change and Africa; Low, P.S., Ed.; Cambridge University Press: Cambridge, UK, pp. 204-217.

[9] Armah, A.K. 1991: Coastal Erosion in Ghana: Causes, Patterns, Research Needs and Possible Solutions. In Proceedings of Coastal Zone '91, Long Beach, CA, USA, ASCE: New York, NY, USA, pp. 2463-2473.

[10] Asangwe, C. K. 2007: The Implications of Rising Sea Level on the Coastal Lowlands of Cameroon. In Robin, G. and J. Jakeways (Eds) INSTABILITY. Planning and Management. Thomas Telford, London, 2007. pp 581-588.

[11] Boateng, I. 2012: An application of GIS and coastal geomorphology for large scale assessment of coastal erosion and management: a case study of Ghana. J Coast Conserv. DOI 10.1007/s11852-012-0209-0.

[12] Campbell, M.O. 2006: The sustainability of coconut palm Cocos Nucifera Linnaeus 1753 in coastal Ghana. J. Coast. Res, 22(5), 1118-1124.

[13] Folorunsho, R., and Awosika, L.F. 1995: Meteorological Induced Changes along the Nigerian Coastal Zone and Implications for Integrated Coastal Zone Management Plan Proc. Int. Conf. "Coastal Change 95" BORDOMER - IOC Bordeaux, 804-811.

[14] Gornitz, V. M. 2000: Impoundment, Groundwater mining, and other hydrologic Trnasformations, in Sea-level Rise: History and Consequences, B.C. Douglas (ed.). Acad. Press.

[15] Hewawasam, I. 2002: Managing the marine and coastal environment sub-saharan Africa: Strategic directions for sustainable development, 57 Washington D.C: World Bank.

[16] Hinkel J. and Klein R. 2007: Integrating knowledge for assessing coastal vulnerability to climate change. In McFadden I., Nicholls R.J. and Penning-Rowsell E.C. (eds.), Managing Coastal Vulnerability: An Integrated Approach", Elsevier Science, Amsterdam, The Netherlands.

[17] IPCC. Climate Change 2007: The Physical Science Basis (Summary for Policymakers). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.ipcc.ch/SPM2feb07.pdf Accessed on 20/04/2007.

[18] Knutti, R. 2007: Global climate projections. In Climate Change 2007: The Physical Science Basis; Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Geneva, Switzerland; Cambridge University Press: Cambridge, UK, pp. 747-846.

[19] Kurz, Herman and Wagner, Kenneth. 1957: Tidal marshes of the Gulf and Atlantic Coasts of Northern Florida and Charleston, South Carolina; Fla. State Univ. Studies, 24, 168p.

[20] Linhoss, A.C., Kikler, G., Shirley M., and Frank, K. 2015: Sea- level rise, inundation and march migration: simulating impacts on developed land and environmental system. Journal of Coastal Research, 31(1), 36-46. Coconut Creek (Florida), ISSN 0749-0208.

[21] Meehl, G.A., Stocker, T.F., Collins, W., Friedlingston, P., Gaye, A., Gregory, J., Kitoh. A., Nicholls. R.J., Lowe, J.A. 2006: Climate stabilization and impacts of sea level rise in Avoiding Dangerous Climate Change; Cambridge University Press: Cambridge, UK, pp. 195-202.

[22] Nicholls, R.J., Marinova, N., Lowe, J.A., Brown, S., Vellinga, P., De Gusmao, D., Hinel, J., and Tol, R.S. 2011: Sea- level rise and its possible mpacts given a 'beyond 4 C world' in the twenty-first century. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369 (1934), 161-181.

[23] Nicholls, R.J., and R.J.T. Klein. 2005. Climate change and coastal management on Europe's coast. Pp. 199-226 in Managing European Coasts: Past, Present and Future. Environmental Science Monograph Series, Springer-Verlag, Berlin, Heidelberg.

[24] Norley, N. 2006: Agambila Alarmed at Sea Erosion; Ghanaian Chronicle: Accra, Ghana.

[25] Oteng-Ababio, M., Owusu, K., Appeaning Addo, K. 2011: The vulnerable state of the Ghana coast: The case of Faana-Bortianor. Jamba J. Disaster Risk Stud. 3, 429-442.

[26] Sagoe-Addy, K., and Appeaning Addo, K.A. 2013: Effect of predicted sea level rise on tourism facilities along Ghana's Accra coast. Journal of Coastal Conservation 17 (1), pp 155-166.

[27] United Nations Framework Convention on Climate Change (UNFCCC). 2013, June 18-20).

[28] WAF Policy NAP workshop poster. LEG. Bonn, Germany. (*http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/7279.php.*) Assessed at 14:23Z on the 18th of April, 2015.

[29] United Nations Environment Programme (UNEP). 2013. Green Economy and Trade: Fisheries and Aquaculture. United Nations Environment Programme.

[30] Verstraete, Jean-Marc and Park, Young-Hyang 1995: Comparison of TOPEX/POSEIDON altimetry and in situ sea level data at Sao Tome Island, Gulf of Guinea. Journal of Geophysical Research: Oceans. 100(C12), 25129–25134, doi:10.1029/95JC01960.

[31] Wellens-Mensah, J., Armah, A. K., Amlalo, D. S., and Tetteh, K. 2002: Ghana National Report Phase 1: Integrated Problem Analysis. GEF MSP Sub-Saharan Africa Project (GF/6010-0016): Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. Accra, Ghana.

[32] Wiafe, G. 2002: Spatial and temporal dynamics of plankton communities in the Gulf of Guinea ecosystem. Department of Oceanography and Fisheries, University of Ghana, Legon. 188 pp.

[33] Woodworth, P.L. and Player, R. 2003. The Permanent Service for Mean Sea Level: an update to the 21st century. Journal of Coastal Research, 19, 287-295.

[34] Zhang, K., Douglas, B.C., Leatherman, S.P. 2004: Global warming and coastal erosion. Climate Change, 64, 41-58.