ASSESSING AND ADAPTING TO CLIMATE-CHANGE INDUCED SEA-LEVEL RISE ON THE SOUTHERN COASTLINE OF THE GAMBIA.

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ABSTRACT

The risk of climate-change induced sea-level rise damage to human and economic development in coastal areas of The Gambia is mounting. The combined effect of sea-level rise and changes in upstream river discharge, erosion of coastal embankmentsand changes to natural sediment dynamics, pose a serious threat to the natural resources base and livelihood opportunities of coastal communities(UNDP, 2012). In addition to recurrent and rapid onset of extreme events (i.e., flash flooding), The Gambia's coastal zone is being confronted with a range of creeping climate risks such as increasing salinity level trends in coastal freshwater resources, growing drainage congestion, dynamic changes in coastal sediment dynamics and morphology and a decline in the functioning of protective ecosystems (e.g., mangroves). Currently, The Gambia has no Integrated Coastal Zone Act or Climate Change Policy; issues of coastal zone management are highlighted in the National Environment Management Act (NEMA). Therefore, there is a need for policy development to guide future strategies in sea-level rise adaptation within the coastal zone.

The purpose of this research is to assess the effects of climate-change induced sea-level rise on the Southern coastline of The Gambia, and recommend possible adaptation options and strategies to mitigate the impact of climate change. The first part of the assessment focuses on a review of common approachesto vulnerability assessment used by international organizations in the field of climate change and environmental management, and assesses the approaches which could be applicable toThe Gambia in future vulnerability assessments. In addition, a review of the tools used in climate change and sea-level rise assessment and case studies from regional and international levels on sea-level impact on coastal erosion, climate change adaptation strategies and options are alsoconsidered, in view of the importance of the coastal zone in contributing to the economy of The Gambia.

The second part of this research mainly focuses on the current status of the Southern coastline of The Gambia including significance of the study area in terms of its contribution to the socioeconomic development of the country, but also its vulnerability to climate-change induced sea-level rise projection, and current problems including the existing adaptation and mitigation

strategies being implemented. The outcome of the research will hopefully encourage new adaptation and mitigation options not currently being applied in The Gambia.

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LIST OF ABBREVIATIONS

ADB African Development Bank

AVVA Aerial Video-taped Vulnerability Analysis

CBD Convention on Biological Diversity

CCVI Climate Change Vulnerability Index

CM Common Methodology

CMEWG Coastal and Marine Environment Working Group

CSE Centre de SuiveEcologique

DIVA Dynamic Interactive Vulnerability Assessment

DNA Designated National Authority

DNR Department of Natural Resources

DNREC Department of Natural resources and Environmental Control

EIA Environmental Impact Assessment

EU European Union

ETC CCA The European Topic Centre on Climate Change Adaptation

FAO Food and Agriculture Organization

FEWS Famine Early Warning System

FID Forest Interior Dwellings

GCM Global Circular Model

GDP Gross domestic Product

GEF Global Environment Facility

GoTG Government of The Gambia

GIS Geographic Information System

GNAIP Gambia National Agricultural Investment Program

ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
INC	Initial National Communication
IUCN	International Union for Conservation of Nature
KSDP	Keta Sea Defence Project
LCDS	Low Carbon Development Strategy
LDCF	Least Developed Countries Fund
LECZ	Lower Elevation Coastal Zone
MEA	Millennium Ecosystem Assessment
METT	Management Effectiveness Tracking Tool
MIT	Massachusetts Institute of Technology
NAMA	National Appropriate Mitigation Actions
NEA	National Environment Agency
NEMA	National Environment Management Act
NEMC	National Environment Management Council
NGO	Non-Governmental Organization
NOAA	National Oceanographic Atmospheric administration
PAGE	Programme for Accelerated Growth and Employment
PARCC	Protected Areas Resilience Climate Change
PIF	Project Identification Fiche
PRSP	Poverty Reduction Strategy Paper
RCC	Regional Coordinating Committee
SNC	Second National Communication
SOER	State of the Environment Report
SOPAC	South Pacific Applied Geo-science Commission

SLAMM Sea level Rise Affecting Marshes Model

SLR Sea-Level Rise

SPM Summary for Policy Makers

TAR Third Assessment Report

TDA Tourism Development Area

TEA Targeted Ecological Areas

UEMOA West Africa Monetary Union

UNCCD United Nations Convention to Combat Desertification

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UNFCCC United Nations Framework Convention on Climate Change

UNESCO United Nations Education Scientific Cultural Organization

USA United States of America

USAID United States Aid for International Development

VAM Vulnerability Assessment Map

WCIRP World Climate Impact assessment and Response Strategies

WFP World Food Programme

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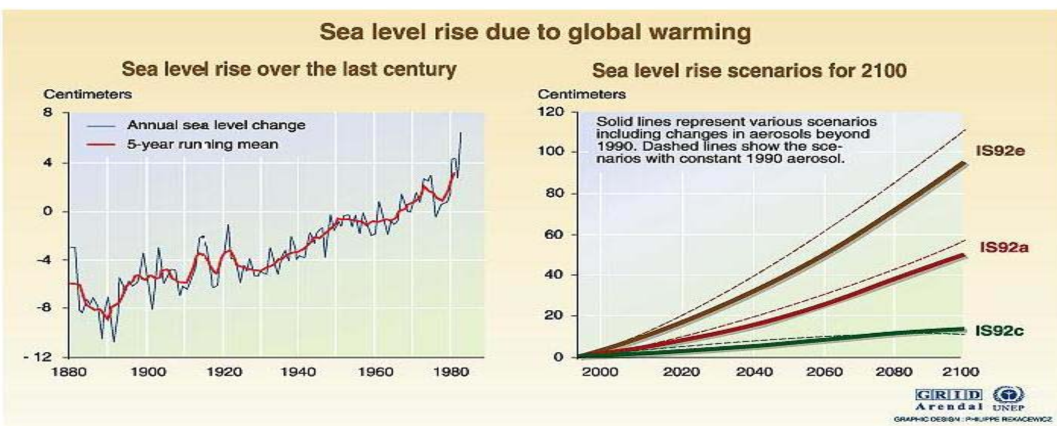
PART 1

CHAPTER 1: INTRODUCTION

1.1 Contextand background

There is scientific consensus, based on an overwhelming body of evidence, that global climate is changing(Russell, 2012).Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea-level has risen, and the concentrations of greenhouse gases have increased(IPCC, 2013). The atmospheric concentration of carbon dioxide (CO2), methane and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. CO2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide causing ocean acidification.(IPCC, 2013).Globally, different set of scenarios predicted that sea-level would continue to rise between 0.18 to above 0.80 as described in Figure 1 below (IPCC 2007).

Figure 1: Sea-level rise projection



Source: (UNEP, 2000)

The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report 2013, report that the rate of Sea-Level Rise[1] since the mid- 19th century has been larger than the mean

[1]Definition of Sea-Level Rise (SLR)- The so called greenhouse effect or global warming may cause a SLR which will have a great impact on the long-term coastal morphology.

rate during the previous two millennia (high confidence). Over the period 1901-2010, global mean sea-level rose by 0.19(0.17 to 0.21cm)(IPCC, 2013). Ocean thermal expansion and glacier mass loss are very likely the dominant contributors to global mean sea-level rise during the 20th century. It is very likely that warming of the ocean has contributed 0.8(0.5 to 1.1) mmyr-1 of sea-level change during 1901-2010.

Climate refers to the average weather in terms of the mean and its variability over a certain time span and a certain area. Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events(Cabas, 2006). Climate Change refers to any changes in climatic condition over a period of time (usually 30 years) whether due to natural variability or as a result of human activities that increases the concentration of greenhouses gases (GHG) in the global atmosphere, (IPCC, 2001).Sea-level rise is just one of the factors that contribute to changes in the coastal landscapes over time. Other factors such as storms, erosion, and sediment accretion act in concert with changes in sea-level to shape the size and make up of sandy shorelines, wetlands and river channels. However, as the rate of sea-level rise accelerates, sea-level rise may increasingly become the driving force in coastal changes.(Delware Sea-Level Rise Advisory Committee, 2012). Accelerated rates of sea-level could cause inundation of low-lying land, saltwater intrusion into groundwater and streams, increased extent and severity of storm flooding, and coastal erosion. Sea-level rise due to climate change is a serious global threat and major coastal issue in the 21st century; because many of the world's built assets and people are located in the coastal zone(Isaac, 2012).

Background information

The Republic of The Gambia is located on the West Coast of Africa and is surrounded by Senegal to the north, east and south and the Atlantic Ocean to the west. With an east-to-west length of 480km, a maximum width of 48km and a total size of 11,300 km^2,The Gambia is the smallest country of the African continent(National Environment Agency, 2010). The river Gambia flowing from the east to the west divides the country into the north and south banks. Seen from a geographic perspective, The Gambia is situated along an ecotone between the tropical rainforest in the South and the arid Sahara desert in the North(Government of the Gambia, 2010). This together with the presence of widespread wetlands due to the River Gambia is providing various types of habitats including a substantial biological diversity.

Figure 2: Map of Africa showing location of The Gambia

Source (Bijl, 2011)

The climate of The Gambia is characterized as sudano-sahelian type with a short rainy season from June to October and a long dry season from October to June. Average temperature range from 18 to 33ºC with temperature peaks around September/October and drops in January/February. The amount and distribution of rainfall over the country is highly variable, but average values range from 850mm to 1200mm per year(National Environment Agency, 2010).

Data from the mid-1940s up to date reveals a decreasing trend in rainfall and length of the rainy season and an increase in temperatures (Government of The Gambia, 2010; National Environment Agency, 2010). Since 1960 the mean annual temperature increased on average by 0.21ºC per decade and the mean monthly rainfall during the rainy season decreased on average by 8.8mm per decade(McSweeney, et al., 2012). It is obvious that the climate is altering and these changes are having and continue to have severe impacts. One of the most vulnerable continents to changes in climate is Africa, whereas The Gambia will be especially affected(Government of the Gambia, 2010). The Gambia already needs to deal with diverse climate hazards such as torrential and unseasonal rainfall, floods, sea-level rise, coastal erosion, storms, cold and heat waves, droughts, fires and pests (National Environment Agency, 2010; UNDP, 2012). Some of these impacts are expected to occur more frequently, and be more powerful and widespread in the future(National Environment Agency, 2010). In general, mean annual temperatures are expected to increase between 3 and 4.5ºC by 2075(Government of the Gambia, 2010). Hereby the projected warming rate will be higher in inland regions than in coastal regions(McSweeney, et al., 2012). Climate projections further show a considerable increase in the frequency of hot days and nights and a decrease in frequency of cold days and nights(McSweeney, et al., 2012). Model projections for mean annual rainfall are highly variable but indicate on average over the country, a decreasing trend in particular during the rainy season. Considering the amount of total annual rainfall in heavy events, climate models show an overall increasing trend but with seasonally-dependent increases and decreases(McSweeney, et al., 2012). The frequency and severity of extreme events like wind, rain, dust storms and droughts will increase in the short term, while sea-level rise, coastal erosion and land cover changes will increase in the long term(Government of the Gambia, 2010). As Gambia is a low-lying country it will be especially affected by the rising sea-level, which will entail other problems like flooding(Boko, et al., 2007). As far as The Government of the Gambia is concerned, climate change represents one of the country's greatest burdens and challenges for development and poverty mitigation, because the economy and the people rely on activities such as agriculture, livestock, energy and water(National Environment Agency, 2010).

The coastal areas of The Gambia consist of estuarine, inter-tidal and oceanic ecosystems that border the Atlantic Ocean and extend to the brackish water environment that borders The Gambia River up to 200km from its mouth- to the Miniminiangbolong on the north bank and the Mootah point on the South bank. This comprises the catchment of the Gambia, Saloum and Allahein rivers. Gambia's coastal areas are severely affected by climate change and variability in two major ways; namely coastal erosion owing to increased wave activity and physical drowning of the low-lying areas as sea level rises(UNDP, 2012). In each case the result is coastline recession and the physical loss of ecosystems and the services they provide. This indicates that the problem is likely to be exacerbated, especially by the increase in sea level and frequency of storm surges.

Although not a significant contributor to climate change, The Gambia is one of the country's most at risk from its projected impacts. According on Jaiteh et al (2011), The Gambia is ranked among the top ten countries in the world with the highest share of population living withinthe Lower Elevation Coastal Zone (LECZ). Coastal erosion and coastline retreat has been a major concern in the Gambia for some time now (Jallow e tal 1999; NEA 2004). A 1 meter sea-level rise will drown over 8.7% of the total land area including the port and capital of city of Banjul, and host of critical facilities including 25.5km of paved roadway in greater Banjul and all the harbors and ferry landings sites along the Gambia River.

1.2 Study Area- Significance of the Southern Coastline of the Gambia

The open coastline of the Gambia is 80km long extending from the mouth of Allahein River in the South to Buniadu point and Karentibolong in the North, and extended 200km of sheltered coast along The Gambia River and is bounded on both sides by Senegal. The sheltered coast is dominated by extensive mangrove systems and mud-flats(National Envirronmental Agency, 2010).The coastal area is a valuable resource for The Gambia, and that a management of this area would have a significant impact on several sectors of the economy. Agriculture, forestry, tourism, marine transportation and quarrying are some of the main economy activities in the coastal zone of The Gambia. The important resources within the coastal zone include coastal wetlands (particularly mangroves), living marine resources (fisheries), minerals (sand and gravel), and groundwater. Being a valuable resource, many individuals, institutions and private entities have a vested interest in the coastal environment. Together, they represent a broad spectrum of socio-economic activities, which make use of the natural resources and opportunities provided by nature.

Figure 3: Showing goggle map of the Southern coastline of The Gambia.

(Source (Bijil, 2011).

The northernand southern coastlines of The Gambia are quite different morphologically and in human use (see figure 3). The main sources of income aretraditional agriculture, which is traditional and small-scale and artisanal fisheries, which takes place throughout the north bank on a small-scale and seasonal basis(Royal Haskoning, 2000).The southern coastline by contrast consists of open coastline measuring approximately 70km and is characterized by sand shores, cliffs and to lesser extent mangroves wetlands. Just some 20km of the southern coastline is significantly developed including Banjul (Capital city), the country's main port, Cape Point, Bakau, Fajara with high value Government and private properties and the Tourism Development Areas (TDA) consisting of 24 hotels built along the coast, 6 fish landing and processing facilities, three coastal protected areas, sand and gravel mining sites and coastal villages. The other areas are mainly coastal settlements, fish landing sites, protected areas, and sand mining sites.

The climate change vulnerability assessment conducted by(Jallow, et al., 1996) shows that a one meter sea-level rise in The Gambia will lead to a loss of 92km² of land by inundation by 2100. Shoreline retreat is projected also to vary between 6.8m in cliff areas to about 880m for flatter and sandier areas. If a one meter sea level rise were to occur as envisaged, without proper control measures the Southern coastline of the Gambia, including the whole capital city of Banjul, would be lost in the next 50-60 years because a majority of the city is below one meter of current sea-level rise. Preliminary analysis of data from the Gambian Department of Lands on the value of land and sample properties between Banjul and the Kololi Beach Hotel suggest that about 1,950 billion dalasi (USD217 million) of property will be lost (Jallow, et al., 1996). A number of hotels face serious beach erosion problems, and in most cases the beaches in front of the hotels have been reduced significantly. In some cases, beaches of hotels like Palm Groves and Tropical gardens have already disappeared(UNDP, 2012)

Apart from physical damages for certain hotels like falling fences, destruction of beach bars, and sea water entering the facilities during spring tide, it may be expected that tourists to The Gambia, attracted by sunny beaches will turn away from these hotels if they no longer have access to an appropriate beach. Six fish landing and processing facilities have been constructed in Brufut, Tanji, Bato-Kunku, Sanyang, Gunjur and Kartung. Total investments at the six landing sites are estimated at USD 0.64million (UNDP, 2012). It has been estimated that about one third of these facilities are threatened by coastal erosion. The Banjul Port and other national industrial facilities built within 200m of the shore along sandy beaches can be included in the infrastructures threatened by the sea-level rise and coastline areas degradation(UNDP, 2012).

1.3 Problem Statement

The Gambia is ranked among the top ten countries in the world threatened by sea-level rise, because of LECZ. It is projected that about 92km² of land in the coastal zone of The Gambia will be flooded and covered by the sea as a result of only 1 meter rise in the present water level of the sea(Jallow, et al., 1996). The whole of the capital city of Banjul will be lost as well as mangrove systems on St. Mary's Island, Kombo St. Mary on the south bank of the River and also on the north bank of the River from Barra to Buniadu point.The densely populated urban zone with port and major tourism facilities are located within the southern coastline. Increase in wave action coupled with poor urban planning and sand mining for construction contributes to the erosion along the Southern part of the coastline. This has led to loss of important cultural sites, infrastructure as well as feeding and nesting grounds for turtles and migratory birds.

Moreover, sea-level rise would have a serious impact on agricultural production in coastal low-land agriculture production since its resilience depends heavily on strategic approaches to water management capable of addressing climate change impacts on future renewals rates on ground water resources, flow and salinity of the River Gambia(UNDP, 2012). Salt water intrusion has already destroyed many farmlands making a large number of farming households poorer. The biggest threat of saline intrusion into the Gambia River comes from projected sea-level rise. The estuary basin of the Gambia River is virtually a tidal inlet with salt water intrusion ranging from 180 kilometers inland during the rainy season to 250 kilometers in the dry season. The short-term rice production may be the most affected making up 64% of all cropland area that will be drowned by the 1-meter sea level rise. This could lead to a decrease of the rice production and impede the achievement of GNAIP (Gambia National Agriculture Investment program)[2].

1.4 Purpose/objectives

The purpose of this research is to assess and make recommendations to policy makers and politicians on how to adapt to climate change induced sea-level rise on the Southern coastline of The Gambia. In order to achieve this overall purpose, the following objectives were pursued:

1. To summarize the findings on potential climate change effects on the coastal environment in The Gambia.
2. To assess the socioeconomic and cultural impacts of sea-level rise on the Southern Coastline of The Gambia.
3. To review approaches/methodologies and tools used in sea-level vulnerability assessment.

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[2]Combine policy, institutional, infrastructure document to address multiplicity of supply side constraints to enhance the growth of The Gambia's agriculture sector

4. To review the regional and international adaptation strategies to climate change induced sea-level rise
5. To influence political/decision makers and civil society on how they should prepare for and respond to the projected impact of climate change in The Gambia.

1.5 Organization and Contribution of research

The methodology applied throughout this review is based on desk-top analysis of existing literature on approaches, tools, and adaptation strategies on sea-level rise induced climate change at regional and international levels.In order to draw some positive conclusions a framework was developed and applied and compared to the current national arrangement in The Gambia.This research is organized in three parts as follows:

Part one consists of two chapters and four sections, and begins with a description of climate concepts including defining climate change, evidence of its change and reasons/causes for the change. The section also provides a description of predictions of future climate change including sources of prediction and the variability of those estimates. The next part of the chapter focuses on the Global and International approaches to vulnerability assessment as well as the tools and methodologies used in sea-level assessment. Also review of case studies on coastal erosion, sea-level rise adaptation strategies at regional and international levels as well as providing analysis on the different strategies.

Part two of the research focuses on the study area (Southern coastline of The Gambia). The first chapter reviews the significance of the coastline of The Gambia in terms of its vulnerability, geomorphological characteristics, actual problem of the coast and the main biophysical and economic characteristics of the study area includingthe legal and institutional framework and the existing coastal adaptation measures-baseline scenarios. The second chapter examines the gaps and needs in sea-level rise adaptation in The Gambia including the existing climate change adaptation and mitigation strategies and the required need for climate change adaptation and mitigation.Part three (conclusions and recommendations) discusses and summarizes the major findings in this review as well as makingsome key recommendations for practical way forward in dealing with present and future sea-level rise induce climate change in the coastal zone of The Gambia.

CHAPTER 2- CURRENT APPROACHES TO SEA-LEVEL RISE VULNERABILITY ASSESSMENT

Introduction

Chapter 1 provided background information on climate change and sea-level rise and their projected impacts on the coastal environment. The chapter also highlights the study area in terms of its vulnerability to climate change induced sea-level rise as well as the purpose and objectives of the research.This chapter reviews the experience on vulnerability assessment methodologies used by international bodies/organizations in the area of climate change and environmental management. In addition,an overview of the common tools and methodology used in sea-level rise vulnerability assessment were analyzed to determine their applicability in The Gambia context.

The assessment of coastal vulnerability to climate involves several concepts that must be clearly defined. Therefore it is important to give an overview on concepts and definitions and methods of vulnerability assessment to climate change. According to Sterlacchini (2011) vulnerability is one of those terms that seem to defy consensus usage showing many different connotations, depending on the research orientation and perspective. This implies that there is no consensus about the precise meaning of the term vulnerability in the much of thescientific literature, and it seems to be open to interpretation.

From the review of literature, the definitions of vulnerability range from the engineering and natural science perspectives with focus on physical exposure (Vandine etal 2004; Wisner etal, 2005) to the social science perspective through the measures of socio-economic status and access to resources (O'Keefe S., 1983; Timmermann P.,1981; Cannon, 1994). From the point of view of sociological investigation of the differential ability of groups to resist harm and to recover afterwards has also been added to discussions of how the hazard of place is linked to social profiles (Dow 1992; Cutter 1996). Various definitions of vulnerability from different perspectives on different issues are summarized below:

O'Keefe S., (1983) defined vulnerability in social science as… "degree to which different classes in society are differentially at risk, both in terms of the probability of occurrence of an extreme physical event and the degree to which the community absorbs the effects of extreme physical events and helps different classes to recover".

Timmermann P., (1981) defined vulnerability as "the degree to which a system reacts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by the resilience of the system (a measure of its capacity to absorb and recover from the event)."

Gabor T. & Griffith T.K., (1979) referred to vulnerability as "a threat to which a community is exposed, taking into account not only the properties of the chemical agents involved but also the ecological situation of the community and the general state of emergency preparedness, at any point in time."

Cutter, (1996) defined vulnerability as "the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of the place (risk and mitigation) with the social profile of the communities."

Clark, et al., (1998) define vulnerability as "a function of two attributes: 1) exposure (the risk of experiencing a hazardous event); and 2) coping ability, subdivided into resistance (the ability to absorb impacts and continue functioning), and resilience (the ability to recover from losses after an impact)."

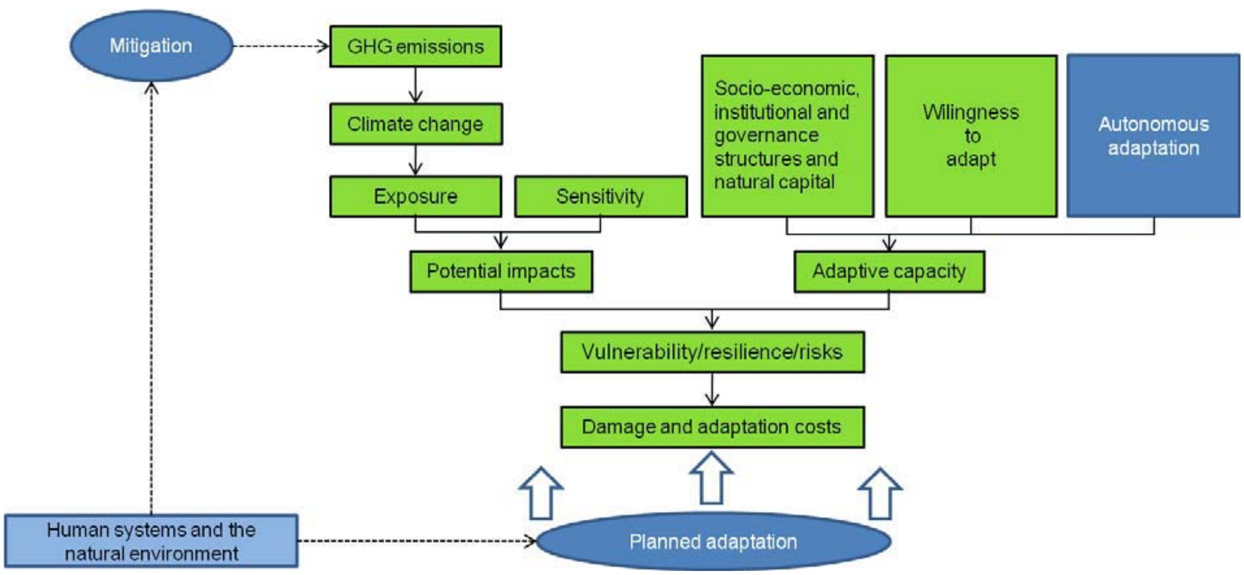
Moser (1996) defined vulnerability as "the insecurity of the well-being of individuals, households, or communities in the face of a changing environment."

The IPCC (2001a; 2007) defines vulnerability in the Third Assessment Report (AR3)and Fourth Assessment report(AR4) "as the degree, to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the chapter magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity

To sum up all the various definitions highlighted above by different researchers and organizations manifest that the concept of vulnerability is defined differently depending on the contextin which it is used and is closely related to other concepts, such as hazard, risk and resilience.

The IPCC definitions of vulnerability imply three important concepts: *exposure, sensitivity and adaptive capacity*. Exposure defines the nature and amount to which the system is exposed to climate change phenomena, sensitivity reflects the system´s potential to be affected (adversely or beneficially) by such changes, while adaptive capacity describes the system's ability to evolve (autonomously or according to planned measures)in such a way as to maintain(totally or at least partially) its key functions in the face of external changes(ETC/ACC, 2011) The vulnerability of coastal systems to sea-level rise and to other drivers of change is determined by their sensitivity, exposure and adaptive capacity R.J & Klein R.J.T(2005). The relationships between all the above concepts can be integrated in the conceptual framework for climate change impacts, vulnerability, disasters risks and adaptation options as shown in **Figure 4** below:-is discussed within this context, which helps to reconcile apparently contradictory definitions of vulnerabilities.

Figure 4: Conceptual framework for climate change impacts, vulnerability, disaster risks and adaptation



(Sources: EEA, 2010a; ETC-ACC, 2010b in ETC/CCA, 2011).

The IPCC definitions of vulnerability to climate change, and its related components (exposure, sensitivity,and adaptive capacity) provide a suitable starting position to explore possibilities for vulnerability assessment but they are not operational. Therefore, a vulnerability assessment should start by defining the policy or scientific objective as clearly as possible, and to choose the scope and methods accordingly. Key questionsin the scoping phase include: What is vulnerable or what specific parts of the system are most vulnerable? Which impacts are relevant? Vulnerable to what climate change effects? What is the timeframe (time scenario) involved in the vulnerability assessment? Indeed the operational definition of the vulnerability concept is related to the specific issue and/or context (e.g. the coastal area) addressed by the analysis, also implying that spatial and temporal variations of vulnerability in general and coastal vulnerability in particular are taken into consideration, as described in the following section(ETC/CCA, 2011).

2.1 International Approaches for assessing coastal vulnerability to Accelerated Sea-Level rise

Introduction

Coastal areas are dynamic and complex multi-function systems. A wide number of often conflicting human socio-economic activities occur in these areas(ETC CCA, 2011). Such activities includes urbanization, tourism and recreation, industrial production, energy production and delivering, port activities, shipping, and agriculture. Besides the issues highlighted above, coastal systems are also characterized by important ecological and natural values; their high habitat and biological diversity is fundamental to sustain coastal processes and provide ecosystem services which are essential also for human well-being(Millennium Ecosystem Assessment, 2005).

In addition(Vellinga P & Klein , 1993) mentioned that coastal zones are of major importance for both man and his environment. Besides, coastal plains and shallow coastal seas, which comprise about 8% of the surface of the earth contribute about 25% of global biological productivity and support most of the world´s fisheries as well as other important living resources.

In the context of climate change, sea-level rise, temperature increase, changes in precipitation patterns and other climate-related changes are expected to occur and to become increasingly more severe over the coming decades.

According to Vellinga P & Klein, (1993) coastal zones are among the world's most densely populated and most industrialized areas. Concentration of population, expansion of economic activities, urbanization, and increased resource use on and near the coast has serious environmental consequences that may lead to unsustainable use of both the living and non-living coastal resources and increase the coastal zone's vulnerability(Vellinga P & Klein , 1993).

Climate change and consequent accelerated sea-level rise will, over the longer term, intensify the stress on many coastal zones, particularly those where human activities have diminished natural and socio-economic adaptive capacities.[3] As suggested by (Bijlsma, et al., 1996)sea-level rise can lead to increased hazard potential for coastal populations, infrastructure, and investment. However, owing to the great diversity of both natural and socio-economic coastal systems and their dynamic response to anticipated changes, future impacts are not always easy to predict.[4]

According to USAID (2009) coastal adaptation guide, assessing a coastal area's vulnerability to the impacts of climate change involves understanding: 1) the climate projections for a given region or locale, 2) what is at risk (climate change exposure and sensitivity), and 3) the capacity of society to cope with the expected or actual climate change (adaptive capacity). The report highlighted these three factors above combined defines the vulnerability of people in a place to climate change. This concept is also similar to the one by (Vellinga P & Klein , 1993), which highlights that in order to conduct assessment of vulnerability to accelerated sea-level rise, the first step in effectively managing a threat is to understand the nature and implications of the threat and the vulnerability of people, their values and the environment to the potential impacts of the threat. It further added that in order to prevent disasters, minimize the risk and manage the consequences, an assessment of a country's or region's vulnerability to the threat is a necessary starting point for taking action(Vellinga P & Klein , 1993).

There are a variety of approaches, frameworks, methods and tools to assess impact and vulnerability, and to prepare adaptation techniques. Some of these approaches and

[3]http://www.decisioncraft.com/energy/papers/hbccia/chap7. Coastal Zones
[4]http://www.decisioncraft.com/energy/papers/hbccia/chap7. Coastal Zones

methodologies are developed by international bodies in the field of environment and climate change to guide countries in theirregional and national vulnerability assessment to accelerated sea-level rise. This section givesa basic summary description of some of the common approaches and methodologies developed by international bodies/agencies such as IPCC, UNEP, and MEA in assessing climate change impacts and vulnerability.

2.1.1 Intergovernmental Panel on Climate Change (IPCC) Common Methodology (CM)

Description

The IPCC was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988. The main responsibility of IPCC is to assess the scientific information about climate change, ranging from emissions, atmospheric chemistry and changes in the radiation balance, to the impact of climate change and the possible response strategies(Vellinga P & Klein , 1993). In order to achieve these objectives IPCC has formed three Working Groups (WGs), which produced a three-volume IPCC First Assessment Report(IPCC, 1990). The WG I assessed the available scientific information on climate change, WG II the environmental and socio-economic impacts, and WG III formulated response strategies. However, in preparation for the Second Assessment Report, the structure of these WGs were modified by IPCC in such a way that its activities would be in line with the United Nations Framework Convention on Climate Change(UNFCCC)[5], and also to ensure an optimum interplay between the scientist(Vellinga P & Klein , 1993).

The WG I remained unchanged, the previous WGs II on (impacts) and III on (response strategies) were merged into a new WG II, which should assess available scientific, technical, environmental, social and economic information regarding impacts of climate change and response options to adapt to and/or mitigate climate. The other newly established WG III should in work in close consultation with WGs I and II, deal with cross-cutting issues, such as emission scenarios and international economic aspects(IPCC, 1990). The subgroup B of the new WG II was tasked to deal with small islands and coastal zone, oceans and marine ecosystems, storm surges and sea-level change. In addition the subgroup B was given the responsibility for two

[5]UNFCCC is a global framework convention to combat climate change

chapters in the Second Assessment Report. According to Vellinga P & Klein,(1993) the important objective of the Second Assessment Report is to develop and test guidelines and common methodologies, such as methodologies for the preparation of national inventories of anthropogenic emissions of greenhouse gases, and guidelines for national assessment of the impacts of climate change.

As described by IPCC, the Common Methodology (CM) is an influential framework for vulnerability assessment that was first proposed in 1991.[6] The CM incorporates expert judgment and data analysis of socioeconomic and physical characteristics to assist the user in estimating a broad spectrum of impact from sea-level rise, including the value of lost land and wetlands. It presents a list of analyses that should be done, but does explicitly instruct the user on how to perform the analyses. Information from this methodology is generally used as a basis for further physical and economic modeling. The CM for the assessment of vulnerability to accelerated sea-level rise outlines the analytical steps necessary for a country to decide which actions it must take to cope with sea-level rise. The main objectives of the CM as described byVellinga P & Klein,(1993) are to provide a tool to:

1) Identify and assess physical, ecological, and socio-economic vulnerabilities to accelerated sea-level rise and other coastal impacts of global climate change;
2) Understand how development and other socio-economic factors affects vulnerability;
3) Clarify how possible responses can mitigate vulnerability and assess their residual effects; and
4) Evaluate a country's capacity for implementing a response within a broad coastal zone management framework.

In addition to the objectives highlighted above, The Common Methodology is actually built up of seven successive steps (IPCC CZMS, 1992)as highlighted in Table 1. It is evident that vulnerability is not merely the identification of resources at risk. The Common Methodology defines it as a nation's ability to cope with the consequences of accelerated sea-level rise and other coastal impacts of global climate change. In this respect, the Common Methodology considers the potential impacts on population, on economic, ecological and social assets, and on agricultural production. It includes three scenario variables: global climate change factors, local

[6] http://www.unfccc.int/.../ipcc_common_methodology

development factors, and response options. A time horizon of 30years is applied. The Common Methodology considers local or national development by extrapolating 30years from the present situation. Regarding sea-level rise, approximations of both the IPCC Business-as-Usual low and high estimates may be used (0.3 and 1m in 2100, respectively).

Table 1:Seven steps of the Common Methodology

1.	Delineate case study area, and specify accelerated sea-level rise and climate change conditions.
2.	Inventory study area characteristics.
3.	Identify relevant development factors.
4.	Assess physical changes and natural system responses
5.	Formulate response strategies identifying potential costs and benefits.
6.	Assess the vulnerability profile, and interpret results.
7.	Identify future needs, and develop a plan of action

(Adapted from IPCC, CZMS, 1992)

The IPCC Third Assessment Report (TAR) Working Group II has outlined impacts, adaptations, and vulnerability of coasts and low lying areas. Whereas there has been a focus on the impact of anticipated sea-level rise, the TAR also considered the primary large-scale effect of other potential impacts, including increases in sea-surface temperatures, changes in wave climate, circulation and acidity of the ocean, and potential changes in cyclone intensity frequency and distribution. The IPCC (2001) indicated that the rates of sea level will be variable at the regional and local scales. The details of this variation are largely unknown; global climate models do enable some aspects of regional variation in sea level to be modeled, but regional projections are not available and local projections are largely impossible. Evaluations of effects on several nations indicate that the likely impacts of sea-level can vary from country to country and from one geographic setting to another(Bijlsma, et al., 1996) Certain geomorphic settings are more vulnerable than others, for example, deltas, small islands and most particularly low-lying coral atolls are especially vulnerable. Coastal wetlands appear to be threatened with loss or significant change in most locations as their present locations is intimately linked with present sea level, although their ability to respond dynamically to such changes by sedimentation and biomass production needs to be carefully considered (French etal 1995). Urbanized sandy coasts may also be vulnerable if development is concentrated too close to the shoreline, primarily due to the large costs of maintaining a sandy beach for both recreational and protective purposes (Nicholls and Lowe, 2004)

2.1.2 *United Nations Environment Programme (UNEP) Guidelines on Methods for Impact Assessment*

Description

UNEP took the initiative for the development of “Handbook on Methods for Climate Change Impact assessment and Adaptation Strategies” as part of its participation in the development of guidelines and handbooks for Climate Change Country Studies, and also part of the World Climate Impact Assessment and Response Strategies Programme (WCIRP) and as such contributes to the International Climate Agenda.(UNEP, 1998) . The activities of the Climate Change Country Studies are divided into four areas: 1) greenhouse gas emission inventories; 2) mitigation studies, 3) impact assessment and adaptation studies and 4) national communications. Thehandbook on methods for impact assessment and adaptation strategies was designed to assist developing countries to conduct climate change impact and adaptation assessments, as inputs to the National Communications as required by UNFCCC(Carter, et al., 1994). UNEP continues to develop and or support the development of global, regional and national harmonized environmental data and databases, especially geo-referenced indicators for environmental assessment and early warning activities. Its Chapter 7 on coastal zones contains several sections outlined in **Table 2:**

Table 2: Methods for climate change impact assessment and adaptation strategies as outlined in Chapter 7 of the UNEP Handbook on methods for impact assessment and adaptation strategies (1998)

7.1Nature and scope of the problem
Delineation of the study area; Absolute and relative sea-level change; Bio-geophysical effects and socio economic impacts

7.2 An array of methods
7.2.1 Acquision and management of data
- Global sea-level changes; Coastal topography and land-use; Socio-economic data
- Management of data

7.2.2 Index-based approaches
7.2.3 Methods for addressing bio-geographical effects
- Increasing flood-frequency probabilities; Erosion and inundation; Rising water tables; Saltwater intrusion
- Summary

7.2.4 methods for assessing potential socio-economic impacts
- Population; Marketed goods and services; Non-marketed goods and services

7.3 Scenarios
- Relative sea-level rise; Other scenarios

7.4 Autonomous adaptation

7.5 Planned adaptation
- Identification of adaptation options
- Evaluation of adaptation option

7.6 Summary and implication

Source (Adapted from UNEP, 1998)

The UNEP methodology establishes a generic framework for thinking about and responding to problems of sea-level rise and climate change. It consists of seven steps:

1. Define the problem
2. Select the method
3. Test the method
4. Select scenarios
5. Assess the bio-geophysical and socioeconomic impacts
6. Assess the autonomous adjustment, and
7. Evaluate adaptations strategies

The last step is itself split into seven sub-steps. At each step, methods are suggested but the choice is left to the user. This approach is useful in a range of situations, including sub-national or national level studies. The UNEP approach might constitute a pilot study, or follow earlier studies such as those completed using the IPCC Common Methodology, or be quick screening assessment prior to more detailed vulnerability assessment(Klein & Nicholls, 1998). Information gathered with this methodology can then be used as input for future modeling. Qualitative or quantitative physical and socioeconomic characteristics of the national coastal zone are the key inputs resulting in evaluation of a range of user-selected impacts of sea-level rise and potential adaptation strategies according to both socioeconomic and physical characteristics.

The UNEP handbook elaborates on the IPCC guidelines by presenting and discussing a broad range of approaches that might be used for addressing the question " What does climate change mean to us?" and, to a lesser extent, "What might be done about it?". It consists of two parts: A generic part deals with the framing of the assessment, the development of socioeconomic and climate change scenarios, integrated assessment, and adaptation. A sectoral part discusses methods for impact and adaptation and presents specific methods for the assessment of adaptation measures (Burton etal, 1998; O'Brien, 2000; Kovats etal., 2003).

2.1.3 Millennium Ecosystem Assessment (MEA)

The Millennium Ecosystem Assessment (MEA) was called for by United Nations Secretary-General in 2000 in his report to the UN General Assembly, *We the peoples: The Role of the United Nations in the 21st Century*. The objective was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being(Millennium Ecosystem Assessment, 2005a). In other words The MEAis a framework report of ecosystems and human well being designed to improve the management of Earth's ecosystems and ensure strategies to build capacity for analysis. The MEA is a global effort to analyze on a global, regional and local scale the state of ecosystems, their capacity to provide goods and services, the multiple stresses that they are facing, and the potential for human action to protect ecosystem goods and service by moderating these stresses(Woodroffe & McLean, 1992). Human well-being depends on a broad range of ecosystem services in a closed loop that allows for feedback within the system. The relationships between different elements of the framework are amenable to human interventions that can alter the dynamics of the system(Millennium Ecosystem Assessment, 2005b)

The conceptual framework for the MEA places human well-being as the central focus for assessment while recognizing that biodiversity and ecosystems also have intrinsic value. The MEA conceptual framework assumes that a dynamic interaction exists between people and ecosystems, with the changing human condition serving to both directly and indirectly drive change in ecosystems and with changes in ecosystems causing changes in human well-being. At the same time, many other factors independent of the environment change the human condition, and many natural forces are influencing ecosystems.Changes in factors that indirectly affect ecosystem, such as population, technology, and lifestyle can lead to changes in factors directly affecting ecosystem such as the catch of fisheries or the application of fertilizers to increase food production. The resulting changes in the ecosystem cause the ecosystem services to change and thereby affect human well-being. These interactions can take place at more than one scale and cross scales. For example, a global market may lead to regional loss of forest cover, which increases flood magnitude along a local stretch of a river. Similarly, the interaction can take place across different time scales. Actions can be taken either to respond to negative changes or to enhance positive changes at almost all points in this framework (Millennium Ecosystem Assessment, 2005c).

The MEA has many things in common with the climate assessments compiled by IPCC. The two assessments share several characteristics: 1) their aims are to provide policy-relevant information to policy makers; 2) the Universal importance of their respective subject of investigation (ecosystems and climate respectively) for humankind; 3) the combination of knowledge from the natural and social sciences with other sources of knowledge and 4) the consideration of issues at widely varying spatial levels.

2.1.4Analysis of the approaches

The increase in economic activities, high urbanization, increased resource use and population growth is continuously increasing the vulnerability of the coastal zone. This vulnerability is now further raised by the threat of climate change and accelerated sea-level rise(Vellinga P & Klein , 1993). Due to the potential impacts coming from both natural and anthropogenic causes, policy-makers are forced to engage and consider long-term planning for climate change and sea-level rise.It is important to highlight that assessment of a country's or region's vulnerability to climate change and sea-level rise especially for the coastal zone is very much paramount as this will help to set up relevant adaptation policies and strategies needed for the country or region. Adaptation to climate change in coastal areas is especially important because many metropolitan cities are located along the coast and the existing problems due to high exploitation of resources in coastal areas may be exacerbated by climate change risks(Yoo, et al., 2011).The concept of vulnerability in coastal areas is not new and it has emphasized the importance of the exposure to climate change related hazards events such as sea-level, storm surge of floods etc. The Gambia like many other developing countries, despite the threat that climate change and accelerated sea-level rise pose to the coastal communities and ecosystems, had not until recently considered the mere likelihood and implications of it, nor the possible ways to adapt. For this reason, some approaches were developed by international bodies in the field of climate change and environment to mainly assist in assessing vulnerability of any specific country or region to accelerated sea-level rise and improve understanding of societal vulnerabilities to sea-level rise IPCC CZMS(1992; Vellinga P & Klein, (1993).

Firstly, the IPCC in its mandate or responsibility in scientific assessment of climate change induced by greenhouse gases, and also the implication of climate change for coastal zones, suggested the development of the CommonMethodology (CM). It is widely acknowledged that CM and similar approaches are the most frequently used framework for coastal vulnerability, as evidence by its application in more than 24 national assessments and 1 global assessment(Robert J & Mimura, 1998). Previous coastal vulnerability studies carried out according to this CM such as U.S, Dutchand other country studies programmes have been compared and combined, from which general conclusions on local, regional and global vulnerability have been drawn, the latter in the form of Global Vulnerability Assessment.Also it has been useful in stimulating further studies and development of derived methodologies and techniques for assessing coastal vulnerability which are suitable for the different legislation and coastal planning systems in Australia(Woodroffe & McLean, 1993). It focused on monetary valuations of vulnerable areas and used a cost-benefits analysis to assess the best response option. However, the development of CM has also stimulated a major debate among the scientist and researchers on methods to assess climate change impacts in coastal areas (Bijlsma et al 1996; McLean &Mimura, 1993). As a result, alternative approaches to vulnerability assessment were developed, most particularly for small South Pacific islands, and in addition the generic IPCC technical guidelines for assessing climate change impacts and adaptation have been developed and then transformed into a form appropriate for coastal regions (Yamada, et al., 1995; Robert J & Mimura, 1998).

Despite the fact that the IPCC CM for assessing coastal vulnerability has been designed for worldwide application, it a has a number of limitations and there have been problems with applying it directly in some countries such as Australia, where it was tested initially at Geographe Bay in Western AustraliaKay, R.C et al., (1992)and subsequent studies were also completed on the Cocos (Keeling) islands, a coral atoll territory in the Indian ocean(Woodroffe & McLean, 1993). It was further applied to Kiribati(Woodroffe & McLean, 1992). The above studies found deficiencies in the CM because the biophysical framework is not adequate to support the engineering and cost-benefit stages. The CM uses monetary valuations as an estimate of a coastal nation’s vulnerability to future sea-level rise, employing a cost-benefit test to assess the preferred response option to mitigate future coastal impacts.

Secondly, UNEP “Handbook on Methods for Climate Change Impact assessment and Adaptation Strategies” was prepared as part of UNEP’s participation in the development of guidelines and handbooks for Climate Change Country Studies, and also part of the World Climate Impact Assessment and Response Strategies Programme (WCIRP) and as such contributes to the International Climate Agenda(UNEP, 1998). In addition it was also designed to assist developing countries in conducting climate change impact and adaptation assessment, as inputs to the National Communications as required byUNFCCC.Thirdly, unlike the IPCC CM and UNEP guidelines, the MEAis not purposely developed to undertake any studies related to climate change vulnerability assessment.Itwas,however,called for by United Nations Secretary-General in his report to the UN General Assembly, We the peoples: The Role of the United Nations in the 21st Century. The objective was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being(Millennium Ecosystem Assessment, 2005a). The MEA framework report of ecosystems and human well-being was designed to improve the management of Earth's ecosystems and ensure strategies to build capacity for analysis, and most importantly places human well-being as the central focus for assessment while recognizing that biodiversity and ecosystems also have intrinsic value. The MEA conceptual framework assumes that a dynamic interaction exists between people and ecosystems, with the changing human condition serving to both directly and indirectly drive change in ecosystems and with changes in ecosystems causing changes in human well-being. At the same time, many other factors independent of the environment change the human condition, and many natural forces are influencing ecosystems.

The similarities between the UNEP methodology and the IPCC Methodology arethat both consist of seven guiding steps, and the same scope covering coastal; and scale; subnational, national, regional and global analysis. However the UNEP methodology establishes a generic framework for thinking about and responding to the problems of sea-level rise and climate change. The IPCC methodology incorporates expert judgment and data analysis of socioeconomic and physical characteristics to assist the user in estimating a broad spectrum of impacts from sea-level rise, including the value of lost land and wetlands.In other words, the IPCC approach is most useful as an initial, baseline analysis for country level studies where little is known about coastal vulnerability. Its main output will be a vulnerability profile and the list of future policy needs to adapt both physically and economically. A range of impacts of sea-level rise, including land loss and associated value and uses, wetland loss. The UNEP approach is useful in a range of situations, including subnational or national level studies. It could comprise the first study, or follow earlier studies such as those completed using the IPCC CM. The possibility of quick screening followed by a more detailed vulnerability assessment has been suggested (Klein and Nicholls, 1999). Information gathered with this methodology can then be used as input for future modeling.

In terms of ease of use and training required, the UNEP methodology is a fairly simple framework, as the level of analysis is not prescribed, the ease of use will depend on the level of analysis that is attempted, whilst the IPCC methodology requires considerable knowledge on a range of techniques for estimating biophysical and socioeconomic impacts of sea-level rise and adaptation. In addition significant training is required to complete the seven steps and is often performed by external consultants rather than in-country experts due to limited capacity in most countries.Comparing the MEA and IPCC, there are many things in common with the climate assessments and share several characteristics: 1) their aims are to provide policy-relevant information to policy makers; 2) the Universal importance of their respective subject of investigation (ecosystems and climate respectively) for humankind; 3) the combination of knowledge from the natural and social sciences with other sources of knowledge and 4) the consideration of issues at widely varying spatial levels.

In conclusion, it has been noted that collectively, this experience of different approaches to vulnerability assessment shows that there are still barriers to the conduct of comprehensive impact and response analysis due to: 1) incomplete knowledge of the relevant processes affected by sea-level rise and their interactions; 2) insufficient data on existing conditions; 3) difficulty in developing the local and regional scenarios for future change; and 4) the lack of appropriate analytical methodologies for some impacts(Robert J & Mimura, 1998).

The Gambia, despite its vulnerability to climate change induced sea-level rise, has undertaken vulnerability studies undertaken (e.g. (Jallow, et al., 1996), Jallow etal 1999), as part of the US country studies, and the Common methodology has used in preparation for these research. No information is available, as whether the MEA framework has been used in previous studies in the past, but since The Gambia has prepared the National Adaptation Plan of Action(2007) as well as the First and Second National Communication(2003; 2012) then it would concluded that the UNEP guidelines were followed to prepare the document

2.2: Review of the tools used in Sea-level rise vulnerability assessment

Introduction

Scientific consensus indicates that the Global Mean Sea-Level has been increasing since the 1990's and as sea-levels continue to rise through the 21st century many island and coastal communities will to need to adapt to the changing landscape by instituting new public policies in order to become more resilient and adjust to the cumulative loss of coastal habitats and shifting shorelines.[7]Some of the world's richest and most diverse environments are found in coastal zones. The coastline is a dynamic interface where land, sea and air interact on scales ranging from pebbles to continent and from seconds to centuries(Klein & Amanatidis, 2004).In recent decades, urban development, agriculture, industry, transportation and tourism have all grown rapidly in coastal zones worldwide. The increasing intensity of these activities and lack of adequate management have created considerable pressure on coastal environments, and climate change, in particular an accelerated rise in sea-level, will add to the existing pressure on coastal zones. The effects of climate change on coastal zones will include increased flood risk and storm damage, loss of low-lying land and coastal wetlands, increased erosion, and intrusion of salt water into coastal freshwater resources(Klein & Amanatidis, 2004).Rising sea-levels may also result in tidal marsh submergence and habitat "migration" as salt marshes transgress landward and replace tidal freshwater and irregularly-flooded marsh landand the loss of the vital and valuable habitat for plants and animals.[8]

These effects will in turn cause socio-economic impacts, such as economic losses and risks to human lives. Hence,this becomes a concernnot only for Governments but also their populace, are stimulating a global debate on how to manage future changes in SLR and how to mitigate future impacts on coastal human communities and natural infrastructure (e.g., habitats).[9]The need to prepare for climate change is widely recognized, and there is a great demand for relevant information. For example in The Gambia, a recent statement by the Minister of Environment during the validation workshop on the UNDP/GEF/LCDF project states that: "the risk of climate change related damage to human and economic development in The Gambia's coastal areas is on

[7]Http//www.slr.stormsmart.org
[8]Http//www.slr.stormsmart.org
[9]Http//www.slr.stormsmart.org

the rise, with the compound effects of sea-level rise and changes in the river discharge, erosion of coastal embankment and changes to natural sediments dynamics posing a serious threat to the natural resources base and livelihood opportunities of coastal communities including tourism”.[10]

This section provides a review of different scientific information and tools that are available and used in sea-level rise vulnerability assessments and how they are applied at the international level. The selection of the tools was based on the actual situation along the southern coastline of The Gambia, considering that the area includes ecologically sensitive areas such as protected areas, coastal settlements, cultural and historic sites, the capital city(Banjul) and other livelihood activities taking place in the area including tourism, fisheries and agriculture.The aim is to build more resilient coastal communities and habitats, which have the ability to mitigate some of the possible effects of sea-level rise. It is important that Government, policy makers, natural resources managers, local authorities and community planners fully understand what impacts sea-level rise can have on their populations and what scientific tools and information are available to them to better inform their decision making process with regards to rising sea-levels.

The tools necessary for adaptation planning are difficult to prioritize because they will depend upon the community needs as well as where each community is in the planning process. Adaptation tools need to be understood in terms of input data requirements, assumptions within the methods, and the reliability and utility of the outputs. The tools discussed in this section have been applied in different sectors (e.g. natural resources, agriculture, built environment, transportation and energy) and many countries in particular in the United States of America along the Gulf of Mexico, inthe European Union and in other developing countries including The Gambiawhere similar existing environmentalproblems prevail such as coastal flooding, erosion, saline intrusion as a result of climate change.It is envisagedtherefore that some if not all selected tools could work in the Gambia, and help reduce coastal vulnerability and increase resilience of communities and ecosystem to climate change. As discussed below, the tools selected for review were based on prevailing circumstances in The Gambia, as well as their applicability in future vulnerability assessments. The selected tools includes: Climate Change Vulnerability Index (CCVI) Sea-level rise Affecting salt Marshes Model (SLAMM), Sea-level Rising and Flooding Impact Viewer, and Dynamic Interactive Vulnerability Assessment (DIVA) (Rozum et al 2013).

[10]Http//www.allafrica.com. (December 19th 2012)

2.2.1 Climate Change Vulnerability Index (CCVI)

Description

The Climate Change Vulnerability Index (CCVI) is a type of model developed by NatureServe used primarily in the natural resource sector to assess the relative vulnerability of plants and animals species to the effects of climate change using readily available information about climate projections and species' natural history, distribution, and landscape circumstances (see figure 5) The index helps group taxa by their risk to climate change and by sensitivity factors and helps users identify adaptation options that could benefits multiple species.[11]The Index uses a scoring system that integrates a species' predicted exposure to climate change within an assessment area and three sets of factors associated with climate change sensitivity: 1) indirect exposure to climate change; 2) species-specific factors relating to sensitivity and adaptive capacity; and 3) documented response to climate change.

Figure 5: Showing the CCVI scoring system

Source: (Rozum et al 2013)

[11]www.ebm tools network/ NatureServe

Example of the application of the CCVI tool in Florida, USA

Floridais home to many wildlife species; 386 species of birds, 86 species of mammals, 90 species of reptiles, 136 species of fish and 56 species of amphibians, all of which will be affected by climate change.[12] According to the projection in Florida, it is predicted that the stressors that will have the most impact are higher temperatures, increased droughts and sea-level rise.[13] Therefore, considering these potential impacts of climate change to the biodiversity, the Fish and Wildlife Conservation Commission (FWC) engaged stakeholdersto discuss climate adaptation measures in order to understand what climate change may mean for Florida's biodiversity. The recommendations developed from the stakeholder engagement provided direction in the development of climate action strategies and integration into existing management activities. The resulting report of the meeting provided the foundation upon which revisions to Florida's State Wildlife Action Plan were made(Rozum et al 2013)

Using the Climate Change Vulnerability Index (CCVI), the Fish and Wildlife Conservation Commission (FWC) partnered with a Non-Governmental Organization (NGO) actually requested Defenders of Wildlife and the Massachusetts Institute of Technology (MIT) to evaluate species and habitat in relation to climate change. A total of twenty-one species (five birds, four reptiles, three amphibians, four mammals, two invertebrates, and three non-native, invasive species) were assessed using this tool.[14] The vulnerability of the species mentioned above was evaluated based on projected exposure and other factors such as migratory patterns, dietary needs, as well as temperature and moisture thresholds. In addition, the spatial analysis portion of the species vulnerability assessment was conducted for six focal species. According to the assessment using the combinations of future land use scenarios and species-habitat models, "impact maps" could be produced, and the resulting maps of Florida's potential alternative futures present scenarios in which changes in coastal inundation, urbanization, infrastructure expansion, and conservation lands are projected to impact the species being analyzed.[15]

It was highlighted from the assessment that by carefully studying the changes in land use and land cover under the different scenarios, the relevance and importance of how humans will impact the landscape and interact with species adapting to a changing climate became evident

[12] http://www.cakex.org/case-studies/florida-fish-and wildlife-conservation-commission
[13] http://www.cakex.org/case-studies/florida-fish-and wildlife-conservation-commission
[14] http://www.cakex.org/case-studies/florida-fish-and wildlife-conservation-commission
[15] http://www.cakex.org/case-studies/florida-fish-and wildlife-conservation-commission

and the number of acres facing projected future conflict as well as the percentage of total habitat that is represented can be estimated. The results of both vulnerability assessments (evaluation of species and habitat and spatial analysis portion of the species) as highlighted above using the CCVI tool were used to develop adaptation strategies for the subset of six focal species (Florida panther; Least tern, Atlantic salt marsh snake, short-tailed hawk, American crocodile and Key deer) using two different methods.

2.2.2 Sea-level Rise Affecting Marshes Model (SLAMM)

Description

Sea Level Affecting Marshes Model (SLAMM) is a mathematical model that uses digital elevation data and other information to simulate potential impacts of long-term sea-level rise on wetlands and shorelines.[16](see figure 6) This model was actually developed by Warren Pinnacle Consulting and has been used mainly in many parts of the United States especially in the natural resources sector. In addition SLAMM simulates wetland conversion and shoreline modification resulting from long-term sea-level rise. It identifies potential changes in both extent and composition of wetlands types and accounts for inundation, subsistence, soil saturation, erosion, accretion, and barrier island over wash. The model uses a complex decision tree incorporating geometric and qualitative relationships to represent wetland changes and provides numerical and map-based output[17]

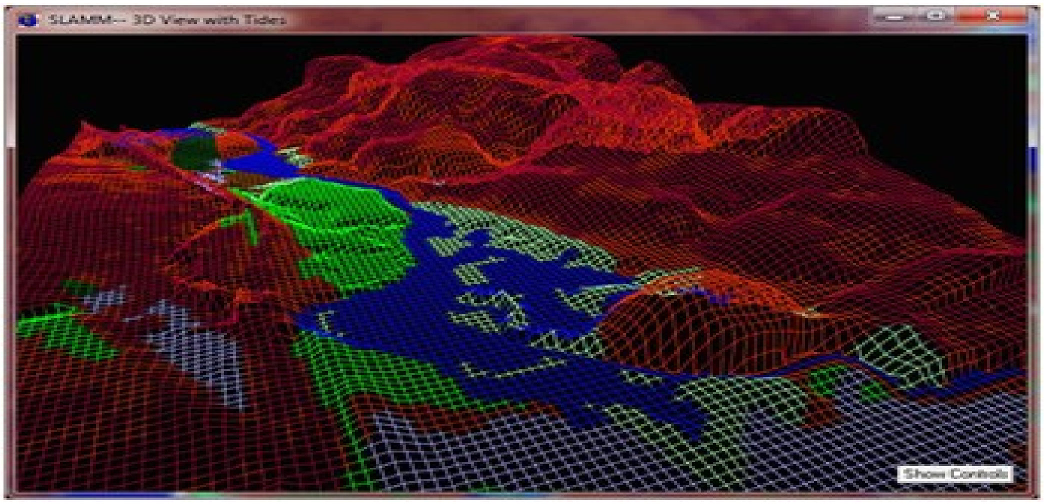
SLAMM also integrates a stochastic uncertainty analysis module to provide best/worst case scenarios and provides likelihood and confidence statistics accounting for uncertainty in future sea level rise, future erosion rates, and feedbacks between marsh vertical-accretion rates and sea level rise. The features of the SLAMM,as provided by the National Oceanographic and Atmospheric Administrative (NOAA), indicate the following characteristics:

- Address various wetland scenarios, including inundation erosion, over wash, saturation, and salinity.
- Computes relative sea-level change for time sequences of 5 to 25years
- Incorporates areas protected by dikes and other hard structures if needed.

[16]http://www.csc.noaa.gov/digitalcoast/tools/slamm
[17]http://warrenpinnacle.com/prof/SLAMM

* Incorporates sedimentation and accretion rates and provides options for computing erosion
* Incorporates standard coastal wetland classes
* Provides outputs that can be viewed in a Geographic Information System (GIS) or other software for additional analysis.

Figure 6: SLAMM model



Source (http://www.csc.noaa.gov/digitalcoast/tools/slam)

According to Warren Pinnacle Consulting, the SLAMM model entails five key primary processes that affect wetland fate under different scenarios of sea-level rise:-

* Inundation: The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping Mean Tide Level (MTL) constant at zero. Spatially variable effects of land subsistence or isotactic rebound are included in these elevation calculations. The effects on each cell are calculated based on the minimum elevation and slope of that cell.
* Erosion: Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open ocean. When these conditions are met, horizontal erosion occurs at a rate based on site-specific data.

- Over wash: Barriers islands of under 500 meters width are assumed to undergo over wash at a user-specific interval. Beach migration and transport of sediments are calculated.
- Saturation: Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to raising sea-level close to the coast.
- Accretion: Sea-level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain.

Example of application of the SLAMM tool in Maryland, USA

There are number of projects in United States that have applied the SLAMM model to reduce the vulnerability of coastal communities and ecosystem to sea-level rise. One of the examples of such case studies was implemented in Maryland, by the Maryland Department of Natural Resources (DNR). The project aimed at identifying conservation priorities for Sea-Level Rise Adaptation in Coastal Maryland.The key climate change issue in Maryland is that the coastal zone is particularly vulnerable to episodic storms, shore erosion, coastal flooding, storm surge and inundation (NOAA)[18]similar to The Gambia. The relative sea level is projected to be twice the global average rate. In the short-term, coastal areas already under natural and human-induced stress are most vulnerable. Of these, the islands and lower Eastern Shore of the Chesapeake Bay are in critical need of protection (Johnson, 2000)[19]Land conservation efforts that accommodate and proactively target areas to allow for the inland movement of coastal habitat, such as wetland migration, are needed to help maintain natural storm surge buffers, wildlife habitat, wetland-dependent human activities, water filtration, and other ecosystem service wetlands provide. However to better understand how sea-level rise could have impact on the Maryland State’s coastal wetland system, the Department of Natural Resources(DNR) conducted wetland migration modeling using the Sea Level Affecting Marshes Model(SLAMM). A variety of spatial criteria were incorporated by the DNR into the model to help identify coastal lands that provide adaptation opportunities under a sea-level rise projection of 1.04 meters by the year 2100. Using the results of the SLAMM projection for the year 2100, DNR selected additional criteria to prioritize areas for land conservation, including criteria for maintaining these areas

[18] http://www.csc.noaa.gov/digitalcoast/stories/slr-maryland
[19]Johnson(2000): Sea-level rise response strategy for the State of Maryland

into the future: large continuous wetland types based on projected wetland rates, and habitat type and size required by most wetland-dependent breeding birds. In addition, wetland areas were prioritized where they aligned with Maryland's Green Infrastructure forest interior dwelling (FID) habitat, Blue infrastructure watershed priorities and suitable non-wetland hydric soils.

The results have achieved significant impact in Maryland today, because the Department of Natural Resources is using the results of this analysis to target areas for land conservation that have adaptation benefits defined by the model criteria. According to DNR, in 2012, these Wetland Adaptation Areas were incorporated into Maryland's Green Print application, which uses targeted ecological areas (TEAs) to locate the best ecological areas in the state for land conservation[20]. In addition to target lands in the TEAs, DNR reviews every parcel of land that is considered for land conservation for potential climate adaptation benefits before seeking funding approval for land acquisition by the Maryland Board of Public Works. These benefits include protection of vulnerable areas, adaptation benefits, and mitigation.

Another important achievement of the results is that institutions or organizations such as U.S Fish&Wildlife, National Wildlife federation, and Maryland Environmental Trust, along with other coastal land trusts, are also incorporating the resulting high-priority areas into land conservation planning, targeting, and parcel-level reviews to aid in climate change adaptation. Conserving these high priority areas will allow habitats to shift inland naturally, protect developed areas, and allow places for wildlife to seek refuge as conditions change in the future.

2.2.3Sea-Level Rise and Coastal Flooding Impact Viewer

Description

According to the description provided by NOAA, the Sea Level Rise and Coastal Flooding Impacts Viewer is a visualization tool that allows users to visualize potential impacts from sea level rise.[21] Users move a slider bar to show the effects of various levels of sea level rise on coastal communities. Visuals and accompanying data and information illustrate sea-level rise inundation, flood frequency, marshes impacts, and socio-economic impacts. The purpose is to provide coastal managers and scientist with a preliminary look at sea-level rise and coastal

[20]http://www.dnr.state.md.us/ccp/habitats_slr.asp
[21]http//www.csc.noaa.gov/digitalcoast/tools/slrviewer

flooding impacts. The viewer is a screening-level tool (see figure 7) that uses a nationally consistent data sets and analyses.According to NOAA, the tool depicts the level of confidence in the inundation estimate based on the uncertainty of the LIDAR-derived land elevation and tidal datum estimate. The process used to map the sea-level rise inundation can be described as a linear superposition approach that attempts to account for local and regional tidal variability and hydrological connectivity. In addition the tool uses the best available and publicly accessible elevation data to map literature-supported levels of sea-level rise. The sea-level rise is mapped on top of Mean Higher High Water, incorporating the local and regional tidal variation for each area. Hydrologically unconnected areas greater than one acre in size are preserved but are displayed separately from hydrologically connected inundation areas.

Figure 7: SLR and Coastal Flooding Impact Viewer

Source: (www.csc.noaa.gov/digitalcoast/tools/slrviewer)

Example of the application of the SLR and Flooding Impact Viewer tool in California

The Sea-level Rise and Flooding Impacts Viewer was used in one project in California entitled: *Adapting to Rising Sea-levels in California.*This project was conceived after a publication of a study by the National Academy of Sciences, which estimates that sea-level, could rise nearly 2 meters along parts of the California coast by 2100. The report highlights that Climate change and its potential impacts on the economy are a growing concern for California decision makers and citizens (Rozum& Carr, 2013). In addition, the California Climate Adaptation Strategy (2009) recommends also that communities in the state begin to develop adaptation plans to address the potential impacts of climate change.There are several institutions and agencies in California currently using the Sea-level Rise and Coastal Flooding Impacts Viewer for their adaptation planning efforts. One of the key institution or places where the tool has been used by the project is at the Port of Long Beach, one of the world's busiest seaports, where the project worked with partners such AECOM (an Environmental engineering and technical services firm) to conduct an initial exposure analysis of Port assets using the Viewer's inundation layers (Rozum& Carr, 2013)

The main outcome of the project is that the Viewer uses a consistent, unified dataset based on high resolution elevation data and currently provides the best available estimates of inundation due to sea-level change for the U.S West Coast. In addition State agencies are increasingly recommending that local organization use the viewer to address climate impacts when updating their local coastal plans. The data collected by the project includes the sea-level inundation (1 foot increment up to 6feet), mean high water tidal datum, confidence intervals and LIDAR-derived topography (Rozum& Carr, 2013).

2.2.4 Dynamic Interactive Vulnerability Assessment (DIVA)

Description

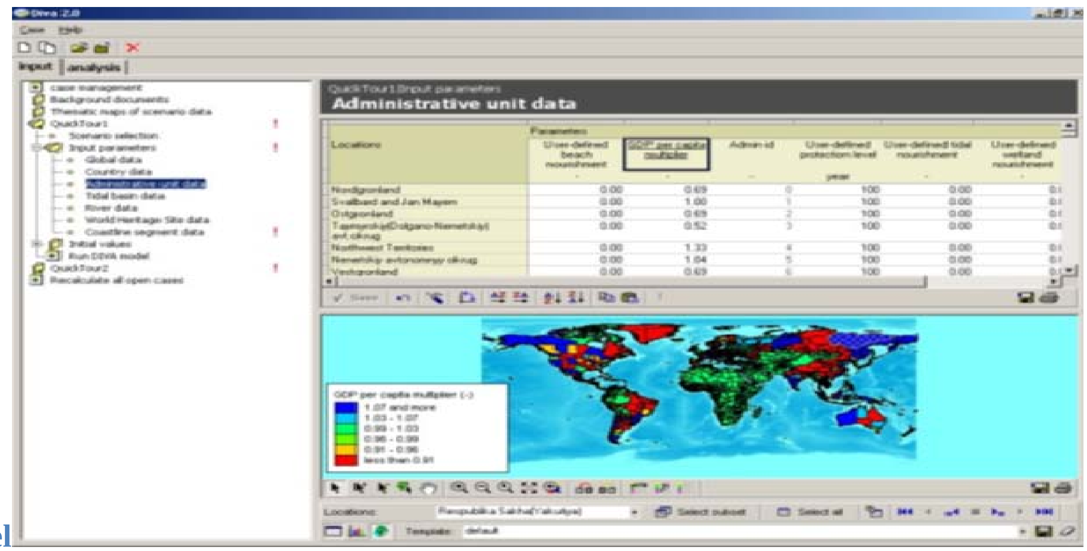
The DIVA tool is an integrated, global model of coastal systems that assesses biophysical and socio-economic consequences of sea-level rise and socio-economic development taking into account the following key impacts: coastal erosion (both direct and indirect), coastal flooding (including rivers), wetland change and salinity intrusion into deltas and estuaries (see figure 8) DIVA also enablesusers to take in consideration within the assessment adaptation in terms of raising dikes and nourishing beaches (predefined adaptation strategies are used in DIVA).(ETC CCA, 2011).

The DIVA is co-developed amongst a number of European research institutions with the aim of helping policy makers and analyst to interpret and evaluate coastal vulnerability to climate change with a range of mitigation and adaptation scenarios at national, regional and global scales.[22] It also considers impact due to extreme water levels caused by sea-level rise over the

[22]http://www.diva-model.net/

21st century at global and regional scales. DIVA allows the user to insert future sea-level rise scenarios to project future impacts on global scale. Metrics include: number of people potentially flooded due to extreme water levels, wetlands loss due to extreme water levels, total cost of damages due to floods, potential costs of adaptation to reduce flood risks.[23]

Figure 8: DIVA model



Source (Klein & Amanatidis, 2004)

Example of application of the DIVA tool

The first version of DIVA was developed as part of a user-friendly policy exploration tool in the EC-funded project DINAS-COAST (Dynamic and Interactive Assessment of National Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-level Rise)(ETC CCA, 2011). Apart from the DINAS-COAST, the DIVA was used within the PESETA project (Julie, et al., 2009) to analyse the physical and economic impacts of sea-level rise in the 22 EU coastal member states with and without adaptation. DIVA was also used at the European level (EU-27) by (Hinkel, et al., 2009)(Hinkel, et al., 2010), to assess physical and socio-economic consequences of impacts induced by sea-level rise and storm surges on coastal areas. The results of the above work were used by European Environment Agency (EEA) to draft the chapter on coastal zone of the European Environment- State and Outlook (SOER, 2010) thematic

[23]http://www.tyndall.ac.uk/research/cities-and-coasts/diva-model

assessment “Adapting to climate change”(ETC CCA, 2011).Also DIVA has been used in a wide range of projects funded byUNEP (e.g. Impacts of sea-level in Africa)[24], World Bank (e.g. Economics of adaptation to Climate Change)[25] and Foreign and Commonwealth Office (e.g. Met Office’s impact of climate change in a 4°C world’).[26]

The DIVA comprises four major components: 1)a detailed global database with biophysicaland socio-economic coastal data; 2) global and regionalized climate and socio-economic scenarios until the year 2050; 3)an integrated model, enabling the interaction between modules that assess biophysical and socio-economic impacts and the potential effects and costs of adaptation; and 4) a graphical user interface for selecting data and scenarios, running model simulations and analyzing the results(Klein & Amanatidis, 2004). Most importantly the output of DIVA will enable its users to explore the effects of climate change on coastal environments and societies, explore the cost and benefits of coastal adaptation options, set priorities for international co-operation with respect to climate change and development and use results for further scientific and policy analysis(Klein & Amanatidis, 2004).

2.2.5 Analysis of the tools

The term “tool” in the context of coastal vulnerability or climate change impacts and adaptation refers to software and web-based applications which help incorporate (geographical, environment or socio-economic) specialized analyses into the planning process(Rozum& Carr, 2013).Anotherdefinition by UNFCCC states that “tool”is a means or instrument by which a specific task is accomplished. Examples include: impact models, decision tools (cost-benefits analysis) and stakeholders tools (vulnerability indexes).In addition, toolshas been used to describe climate data, models, and sensitivity analysis to molecular markers an essays, GIS methods and a wide variety of processes, policies, and analytical approaches that assist decision makers develop and assess potential solutions to problems (Burkett & Davidson, 2012; Rozum& Carr, 2013).

[24]http://www.unep.org/climatechange/adaptations/Portals/133/documents/Adapt
[25]Http://climatechange.worldbank.org/content/economics-adaptation-climate
[26]Http://www.fco.gov.uk/en/global-issues/climate-change/priorities/science

This review of tools has identified quite a number of tools for adaptation planning developed by different research institutions in the field of climate change vulnerability studies. Also the experience gathered from the countries or projects where these tools have been applied are quite different from one another. Some of the tools appliedwere used in the different sectors such as natural resources, agriculture, built environment, transport and energy.Most of the tools have been developed by researchers from different institutions, Government agencies, and NGOs, and it is clear that not only the quality and effectiveness of the tool is required but also they need to consider or carefully select as they are designed for very different purposes.From the literature review, the tools are generally categorized into three types:visualization, modeling and decision support tools. However, the tools selected or discussed below in this review are two types, visualization and modeling. The reason of not discussing decision support tools in this review is because they have functions similar to visualization tools in analyzing and communicating about planning decisions.

As highlighted above, the first types of tools in this review are the visualization tools, such as sea-level rise and coastal flooding impact viewer. These are important in the stakeholder engagement stage and during the adaptation planning process.This is because it creates simulations and graphics of current and potential future conditions and processes to help stakeholders understand and envision potential consequences of different management decisions (Rozum& Carr, 2013). These types of tools often perform analyses but generally require less user input and customization than other analytical tools. Commonly, they do not have the ability to run customized analyses with local data, are generally easy to use and do not require specialized software or hardware.This tool has been developed by NOAA and used in the USA in particular in a project called "Adapting to Rising Sea-level in California. There is no other information where the tool has been used before although after its application in California, the San Francisco Bay Conservation and Development Commission is considering using the viewer to implement new policies requiring that sea-level rise be considered when permitting coastal projects. Other State agencies are increasingly recommending that local organization use the viewer to address climate change.

As a result of the impact and success of the outcome of the Sea-level and Coastal Flooding Impact Viewers, this tool could potentially be applicable to the situation in the southern coastline of The Gambia, especially at the Gambia Ports Authority (whose offices, ferry services and warehouses) are all located close to the sea. The tool could help to conduct exposure analysis of Gambia Ports Authority's assets using the Viewer's inundation layers as applied at the port of Long Beach (one of the world's busiest seaport) in California. Apart from the Port Authority, there are other Government buildings such as the State House, National Assembly building, some key hotels, and cultural and historical sites, all which are within the Capital city of Banjul. In addition the tool could be used to determine if future development projects within the capital city or along the coastline of The Gambia would be impacted by sea-level rise, and if so, to what extent. This information will be useful to policy and decision makers in formulating policies or strategies geared toward addressing climate change impacts. On the otherhand, the disadvantage of using this tool is that inundation scenarios do not include coastal storm surge, erosion, or other coastal processes and cannot customize outputs or load additional local inputs into the tool for analysis (Rozum& Carr, 2013).

On the other hand modeling tools such as SLAMM, CCVI and DIVA are very important and essential during the scoping or inventory stage of the adaptation planning process. In other words theymodel current and potential future conditions of geophysical, biological, and/or socioeconomic processes. These are generally the most technically challenging tools to use and often require GIS software and appropriate hardware, topical expertise, and training. Models also generally require local data on the process being investigated. It is important to consider data requirement when assessing the appropriateness of these tools.The success story of the SLAMM model is demonstrated in Marylandfor the purpose of identifying conservation priorities for sea-level rise adaptation, as well as its ability in simulating wetland conversion and shoreline modification resulting from long-term sea level rise. This tool is definitely recommended for use in The Gambia, particularly at Tanbi Wetlands National Park (RAMSAR Site) and other wetlands ecosystem. Due tothe vulnerability of the Capital city of Banjul to sea-level rise, Tanbi Wetlands National Park with its associated biodiversity and socioeconomic potential for the communities through fishing are threatened by sea-level rise.The SLAMM model has the advantages of providing information needed by policy makers and contains the major processes pertinent to wetland fate. It is also relatively simple to employ, is open source, has minimal data requirement, and has low financial and computational costs of application and integrate uncertainty analysis (Rozum& Carr, 2013). As mentioned in (ETC CCA, 2011), the disadvantages of SLAMM is that it is tailored for coastal habitat and related changes, lacks feedback mechanisms between hydrodynamic and ecological systems that may be altered by changes in sea-level, and does not include a socio-economic component.

As discussed above, The CCVI has been used in Florida to determine the vulnerability of some key species and their habitat to climate change. The results of both vulnerability assessments (evaluation of species and habitat and spatial analysis portion of the species) were used to develop adaptation strategies for the subset of six focal species (Florida panther,least tern, Atlantic salt marsh snake, short-tailed hawk, American crocodile and Key deer). The IUCN Red-List assessments of threatened species have been using a similar tool to assess species for their extinction risk and vulnerability to climate change. Also the World Commission on Protected Areas (PAs) has developed a framework on the assessment of management effectiveness of PAs, which led to development of the so called Management Effectiveness Tracking Tool (METT)(Ulrichs, 2013). This rapid assessment tool is commonly used and was applied to evaluate the threats as well as the management effectiveness of PAs in order to identify management strengths and weaknesses. However, with the threats facing PAs due to climate change, a new METT tool has been developed incorporating climate change observations and future expectations under the GEF funded project "*Protected Areas Resilience to Climate Change in West Africa*" (PARCC). This has been recently tested in The Gambia as a pilot project, and if found to be fit for purpose, will be replicated to other countries in West Africa. CCVI is highly recommended in other protected areas along the southern coastline, such Tanji/Karenti Bird Reserve, and BolongFenyo Community Wildlife Reserve (the first Community Wildlife Reserve) in The Gambia.The advantages of the CCVI tool are that it provides a common framework for assessing a variety of terrestrial and aquatic plants and animals, andallows screening of relatively long lists of species. The disadvantages associated with in using the tool is that it does not apply to marine species, and is not a substitute for an in-depth vulnerability assessment of high profile species (Rozum& Carr, 2013).

Unlike the three tools discussed above, the DIVA is more common and widely used not only in the USA, but also in many parts of the world. After its development by the EC-funded project DINAS-COAST, it has been used in EU coastal member states by (Hinkel et al, 2009 and 2010) to assess physical and socio-economic consequences of impacts induced by sea-level rise and storm surges on coastal areas, and also within the PESETA project by (Richards & Nicholls, 2009) to analyze the physical and economic impacts of sea-level rise in the 22 EU coastal member states with and without adaptation. In The Gambia, DIVA has been used by Brown et al (2011) to project sea-level rise in The Gambia. They projected a sea-level rise (in comparison with 1995 levels) of 0.13 m in 2025, 0.35 m in 2050, 0.72 m in 2075 and 1.23 m in 2100.Other tool used in vulnerability assessment along the coastline of The Gambia is Aerial Videotape-assisted Vulnerability Analysis (AVVA) used by (Jallow e tal 1996) to assess the vulnerability of the coastal zone of The Gambia to sea-level rise. They predicted that a 1 meter sea-level rise in The Gambia will lead to inundation of about 92 km² of the coastal zone. It has been estimated that about 50% (47 km²) of the land loss to inundation will come from the sheltered coast (Government of The Gambia 2007); Shoreline retreat is projected to vary depending on topography, between 6.8 m in cliff areas to about 880 m in flatter and sandier areas (Jallow et al. 1996). The advantages of DIVA is that it is a Robust tool for coastal vulnerability assessment from global to national/regional level, it also enables the user to address various key impacts and possible pre-defined adaptation strategies, and it has already been used at the European and international level (Richards J. and Nicholls R.J., 2009; Hinkel eta l.. 2009). However its disadvantages include limited model resolutionwhich requires medium-high expertise and does not consider ecosystem-based adaptation measures(ETC CCA, 2011).

CHAPTER 3- CASE STUDIES OF STATES: REGIONAL AND INTERNATIONAL

Introduction

Previous chapters (1& 2) focuses mainly on climate change projections and adaptations as well as review of approaches and methodologies used in coastal vulnerability assessments. This chapter highlights reviews case studies on selected countries at both regional and international level to determine the extent of coastal erosion problems in each of the countries highlighted as well as the management and policy options implemented or applied to address the problem. The first section focus on three case studies in West Africancountries (Senegal, Ghana and Nigeria).The main reasons for focusing on coastal erosion at this stage of the review, is that it is a major coastal problems along the coastline of The Gambia and hence becomes a high priority for The Government of The Gambia. These countries were selectedbased on their experience in implementing coastal protection projects over the past years, so we could benefit from the good and bad practices and learnt from them. Another reason is that future climate change in West Africa will not be evenly distributed in each country, but the impact of accelerated sea-level rise are almost the same due interconnecting coastline of the region. Therefore, we cannot only gain experience from different local strategies for adaptation available in each country, but we can also strength existing regional cooperationto mainstream climate change issues and also combat the problem of coastal erosion which is threatening the coastal communities and ecosystems and hence reducing our resilience.The second section focuses on the case studies in United States, Netherlands and Indonesia. Despite having similar problems of coastal erosion,these countries have embarked on more active coastal protection measures and possibly developed some good strategies and institutional frameworks for addressing short and long-term mitigation measures. In addition, the level of experience and knowledge in the application of coastal adaptation differs from country to country, but it is widely acknowledged that experience and knowledge of coastal adaptation is more advanced in developed countries(UNEP/GEF, 2010).

3.1 Regional Case studies on Coastal Erosion

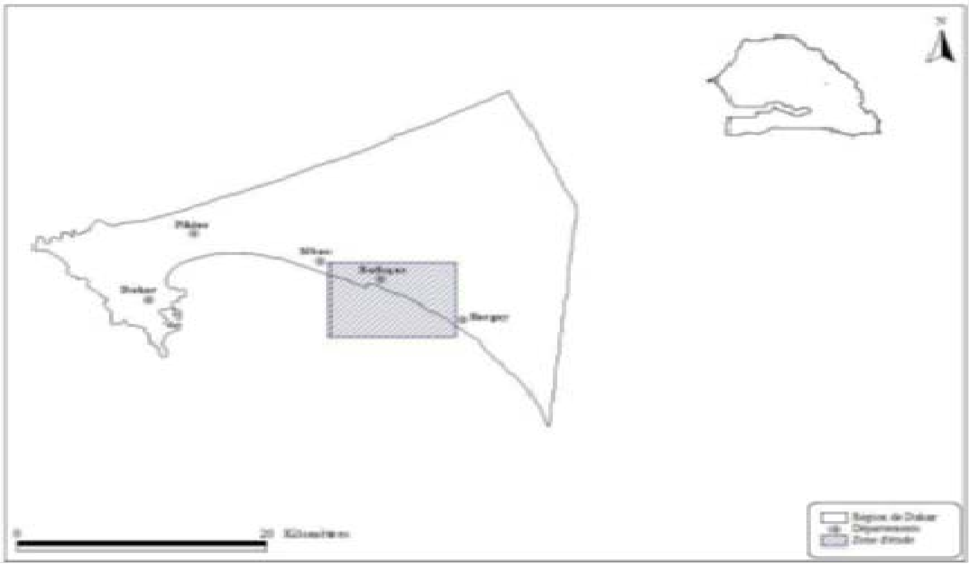
3.1.1 Case study on coastal erosion,Rufisque, Senegal

Country overview

Senegal is located on the West Coast of Africa. It borders the Atlantic Ocean on the westernmost point, Mauritania to the north, Mali to the east and Guinea and Guinea-Bissau to the South. Internally it almost completely surrounds The Gambia. Senegal covers a land area of almost 197,000 square kilometers and has an estimated population of about 13 million.[27]Three quarters of the population of Senegal live near the coast in the country's most economically important region.[28]The coastline of Senegal is 700km long, and the country is extremely dependent on its coastal and marine zones. Not only are important highly productive ecosystems present along the coast (mangroves) but most of the population as well as major economic activities are also located close to the sea. Fisheries and tourism are the main sources of earning in Senegal, and these economic activities are linked to the coastal and marine zone.Fish stocks are declining due to climate change as a result of changing water temperature and overexploitation, leading to decline in productivity, decreases in coastal biodiversity especially the mangroves. Rufisque is a town located in the capital city of Dakar, western Senegal (see fig 9)

[27]http://www.wikipedia.org
[28]http://atlanticrising.org/coastal-erosion.asp

Figure 9: Location on Rufisque on Senegal map



Source (IUCN/UEMOA Regional Coastal study report, 2011)

Projections indicate that a one-meter rise in sea level by 2100 would result in the disappearance of between 55 and 86 square kilometers of the country's beaches and could flood 6000 square kilometers of low-lying areas, notably the estuaries. Likewise, with a rise of 40 to 120cm, coastal facilities and human settlements could suffer heavy damage. Mangroves are extremely dependent on sea-level variation, rainfall, and salinity and could therefore migrate or decrease significantly(UNFCCC, 2011)

Tourism is also an important economic activity in Senegal. The country's entire touristic infrastructure lies along the petite cote (especially around Saly, in Saint Louis, and Cassamance), which are themselves already threatened by coastal erosion). The potential loss of this valuable infrastructure and consequent loss of employment represent a substantial risk for the many actors whose primary income is derived from tourism. Traditional rice growing activities carried out in valleys and estuaries will be affected by a larger intrusion of saline waters, making the drainage of those areas even more difficult (UNFCCC, 2011).

Coastal protection measures

Significant portions of the coastline in Senegal have been lost to coastal erosion in the past few decades, forcing communities to retreat or relocate. The causes are both anthropogenic and natural, with human pressure creating conditions for natural storm events and coastal process to have greater impacts(USAID, 2011). The littoral zone of Rufisque has long been threatened by coastal erosion, which led to the building of protective structures including groyneswhich were consolidated in the 1980s, causing deterioration in the natural environment of the beach. The protective walls have intensified the recession rates of the Rufisque shoreline especially at the extremities of these structures causing rapid erosion at the seafront of the local graveyard and threatening houses and other economic infrastructures. The shoreline erosion rates vary and it is estimatedbetween 1-3meters per year for sandy beaches(UNFCCC, 2011).According to recent studies conducted by International Union for Conservation of Nature(IUCN, 2010) a comparison between the positions of the high water mark limit on aerial photographs and satellite images between 1954 and 2006, shows a significant regression of the beach of Rufisque from 0.4-1.5m per year[29].

In response to the rapid and severe rate of erosion which is not only threatening the houses, graveyard and economic livelihood of the local communities of the Rufisque, the Government of Senegal implemented some management intervention in 1980s by dumping stone boulders at the seafront to reduce the impact of accelerated erosion(see figure 10).[30] However the rock boulders did not actually stop the rising waves from eroding the shoreline.Then an option of building three protective sea wallswas conductedat various times, which all failed due to lack of well and effective planning and resulted in the loss of many homes[31]. The reasons for collapse of the sea wall is that there were no proper channels, so when the wall is breached pools of water form behind it, and therefore undermine the structure. This area is used as a rubbish dump so it quickly becomes very unhygienic (see fig 11).

The latest sea wall built in Rufisque was in 2012, through the USD8m project from Adaptation implemented by Centre de SuiveEcologique (CSE) as the first accredited national Implementing Entity of the adaptation fund. The project will also include protection of the livelihood of the communities living along the coastline, especially at the rice fields.

[29]UEMOA/IUCN Case study on coastal erosion in Senegal, 2011.
[30]UEMOA/IUCN Case study on coastal erosion in Senegal, 2011.

[31]Http//www.atlanticrising.org

Figure 10: Boulder stones and eroded graveyard in Rufisque

(Sources Sall et al, 2011-UNFCCC expert meeting)   (IUCN/UEMOA, 20

Figure 11: Collapse and new sea-walls built at Rufisque

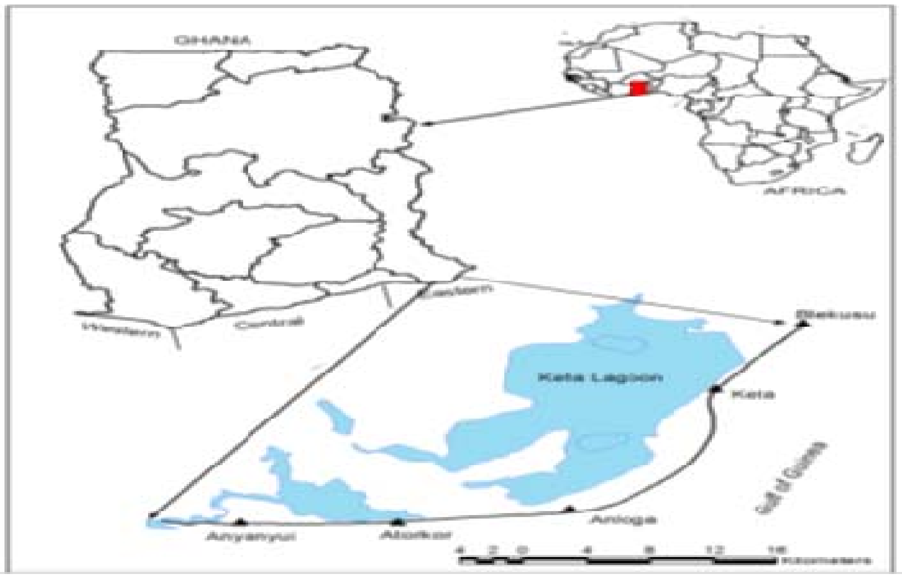
Source IUCN/UEMOA, 2011 UNFCCC Adaptation Fund 2012

3.1.2 Case study on coastal erosion, Keta Sea Defense Project, Ghana

Country overview

Ghana is located in Western Africa and has about 540km coastline. The coastal zone of Ghana is generally divided into three sections by geomorphology: the Western, Central and Eastern regions(Appeaning Addo, et al., 2011) (see figure 13**).**Keta is located on the eastern coast, which is about 149km, and stretches from Aflao (Togo Border) in the East to the Laloi Lagoon west of Prampram. It is a high-energy coast with wave heights often exceeding 1m in the surf zone and has a tidal range between 0.68m (neap tide) and 1.32 (spring tide).

Figure 12: Map of Ghana showing the location of Keta



Source(Ly, 1980 in Appeaning et al 2011)

Ghana’s coastal zone represents about 6.5% of the land area of the country, and yet accommodates 25% of the nation’s population. This small strip of land host 80% of the industrial establishment in Ghana. Over 70% of the shoreline of 550km is sandy(Appeaning Addo, et al., 2011). Coastal flooding and shoreline retreat are serious problems along the coast. According Ly (1980) and Boateng (2011) the eastern coast is highly vulnerable to accelerated sea-level rise and is therefore identified as the most erodible stretch with rates as high as 4m/year prior to the construction of the Dam in the early 1960’s which has supposedly reduced sediment supply to this coast, offsetting the balance between the sediment lost to long shore drift and replenishment. Erosion rates increased a reaching as high as 8m/year around 1970(Appeaning Addo, et al., 2011).

The coastline is fronted by sandy beaches and barriers of varying width spatially and temporarily. The Eastern coast has two major water bodies at its backshore. They are Volta delta and the Keta lagoon complex. The Keta lagoon is the largest lagoon in Ghana (Boateng, 2011) and has a large wetland, which extends to the Volta delta and is surrounded by marshy areas with a sandbar separating the lagoon from the Gulf of Guinea and a number of creeks along the coast. The sand spit is very narrow; barely more than 2.5km at its widest point, with a general elevation up to 2m above mean sea level(Boateng, 2009).As highlighted by Appeaning-Addo, et al (2011) the main causes of erosion along the eastern shores of Ghana are both natural and man-made.

The natural causes include, wave and current actions, shoreline orientation, and sea-level rise. Man-made actions include; sand mining, damming of rivers (Volta), overharvesting of mangroves and defense structures. However, the degradation of mangrove ecosystem through human exploitation reducesthe loss of its shoreline protective feature. This contributed to the enormity of the erosion problem in the catchment. In addition it is mentioned in the Ghana national report byAppeaning-Addo, 2011) that"following the damming of the Volta River, the result of which cut off substantial amounts of sediments that reach the littoral zone, erosion has become of critical concern averaging about 2-3m/year in recent times. It is estimated that the recession rate in the Keta area has increased from 4m/year before the construction of the dam on the Volta River in 1965 to 8m/year after the dam construction. The rate of erosion in the Keta area is the worst that Ghana has ever experienced"(Ly, 1980).[32]

Coastal protection measures

In 1999 Ghana's Government secured a loan from the US Exim bank and started aUSD 84million protection project in 2000 known as the Keta Sea Defence Project (KSDP).This giant initiative was deemed necessary by the Government because coastal industries such as salt extraction and fishing are in danger, coastal communities, cultural and archeological sites as well as future development sites are threatened by accelerated sea-level rise.[33]A number of coastal defense measures have been implemented by the project in Ketaincluding construction of six(6) rock filledgroynes and revetments, 80m long flooding control passage,14km of hard-surfaced road network equipped with 14 drainage mechanisms,and 225 hectares of embankments suitable for equipment. More than 5,000m of protective banks have been planted with local tree speciesand the project was completed in 2004. In addition, offshore dredging from the lagoon was done to fill in-between groynes(figure15)

Figure 13: Showing Keta Lagoon and the Groynes

[32]Project Proposal on Coastal Erosion: Mitigation of coastal erosion and restoration of degraded areas in Sub-Saharan Africa)
[33]Http://www.atlanticrising.org

Source (Http://www.atlanticrising.org)

Prior to the implementation of KSD project between 1986 to 2001,erosion dominated the entire shoreline with annual rates ranging from 0.1 to 15.4m/year to 21m/year with an average of 5.90m/year(Appeaning Addo, et al., 2011). The higher erosion rates were reported to occur between Keta and Blekusu and other areas such as Atorkor and Anyanui respectively. While there is evidence of significant accretion taking place in some areas, close to the estuary shows evidence of both erosion and accretion over the period. The erosion rates were as high as 15m/year and accretion rates also at a high of 14m/year(Appeaning Addo, et al., 2011).

However following the completion of the KSD project in 2004, records shows a reversal of the situation with the entire coast experiencing more accretion. This was determined by comparing shoreline change before and after the construction. There is also a significant reduction in the rate of erosion along the shoreline especially between Keta and Havedzi and also at the level of the lagoon outlet and re-establishment of the sand spit(Appeaning Addo, et al., 2011). In conclusion, the construction of site-specific hard structures such as the Keta Sea Defense tends to stabilize a specific section of the coastline and cause a “knock on effect” down drift (Boateng, 2009). As confirmed by studies(Appeaning-Addo, 2011) to the immediate east of the Sea Defense, erosion is occurring at high rates leading to the destruction of properties.

3.1.3 Case study on coastal erosion, Victoria island, Nigeria

Country overview

Nigeria is located on the west coast of Africa with a coastline on the Atlantic Ocean. Victoria Island is in the west of the country in the city of Lagos.[34] Victoria Island is a very popular island of real estate and part of this barrier system is often referred to as the "Hollywood of Nigeria".[35]Its coastline is approximately 853km long, bounded to the West by the Benin Republic and to the East by Cameroon. Because of the extremely low elevations and slopes, the coastal zone in Nigeria is currently subject to recurrent flooding from coastal storms and during the annual rainy season of May through September. An estimated 25 million people (or 28% of the Nigerian population) are concentrated in the coastal zone(French, et al., 1995). The largest city, Lagos is expanding rapidly on ground which is often no more than a 1 meter above existing sea-level and even under present conditions experiences serious problem with periodic flooding. According to French et al (1995), some 85% of the country's two thousand (2000) industrial establishment are located within the coastal zone. Other activities in the coastal areas include: shipping, fishing, tourism, agriculture, lumbering and communication(Nwilo, 1996)

Coastal erosion problems and measures

Coastal erosion and flooding have been considered the two most devastating environmental hazards affecting the coastline of Lagos which harbors about 40% of the urban population.(Folorunsho, 1999).[36]Victoria Islandis not only a widely popular beach for tourists but is also well known for high real estate structures consisting of private and commercial buildings fronting the beach. One of the key prominent buildings is the College of Fisheries School built and donated by the Japanese Government to Nigeria (Folorunsho, 1999).

The beach of Victoria Island has long since been experiencing serious erosion, which is considered as the fastest erosion rates in Nigeria and one of the fastest eroding beaches in the world (Folorunsho, 1999). The main reason for this alarming rate of erosion was due to the construction of two jetties or two stone moles (east and west) at the entrance to Lagos harbor between 1908 and 1912 (Awosika et al 2002, and Folorunsho, 1999). The purpose of the moles or jetties was to protect the dredged deep-water entrance into the Lagos harbor from intense

[34]http://www.unep.org/pdf/TNAhandbook
[35]http://www.csiwisepractices.org
[36]http://www.csiwisepractices.org

wave action, and prevent silting of the entrance by the west to east drifting sand. In essence, the intervention was designed to intercept the long-shore transport of large quantities of sediment. However the interception of sediments became disastrous for Victoria beach, because without the construction of the jetties, these sediments would naturally be deposited on the beach, helping to maintain its sediments volume(UNEP/GEF, 2010).Between 1900 and 1959 Victoria beach has retreated by over 1km near the eastern mole, while the Lighthouse beach near the western breakwater on the other hand accreted by over 500m within the same periodFolorunsho, (1999). The landward erosion rate on Victoria beach was observed to be between 25- 30m per year between 1981 and 1985 (UNEP/GEF 2010;Folorunsho, 1999). The problem of beach erosion is further aggravated by periodic storm surges, which are accompanied by plunging waves causing the offshore transport of Victoria beach'sremaining sediments (Awosika et al, 2002).

Since in the late-fifties, many erosion control measures have been implemented by the Government of Nigeria to reduce the serious rate of erosion and flooding in Victoria Island and protect the high real estate structures consisting of both private and commercial buildings along the seafront. Some of the interventions taken include extension of the groynes, and beach nourishment and constructing of permanent pumping stations(Nwilo, 1996). According to Folorunsho, (1999) beach nourishment was implemented between 1985 and 1986, which involved the dumping of 3 million cubic meters of sand dredged from nearby offshore areas. This intervention actually extended the beach width by an average of 75m. However, following the beach nourishment, erosion continued averaging 46m to 110m at various points on the beach between 1986 and 1995(French, et al., 1995).

The most critical area of the Victoria beach facing serious erosion after the beach nourishment was beach front of the Federal College of Fisheries and Marine technology building worth over 10million US dollars, which was donated to Nigeria by the Japan Government. It is reported by (Folorunsho, 1999) that when the new Fisheries College was being commissioned in 1993, the seafront or beach was 150m wide, but reduced to few meters in 1995 from the foundation to the high water mark. In response to this rapid and accelerated erosion "T-shape

Groynes were built in 1995 to protect the college building from being washed away. However the intervention resulted in rapid erosion along the down drift side, and hence requires another shore parallel breakwater was constructed between to protect the eastern part of the College as a management intervention. In addition the table 3 below highlights a number of engineering solutions that have been applied at the beach.

Figure 14: Revetment at Victoria beach

Source (www.starafrica.com) Pius UtomiEkpeu, 2013,

Table 3: History of erosion measures, Victoria Beach, Nigeria

Period	Coastal erosion measures applied
1958	Construction of a groyne at the foot of eastern breakwater to avoid undermining
1958-60	Dumping of dredged sediments from the harbor channel for dispersal along the beach by waves
1960-68	Permanent pumping station built on eastern breakwater supplying an average 0.66 million m3 of sediment from the channel to the beach
1964	Shoreline-parallel timber groyne constructed 26m from the shoreline
1969-74	Artificial sand replenishment
1974-75	3 million m3 sand dumped and spread on beach
1981	2 million m3 sand dumped and spread on beach
1985-86	3 million m3 sand dumped on beach
1990-91	5 million m3 sand dumped on beach(all the sand deposited from 1985-86 had been washed away in most places)
1995-97	6 million m3 sand dumped on beach(2 million m3 per year)
1998	Groyne constructed
1999	2 million m3 sand dumped and spread on beach using dredger
2002-03	Dredging of more than 2million m3 of sand

Source (Adapted from Sunday & John 2006 in UNEP/GEF, 2010)

3.1.4 Analysis on the best and bad practices

Low-lying coastal areas are highly prone to inundation from sea-level rise(Saleem Khan, et al., 2012). Coastal environments are constantly changing as a result of the interaction between waves, wind and ocean currents(Gopalahrishnan, et al., 2011). One of the most likely consequences of global warming is an accelerated sea-level rise mainly due to oceanic thermal expansion and melting of glaciers, and the Greenland and Antarctic ice sheets(Ragoonaden, 2006). The rate of sea-level rise indicates a recent increasecomparing the last two millennia and the last century IPCC (2001). According to the Third report of the IPCC (TAR) the global sea-level rise in the 20th century was between 10 and 20cm and predicted that a further accelerated rise of 9-88cm will occur between 1990 and 2100 with a mid-estimate of 48cm(Kennedy, et al., 2002). On the other hand the IPCC Fourth Assessment Report (AR4) projected a global sea-level rise of 18-59cm from 1990 to the 2090s(Saleem Khan, et al., 2012). These ranges are narrower than in the Third Assessment Report, and the main reason was attributed to improved information about some uncertainties in the projected contributions(IPCC, 2007).

Sea-level rise is a major coastal issue in the 21st century because many of the World's built assets are located in the coastal zone(Isaac, 2012). Some of the impacts of sea-level rise induced climate change along the coast include coastal erosion and flooding, which are threatening major activities such as tourism, artisanal fisheries, biodiversity and coastal settlements. This gradual landward movement of the shoreline is being observed in many parts of the world, and The Gambia and many countries in West Africa are experiencing this phenomenon.Apart from the natural causes of climate change impacting the coast, past human interventions such as sand mining, unsustainable utilization of coastal ecosystems such as mangroves, uncontrolled and unplanned urbanization along the coast also contributed immensely to the serious rate of erosion along the coast in many countries in West Africa. The previous failed hard engineering interventions for example seawalls in Senegal and revetment in both Ghana and Nigeria have also contributed to the fast disappearance of the coastline.

As defined by the European Commission (2004), coastal erosion is the encroachment upon the land by the sea and is measured by averaging over a period, which is long enough, to eliminate the impacts of weather, storm events and local sediments dynamics.Coastal erosion is often associated with short-term events such as storms but is, in fact, a dynamic and long-term process(United Nations Environment Programme, 2012). It is considered a more serious problem when it affects the areas inhabited by people or where economic activities take place. It becomes a hazard when coastal erosion poses threat to humans such as collapse of houses and other structures into the sea and intense flooding of backshore low-lying areas(United Nations Environment Programme, 2012).

As discussed in the report by EC (2004), the causes of coastal erosion are mainly the result of a combination of factors- both natural and human induced- that operate on different scales. The most important natural factors are: winds, storms, near shore currents, relative sea-level rise (a combination of vertical land movement and sea-level rise) and slope processes. Human-induced factors of coastal erosion include: coastal engineering, land claim, river basin regulations works (especially construction of dams), dredging vegetation clearing and mining (European Commission, 2004).The three different types of impacts identified by EC as result of coastal erosion includes: loss of land with economic, societal or ecological value, destruction of natural sea defences as a result of single storm events, which in turn results in flooding of the hinterland, and undermining of artificial sea defences, potentially also leading to flood risks(European Commission, 2004).

Based on the review of case studiesthe West African coast is relatively undeveloped and there is limited coastal engineering except at harbours. However existing coastal hazards are already a worry and the coastal population is growing rapidly(Hoozemans, et al., 1993). The West Africa region is poorlystudied; there are insufficient national or regional studieson coastal vulnerability to sea-levelinduced climate change(Robert J & Mimura, 1998). The few research projects conducted in the past for example in Senegal by (Dennis, et al., 1995) and in Nigeria(French, et al., 1995),provide some information on potential impacts on the 1990 situation given a 1m rise in sea-level. Large areas of land could be lost in these countries, and most of the threatened land is wetland areas within estuaries and lagoons. In Nigeria for example the problem of land loss in the Niger delta will be compounded by local subsidence and sediment starvation, and moreover, important resources to human society could also be affected (Robert & Mimura, 1998). In Senegal a similar situation will happen and most tourist facilities could be destroyed and up to 180,000 people could lose their homes. In Ghana coastal erosion is impacting negatively on the emerging coastal tourism industry, small-scale fishing industry and local revenue generation(Amoani, et al., 2012).These impacts are expected to be severe because of the availability of fewer resources and their lower social, technological and financial ability for adaptation, developing countries, particularly those with low-lying coastal areas with high population density are most vulnerable(Saleem Khan, et al., 2012).

Thisshows that despite having a common problem of coastal erosion, each of the countries has taken different management intervention approaches in the past or present to address the serious, alarming rate of erosion. The rates of coastal erosion differ from one case study site to another, for example in Nigeria annual rates at Victoria beach between 20 to 30m per year(Nwilo, 1996), in Keta Ghana the annual rate is 5.9m/yr. whilst in Rufisque, Senegal with 1.5m as the lowest among the case studies. This finding relates to that argument that the magnitude of sea-level change impacts will vary from place to place depending on topography, geology, natural land movements and human activities (Kebede, et al., 2010). The potential impacts are uneven, and are likely to affect the most vulnerable, due to multiple stresses and their lower ability to prepare, adapt and respond(Kebede, et al., 2010).It is quite evident that coastal zone plays animportant role for the economy and livelihood of the population of the above countries through tourism, shipping, fishing, agriculture and oil exploitation. However these economic activities are threatened by coastal erosion as a result of sea-level rise induced climate change.

The options for combating coastal erosion are traditionally two fold; namely hard structure/engineering options and soft structure/engineering options. These solutions have at least two hydraulic functions to control waves and littoral sediments transport (Kawata, 1989). In applying the solutions, their underlying principles should be well-understood, otherwise they will fail. In Nigeria since the Government began implementing coastal erosion measures at the Victoria beach from the mid-fifties to date, combination of groynes and beach nourishment arethe most common practice for coastal protection. It has been observed during this review that groynes were the initial protection measures for years, before combining themmore recently withbeach nourishment. The reason for more beach nourishment as opposedto groynes is not well understood, but could be attributed to the construction of permanent pump-station between 1960-1968 which provide 0.66million m^3 of sediments from the Commodore channel to the beach, and also because the Victoria beach is quite a famous area for tourist, it would more attractive to have wide open beaches rather than the groynes, which might be less attractive to tourist in the area. Whatever reasons might have led to this strategy by the Government of Nigeria to do combinations of protections measures, one good thing is that the coastline of Victoria beach is winning the fight against coastal erosion.

On the other hand, Ghana and Senegal have both implemented hard measures in Keta and Rufisque respectively. Keta Sea Defence Project has a component of soft measures which includes some tree planting to protect the banks. In essence,the objectives of a good sea defence systems are to stabilize areas of existing and planned development; to prevent flooding of the coastal communities; to minimize disruption of human activities associated with the coastline, particularly fishing and movement of aquatic/marine species; and to avoid transferring the erosion problem to neighboring coastlines(Nairn, et al., 1998). However, studies have shown that coastal protection means more than building protective structures at the coastlines, and in most cases, these structures have not been effective in solving the problem. It either provides a temporary solution to protected coastlines, or the problem is shifted to neighboring coastlines(Kusimi & Dika, 2012). In Keta for example, studies have shown that groynes have only protected the western coastlines, but in the eastern sections of the defence structures, erosion is increasing(Boateng, 2006).According to Boateng,(2006), the rock-amour groynes constructed as part of the Keta Sea Defence were not long enough to stop the transfer of sediment down drift. Field evidence gathered in studies by (Kusimi & Dika, 2012) in 2006 suggests that the groynes have started losing the beach nourishment materials. However, complete interception of the littoral transfer by constructing long groynes might reduce or stop the transfer of sediment down drift, but it is likely to cause severe erosion to the coastline of the neighboring Togo and Benin that seems to benefit from the down drift transfer of sediment.

In Rufisque, the construction of seawalls in the early eighties and nineties to protect houses and cultural sites such as graveyards along the coastline, could not protect the city and prevent the highest waves from overtopping. As a result, they all collapsed partly due to poor design, and also the absence of a connecting arm at the southern end of the wall which explains why waves are skirting round the Muslim graveyard which is highly exposed(UNESCO/IOC, 2012). In 2010, the Senegalese Government got approval from Adaptation Fund of the UNFCCC of US$8million to be spent on a new sea wall as well as to prevent the salinization of agricultural land.

In conclusion, whether this new project will build on the experience or lesson learnt from the previous sea walls built, one thing for certain is that hard engineering implemented in Rusfisque was not a good practice at all, and this mainly due to poor engineering design.

3.2 International Case study on sea-level rise adaptation strategy

3.2.1Case study on sea-level rise adaptation strategy: California, USA

Overview

California’s coastline, which includes more than 2,000 miles of open coast and enclosed bays, is vulnerable to a range of natural hazards, including storms, extreme high tides, and rising sea-levels resulting from global climate change. Development along California’s coast is extensive, and it is estimated that 31million lived in coastal counties. Major transportation corridors and other critical infrastructure are found along the California coast, including oil, natural gas, and nuclear energy facilities, as well as major ports, harbours and water and wastewater plants. The

California coast is also an extraordinary cultural and ecological resource and offers extensive tourism and recreational opportunitie**s**(Heberger, et al., 2009)**.**

Vulnerability of California coast

California has seen a rise in sea-level of approximately 7inches (18cm) over the past century (1900-2005). During this time sea-level along most of the coastline has been rising (the only exception is in Crescent City where due to tectonic uplift, sea-level has been dropping relative to land)(Comission, 2006).Coastal flooding, erosion, and salt-water intrusion pose a threat to communities along the California coast and there is compelling evidence that these risks will increase in the future. Based on a set of climate scenarios prepared for the California Energy Commission's Public Interest Research(PIER) Climate Change Research Program, it is projected that, under medium to medium-high emissions scenarios, mean sea-level along the California coast will rise from 1.0 to 1.4meters(m) by the year 2100. Rising seas put new areas at risk of flooding and increase the likelihood and intensity of floods in areas that are already at risk (Heberger, et al 2009). Reports have indicated that erosion is not new issue in California but rising sea-level threatens to increase the severity and frequency of erosion damage to coastal infrastructure and property. Statewide, a 1.4m rise in sea-level has the potential to erode approximately 68km^2 of coastline by the end of the century(Heberger, et al., 2009). The southern portion of Monterey bay is eroding more rapidly than any other region in the state, with coastal dunes between the Salinas River mouth and Wharf II in Monterey eroding at rates between 0.3-1.8m/yr. per year (Heberger, et al., 2009; Brew, et al., 2011; Hapke, et al., 2009). Along the northern shore of Monterey Bay, sea cliffs in Santa Cruz County experience average retreat rates of approximately 0.07-0.63m/yr.(Moore & Griggs, 2002).

Strategies of sea-level rise adaptation

Sea-level along most of California's coast is already rising and the best science available suggest it will continue to rise at an increasing rate in the future (Price et al 2011; Nicholls and Cazenave 2010; Jevrejeva et al. 2009; Nicholls et al.2007). In 2008, in recognition of the threats posed by sea-level, the former California Governor(Arnold Schwarzenegger) signed executive Order S-13-2008, which called for the development of the statewide Climate Adaptation Strategy and ordered state agencies to plan for sea-level rise impacts.[37] In 2009, California completed its climate Adaptation Strategy, and it has been recently reviewed and updated (Herzog & Hecht, 2013). In 2010 the California Ocean Protection Council (OPC) worked in conjunction with the OPC Science Advisory Team and 16 state agencies through the Coastal and Ocean working group of the California Climate Action Team (CO-CAT) to develop the State of California Sea-Level Rise Interim Guidance Document. In March of 2011, the OPC adopted a non-binding sea-level resolution asking state agencies to incorporate consideration of sea-level rise into decision and program (including funding) and to follow the recommendations in the state guidance document on sea-level rise (Finzi Hart, et al., 2012). In addition to the Climate Strategy, several California state agencies partnered with Oregon, Washington and three federal agencies through the West Coast Governors' alliance for Ocean health to fund a National Academy of Sciences expert panel to review sea-level rise science for the entire West Coast.

Apart from the development of policies and an institutional framework geared towards addressing climate change and sea-level rise in California, a number of strategies to address sea-level have applied including: Setback, buffers, development conditions, shoreline protection devices overlay zones, non-conformities etc. The examples of application of some of the strategies are discussed here. Setback and buffers: Coastal setback requirements are standards that protect structures from hazards or create buffers between structure between structures or uses by preventing development a minimum distance from a baseline; often the shoreline[38].For example, the California Adaptation strategy recommends "mandatory construction setbacks-to prohibit construction and significant redevelopment in areas that will likely be impacted by sea-level rise within the life of the structure(NOAA, 2010)[39].Similar to setback requirements, buffers are standards typically designed to protect natural resources, rather than buildings. Buffers provide "a transition zone between a resource and human activities" and are intended to reduce the impact of development on natural resources and protect the beneficial services provided by

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[37]Executive order S-13-2008, office of the Governor of California

[38]California Coastal Commission, Staff Report and Preliminary Recommendation on Coastal Development Permit Application No. 6-10-064 at 2 (Jan 6, 2011), available at http://documents.coastal.ca.gov/reports/2011/1/Th10b-1-2011.pdf.

[39]http://coastalmanagement.noaa.gov/climate/docs/adaptationguide.pdf.

natural resources.[40]For example, the California Climate Adaptation Strategy recommends the use of the buffer areas to avoid risks to structures within projected “high” future sea-level rise or flooding inundation zones.In addition the California Coastal Act suggests the use of buffers to protect the biological productivity and water quality of “coastal waters, streams, wetlands, estuaries, and lakes.[41] Also, development conditions have been applied by State and local governments often to impose conditions when issuing development permits.[42] It can used to manage risks to public assets and private development in areas that are vulnerable to sea-level rise by restricting future construction of coastal armoring. For example California Coastal Commission often conditions approval of coastal development permits on a landowner’s agreement not to construct bluff or shoreline protection devices in the future. Such permits also contain provisions that waive risk and liability and a impose permanent deed restriction to notify subsequent owners of limits on future development.[43]

3.2.2 Case study of the Sea-level rise and adaptation strategies:TheNetherlands

Country overview and description of the coast

The Netherlands lies on the northern coast of Europe and is situated between Belgium in the southwest and Germany in the northeast. The Netherlands borders the North Sea which stretches from Cap Blanc Nez (France) to the north part of Jutland (Denmark) and is subdivided in three sections: the Delta coast, the Holland coast and the Wadden coast (see fig 15).

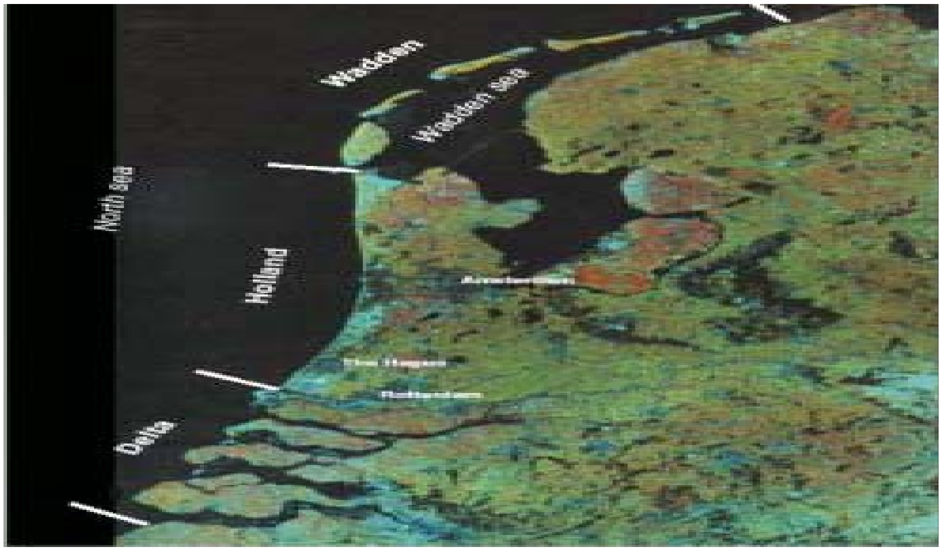
Figure 15: Morphology of Dutch Coast

[40]California Coastal Commission, Staff Report: Appeal-Substantial, Appeal No. A-5-RPV-10-002 at 13(June 1, 2011), available at http://documents.coastal.ca.gov/reports/2011/6/Th19a-6-2011.pdf.

[41]California Natural Resources Agency, 2009 California Climate Adaptation Strategy: A Report to the Governor of the State of California in Response to Executive Order S-13-2008 at 176 (2009), available at http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF.

[42]City of Malibu, Local Coastal program Local Implementation Plan S4.2(adopted September 13, 2002).

[43] Jennifer Grannis, Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use: How Governments Can Use Land-Use Practices to Adapt to Sea-Level Rise at 29 (October 2011), available at http://www.georgetownclimate.org/sites/default/files/Adaptation_Tool_Kit_SLR.pdf.



Source (Eurosion, 2003)

The coastline is characterized as wave-dominated and has been subdivided into three parts based on differences in morphological appearances and the dominance of related physical processes:

1) The Delta coast- a delta/estuary coast in the south-western part of The Netherlands. The Delta coast consists of number of former islands, separated by tidal basins, inlets and estuary. 2) The Holland coast- an uninterrupted coastline in the central part of The Netherlands between the Hook of Holland (south) and Den Helder (north), with city areas close to the sea. 3) The Wadden coast- a barrier island coast in the northern part of The Netherlands. The Wadden coast consists of barrier islands alternating with tidal inlets and their related ebb-tidal deltas at the seaward side. The lagoon area (the Wadden Sea) between the barrier islands and the mainland consists of several connected tidal basins with extensive tidal flats.

Vulnerability of the Dutch coast

The Dutch coast is low-lying and thus extremely vulnerable to flooding and the potential risks of rising sea-levels as a result of climate change. With 60% of the population living in low-lying areas and with 65% of the Gross National Product generated in coastal areas it is vital that coast protection and management are high on the national agenda,(EU, 2005). The pressure on the coast increases, both from the sea and the land. The pressure from the sea increases because of the increasing sea-level rise and the expected storm intensity. The pressure from the land increases as a result of the growing number of inhabitants and the intensification of the area's use(EUCC-D, 2003)[44] The risk of sea-level rise as a result of climate change has placed an ever-increasing threat on The Netherlands coastline and, as such, the policy for the coast is dominated by safety demands. Coastal squeeze, where the coastal margin is squeezed between the fixed landward boundary (artificial or otherwise) and the rising sea-level has occurred in The Netherlands as a result of both the intensification of economic and social demands on the landward boundary and sea-level rise (EU,2005).[45]

In the coastal zone of the Holland coast, a lot of socio-economic functions come together. The area serves a key economic function, encompassing tourism, port industries, bulb growing, water abstraction activities and fisheries. Currents waves, wind, sediments deposits from the rivers and human made structures have resulted in the present geomorphologic features of the coast. Coastal erosion was estimated to occur over 134km²,[46] spread along half of the Dutch coast. Large sections of the Dutch coast have been eroding for centuries, at some locations resulting in a retreat of 5km in four centuries. In the past, only an ad-hoc policy against coastal erosion was followed: measures were only taken when the safety of polder land was at stake or when special values in the dune area, e.g. drinking water areas, nature reserves, camping places, were threatened.[47]

Coastal erosion policy and management strategies

Historically, protecting flood risk management in the Netherlands was based on man-made hard engineering structures such as building dams, and dikes.[48]However to ensure safety against flooding, safety standards for all the flood defences including dunes has been specified by law (Delta Act 1957; Flood Defence Act 1996; Water Act 2009): prevention or reduction of flooding, water trouble and-shortage in connection protection and improvement of chemical and ecological quality of water systems, and with societal functions of water system(Mulder J.P, et al., 2011).[49] In addition, the latter two Acts define the need to preserve the coastline, because it was realized that erosion was destroying these defences along with the majority of the Netherlands coast and

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[44] Http//databases.eucc-d.de
[45]EU- a case study documenting coastal monitoring and modelling techniques in the Netherlands
[46]www.eurosion.org
[47]www.clinateadaptation.eu/netherlands
[48]www.clinateadaptation.eu/netherlands
[49]Implementation of coastal erosion management in the Netherlands

so a softer engineering option was introduced whereby structures were built that worked with the natural depositional processes occurring at the coast.Groynes and breakwaters were seen as the preferred option to build up beach and dune levels in order to offer a natural barrier to the sea. A policy of managed retreat, whereby nature is left to take its course to a large extent, was adopted around much of the remaining coastline of the Netherlands(EU, 2005).

In1990 Parliament adopted the policy of the Dutch Government to stop further structural coastal recession. The Ministry of Transport, Public Works and Water Management established the "basal coastline" as the position of the coastline on 1st January 1990 and determined that the coastline should be prevented from moving inland. The coastal policy of 1990 is referred to as "Dynamic Preservation", and since then coastal erosion management in the Netherlands has been translated into an ongoing nourishment policy. The three goals formulated were: i) no further retreat of the coastline, ii) preservation of valuable dune areas and iii) preservation of the natural dynamic character of the coast (EU,2005; Mulder J.P. et al., 2011).(EU, 2005).

3.2.3 Case study on sea-level rise adaptation strategies: Indonesia

Country overview

Indonesia is an archipelagic country (with 17,480 islands) in Southeast Asia lying at the equatorial zone between the continents of Asia and Australia and between the Pacific and Indian Ocean (see fig 16). The total landmass of 3.1 million km² with an intricate coastline of 95,181 km. All 33 provinces have a coastline and 74% of the total population lives in the coastal area (United Nations Environment Programme, 2012; Sulaiman, 1989). The population of Indonesia is about 240million, among the world most populous nations.[50] About 60% of the population is

[50] http//www.worldpopulationreview.com

concentrated on the island of Java whose total area is 139,000km². Other large islands such as Sumatra, Kalimantan, Irian Jaya and Sulawesi are also populated.(Sulaiman, 1989).

Figure 16: Map of Indonesia

Source (www.google.com)

Vulnerability to sea-level rise

Indonesia is prone to natural disasters such as floods, storms, and has experienced more frequent and severe climate related hazards in recent years.[51] As an archipelago, the country is exceptionally vulnerable to sea-level and the inundation of coastal areas. A recent statement, by the Minister of Environment, featured in the local newspaper highlighted that Indonesia could lose up to 2,000 islands by 2030, and already approximately 24 small islands are submerged.[52] The vast archipelago is extremely vulnerable to sea-level with the majority of the population living in coastal zones where most of the country's economic activity takes place. Climate change could affect millions of Indonesians, if not by displacing them directly, then by eliminating the industrial or agricultural zones or fisheries upon which their livelihoods and welfare depend.[53]

Coastal erosion was first observed as a problem in the northern coast of Java Islands in the 1970s when most of the mangrove forest had been converted into shrimp ponds and other agriculture activities, and the area was also subjected to unmanaged coastal development, diversion of

[51] http//www.acccrn.org

[52] Http// www.terradaily.com

[53] http//www.acccrn.org

upland freshwater and river damming(FAO, 2007).In the last decades, coastal erosion has become serious in many provinces but mainly in Aceh, North Sumatra, West Sumatra, Riau, Bengkulu, Lampung, Banten, East and West Kalimantan, Nusa Tenggara, South Sulawesi and Bali(UNEP, 2012; Nurkin, 1994; Prasetya and Black, 2003). The Government of Indonesia provided $79million to combat coastal erosion from 1996 to 2004, but only for Bali Island in order to protect this valuable coastal tourism base(FAO, 2007). A combination of hard structures and engineering approaches (breakwaters/jetties/revetments) of different shapes that fused functional design and aesthetic values, and soft structures and engineering approaches (beach nourishment) were used. However, succeeded in stopping coastal erosion at other places such as Sanur, Nusa Dua and TanjongBenoa beaches, but were neither cost effective nor efficient, because during low tide all of the coastal area was exposed up to 300m offshore; thus these huge structures were revealed and became eyesores(FAO, 2007).

The commitment of the Government of Indonesia to combat climate change has started since its ratification of the UNFCCC in 2004 and Kyoto protocol in 2007. Indonesia has further acknowledged the importance of preparing the country to face potential challenges occurring from climate change in its 'National Action Plan on Mitigation and Adaptation to Climate Change' and 'National Development Planning': Indonesia response to Climate Change in 2007.
Some of the current policies developed by the Government of Indonesia(Syahrani, 2011). In addition, the Government of Indonesia issued 'Indonesia Climate Change Sectoral Roadmap' (ICCSR) in December 2009. The document outlined the main priority programs for Indonesia for climate change related matters covering the period of 2010-2029(Syahrani, 2011).

3.2.4 Analysis of the sea-level rise adaptation strategies

Sea-level rise is a complex and dynamic process ultimately controlled by levels of heat-trapping greenhouse gases in the atmosphere. Globally, sea-level rise is driven by two primary factors- global ice melt and thermal expansion of seawater- but locally there are numerous processes that can alter the rate, extent and duration of changes in sea-level.[54]The vulnerability of coastal communities to sea-level rise depends on their exposure to climatic hazards such as floods, storms, ecosystem changes, erosion and saltwater intrusion. These types of events are likely to become more frequent and intense as sea level rises (Tol, et al., 2008). There are three

[54]www.centreforoceansolutions.org/montereybay

basic strategies to reduce society's vulnerability to these events highlighted above, and for each strategy a range of adaptation options is available (Biljsma et al 1996; IPCC, CZMS Staff 1990; Klein et al 2001). The three basic strategies are as follows: "Protect" to reduce the risk of the event by decreasing its probability of occurrence, "Retreat" to reduce the risk of the event by limiting its potential effects; and"Accommodate" to increase society's ability to cope with the effects of the event.

This review of case studies shows that global sea-level is rising and there are likelihoods and consequences associated with each degree of sea-level rise. For instance, the lower amount of projected sea-level rise is extremely likely and has fewer consequences, while the greatest level of projected sea-level rise is somewhat likely and has many consequences.[55] Given the significant impacts associated with higher levels of sea-level rise (which is different in each geographic location) it is important to consider them in adaptation planning efforts. For example, California has seen a rise in sea-level of approximately 7 inches (18cm) over the past century (1900-2005)(Comission, 2006).The local tide gauge of Monterey Bay only goes back to 1973(compared to San Francisco's which goes back to 1855), yet even in this short time period, we see a weak trend of sea-level rise at the rate of approximately 1.34mm/yr. +/- 1.35mm/yr. Due to local oceanographic conditions, sea-level rise in Central California has been relatively stable or even declining over the past several decades. The impact of sea-level rise is felt acrossCalifornia, especially in Monterey Bay region and Santa Cruz. It has been highlighted that southern Monterey Bay is eroding more rapidly than any other region in the state, with coastal dunes between the Salinas River mouth and Wharf II in Monterey eroding at rates between 0.3-1.8m/yr.(Heberger, et al., 2009). Other places such as the northern shore of Monterey Bay, sea cliff in Santa Cruz County also experience average retreat rates of approximately 0.07-0.63m/yr.(Moore & Griggs, 2002).

On the Other hand, The Netherlands and Indonesia are low-lying countries and thus extremely vulnerable to flooding and the potential risks of rising sea-levels as a result of climate change. For example, 60% of the population of the Netherlands is living in low-lying areas and with 65% of the Gross National Product generated in coastal areas it is vital that coast protection and management are high on the national agenda (EU, 2005). The coastal zone itself however, also

[55] www.centreforoceansolutions.org/montereybay

accommodates important other functions: e.g., ecology, drinking water supply, recreation, residential and industrial functions. Coastal erosion is visible and dominant along half of the Dutch coast and endangers these functions highlighted above, raising the need for coastal erosion management(Mulder J.P, et al., 2011). The necessity for coastal erosion management may increase even further in the near future as the Netherlands has a highly vulnerable coastal zone in terms of the potential consequences of sea-level rise. Concentrations of people and economic values in low-lying areas are expected to increase and at same time climate change is also expected to raise both everyday(Mulder J.P, et al., 2011). As an archipelagic country, large number of major cities in Indonesia has coastal cities with altitude of less than 10meters above sea-level or Low Elevation Coastal Zone (LECZ), and hence exceptionally vulnerable to sea-level and the inundation of coastal areas(Syahrani, 2011).Reports indicated Indonesia could lose up to 2,000 islands by 2030, and already approximately 24 small islands are submerged.[56]Coastal erosion hasbeen observed as a problem in the northern coast of Java Islands and many other cities. The causes of erosion, apart from sea-level rise is due to the conversion of mangrove forest into shrimp ponds and other agriculture activities as well as unmanaged coastal development, diversion of upland freshwater and river damming (FAO, 2007).Sea-level rise adaptation strategies is in three fold: “Protect” to reduce the risk of the event by decreasing its probability of occurrence, or “Retreat” to reduce the risk of the event by limiting its potential effects, and “Accommodate” to increase society’s ability to cope with the effects of the event(Biljsma et al 1996; IPCC, CZMS Staff 1990; Klein et al 2001). This review found that the case study countries are using different strategies and policiesto reduce the impact of sea-level rise, especially coastal erosion and inundation which are quite common problems in the case study countries. In the Netherland for example, they have traditionally relied on man-made hard engineering structures such as dikes and dams as strategy to flood risk management. This strategy is however backed by legislations such as (Delta Act 1957; Flood Defence Act, 1996; and Water Act 2009)to ensure safety against flooding, safety standards for all the flood defences including dunes(Mulder J.P, et al., 2011). Since 1990, coastal defence in the Netherlands is primarily based on soft engineering, in particular, sand nourishment. A new coastal policy (Dynamic Preservation of the Coast) was introduced in which sand nourishment was, and still is the major means of controlling coastal erosion. No structural erosion is allowed (the coastline of

[56]Http// www.terradaily.com

1990 is the basal coastline which must be maintained), but the coastal area is to remain as natural and dynamic as possible (EU 2005). For the case of Indonesia, the strategy to combat coastal erosion has been mainly through a combination of hard and soft engineering structures (breakwater/jetties/revetment and beach nourishment) especially at Bali Island where $79million was spent between 1996 to 2004, in order to protect this valuable coastal tourism base (FAO, 2007). However, this intervention has succeeded in stopping coastal erosion at other places but were considered neither cost effective nor efficient, because during low tide all of the coastal area was exposed up to 300meteres offshore; thus these huge structures were revealed and became eyesores((FAO, 2007). The government of Indonesia has developed some policy measures to address climate changes (e.g. NAPA, and Climate Change Sectoral Roadmap), but there is no specific policy to address coastal erosion. In California, there was a strong political commitment in recognition of the threats posed by sea-level rise, and this actually prompted the former Governor to pass an executive order S-13-2008 for development of the statewide Climate Adaptation Strategy, and instructed state agencies to plan for sea-level rise impacts. There is evidence of the impact of coastal erosion as a result of sea-level rise, notably southern and northern Monterey Bay and Santa Cruz.Strategies applied to address these concerns include: coastal setbacks, non-conformities, buffers, development conditions, shore protection devices, and managed retreat. it was found that these strategies are fully backed by good policies and regulations such as the Climate Change Strategy and California Coastal Act, and also key institutions like the California Coastal Commission, the Federal Emergency Management Agency(FEMA) and local governments helping to enforce the regulations.

In conclusion, some of the strategies applied in the case study countries are highly recommended in The Gambia, especially setbacks, buffers, development conditions and shoreline protection devices. However these strategies should be implemented alongside with proper policies and regulations. Currently The Gambia has no coastal Act, or climate change strategy, the only policy that highlight coastal zone management is the National Environment Management Act (NEMA). Therefore there is a need for policy development to guide future strategies in sea-level rise adaptation within the coastal zone.

PART 2

CHAPTER 4: SOUTHERN COASTLINE OF THE GAMBIA- WAY FORWARD

Part One shed light on the different approaches used in vulnerability assessment at both international and global levels, as well as highlight the applicability of tools and methodologies depending on the target level of the society the results of the vulnerability wants to achieve. Case studies on coastal erosion from various states at regional and international were reviewed and best practices as well as bad ones identified. This part is divided into two chapters: the first focuses on the status of the Southern coastline of The Gambia, where the area is described briefly in terms of its physical features, coastal processes, significance of the area and its vulnerability to the impact of climate change, coastal problems and previous and existing coastal protection measures. The second chapter highlights the future state of Southern coastline, the prevailing policy addressingcoastal erosion issues, gaps and need in policy, mitigation and adaptation options and best practices at global and international levels which could be applicable for a robust mitigation and adaptation strategy for the impact of sea-level rise in the coastline of The Gambia.

4.1Current Status of The Gambia's coastline

4.1.1 Physical Characteristics of coastal zone

Climate

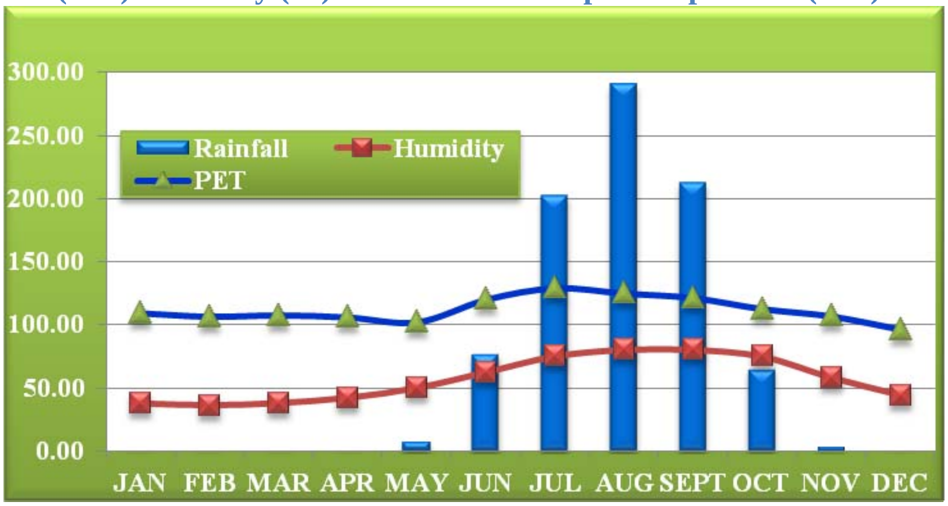
The climate of The Gambia is sub-tropical and is characterized by two distinct seasons: a short and hot rainy season from June to October and a long dry season from November to May. Significant rainfall is recorded between June and October with mean annual rainfall being about 860mm with the highest mean monthly of about 290mm. Average monthly humidity is low during the dry season and reaches about 80% in August and September(Jallow, 2011) (see fig 17). The temperature has been increasing in The Gambia since the 1950s based on analysis of records from the four meteorological stations (Banjul, Yundum, Janjanbureh and Basse) temperatures varies little throughout the year, but January and February are the coolest months of the year, whereas the highest temperatures are registered around April/May. Average maximum and minimum monthly temperatures are shown in Table 5

Table 4: Average Minimum and maximum temperatures 1951-2005

Temp	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	16.1	18.4	21.3	23.9	25.6	25.1	23.9	23.4	23.0	23.2	19.0	16.0
Max	33.9	36.1	37.9	38.6	38.1	35.8	32.8	31.8	32.3	34.0	35.4	34.1

Source (AdaptedJallow, 2011)

Figure 17: Rainfall (mm) Humidity (%) and Potential Evapotranspiration (mm) Elements in The Gambia



Source (Jallow, 2011)

Geological background

The subsurface geology of The Gambia as described by Whyte W.J &Russel, (1988) consists almost entirely of flat-lying sedimentary beds, dipping gently and also thickening gradually to the west. The surface geology of The Gambia is entirely Upper tertiary and Quaternary. The Upper Tertiary consists of the Continental Terminal Series (CTS) which is an undifferentiated complex of Oligocene, Miocene and Pliocene age (Haskoning, 2000). The CTS, with a thickness of 100 to 200m, is composed of poorly consolidated sandstone, argillaceous sandstone and clay stone, showing lateral discontinuity. This unit is dissected by rivers, and locally covered by Quaternary and Holocene sediments of fluviatile and marine origin.During the Early Pleistocene the CTS was affected by profound lateralization, causing the so-called ironstone crust. This crust often tops hills and plateau in the Eastern and Central part of the country. In the Western part of the country laterite occurs near the surface. The laterite along the coast can be distinguished from the iron crust formation in the eastern part of the country on several characteristics. The laterite at the coast is softer, less dense, contains significant quantities of kaolin clay and includes more quartz grains. Outcrops of laterite can be found at several locations along the coastline, such as at Bakau and Fajara. Here it is responsible for the presence of coastal escarpments. The capes and hard points, found further South along the coast, also owe their existence to the presence of laterite rock at or near the present sea-level Haskoning, (2000).

The coastal wetlands (the River Gambia and its estuary plus other coastal rivers) consist of Pleistocene and Holocene formations. These include the Pleistocene alluvium of undivided sand, silt and clay, and the Holocene marine fluvial (typically of the River Gambia estuary) of undivided sand silt, clay salt and organic deposits. The present coastline consists of the coastal beach complex, including the modern surf zone and other raised beaches that lie behind the modern beach. The deposits are of Holocene age and consist predominantly of fine to medium fine sands, with significant amounts of heavy minerals (ilmenite, ritual and zircon).Most of the beaches consist of medium to fine, white, well-sorted sand comprised of nearly pure quartz grains. Other beaches are characterized by concentration of cockle shells, resulting in well-sorted yellow sand. Beaches are often bounded by rocky headlands, composed of sandstones and laterite rock. Large block of sandstone or laterite lie scattered in the near-shore as at Sanyang, Cape Point and Solifor point along the Southern part of the coastline (Haskoning, 2000). The Banjul spit is considered to be Holocene-age feature. The upper 4m consists predominantly of sand, with isolated bands of clay, at 4m depth a compact fine to very fine sand occurs, and below 7to 8m of clay dominates. In this regard, therefore, the Capital of The Gambia (Banjul) as described in the Haskoning report has been constructed on a low-lying barrier landform that is entirely composed of erodible sedimentary materials.

Geomorphologic aspects

The lower course of the Gambia River is a drowned valley, where the water level has risen to its present level from- 100m below present sea at the end of the Pleistocene. The sediment supply from the Gambia River is limited and hardly reaches the coastal zone. The river’s estuary acts as sediment trap for material transported along the coast by wave induced littoral drift. Sedimentation is expected to be the dominant process along the north coast of Kombo North, giving rise to the formation of spits and bars. The raised beaches consist of yellowish medium to fine sands with distinctive black colouring as a result of heavily mineral presence. These sands have been originally reworked by waves and exceptionally high waters into series of broad, low ridges, parallel to the present shoreline, and later modified by Aeolian processes Haskoning, (2000)

Landward behind the beach complex, the geology of the coastal area is made predominantly of the CTS. The CTS rise from 10-15m at the coast to 100m at 400km inland. The protruding rocky headlands along the coast all appear to consist of laterite formed within these CTS. The laterite layer that can be observed at several places along the coast has a thickness of 1 to several meters. It is not necessarily a horizontal layer; it can be undulating or sloping, as can be seen at the coast near the jetty at Bakau). At all locations where the material underlying the laterite could be observed, it was found to consist of coarse sandstone, well cemented by iron oxides or hydroxides. The sandstone is fairly hard due to this cementation, though it is easily friable. On the southern part of the headland near Sanyang, this sandstone was used to construct a low dike to protect private property against wave actionHaskoning, (2000).

River discharge

The Gambia River, with a catchment area of 77,000km^2 and a length of about 1150km, runs through Guinea, Senegal and The Gambia. The mean annual discharge at 490km from the mouth was in the order of 250 m^3/s between 1953 and 1981. The once in ten years flood reaches a discharge, which vary between 2,500 m^3/s and 4,000 m^3/s 200km from the river mouth, and 30,000 m^3/s to 45,000 m^3/s at the river mouth of the estuary at Banjul.The dominance of the tidal discharge over the river indicates that the lower 200 to 250 km of the system is much more an estuary than the lower part of a river. The total sediment yield from the river Gambia is estimated to be smaller than the virtual loss of sand to the estuary due to sea-level rise. Since this virtual loss exceeds the sand load coming from the river, the estuary acts as sediment sink for sediments coming from the river and the coast. As a result, no significant volumes of sediment transported by the river reach the coast(Bijl, 2011). The above consideration of the estuary having a hunger for being a drowned valley which is now filled up both by sediment of the river and the sea.

The small streams along the coast of The Gambia bring small volumes of sediment to the coast. The contribution of river sediment yield to the coast is estimated at 25,000 to 70,000m^3/yr. of total load. Only a part of this sediment will be sandy and thus contribute to the nearshore coastal dynamics. The fine sediments (silt) will be distributed over the deeper (offshore) area. The sand supplied to the nearshore coastal region by the streams is estimated to be several thousands of m^3/yr. only.Apart one river (North of Barra) on the Northern coastline, the rest of the 5 rivers are all located within the study area as summarized in the Table 5 below.

Table 5: Sediment supply to coast by rivers

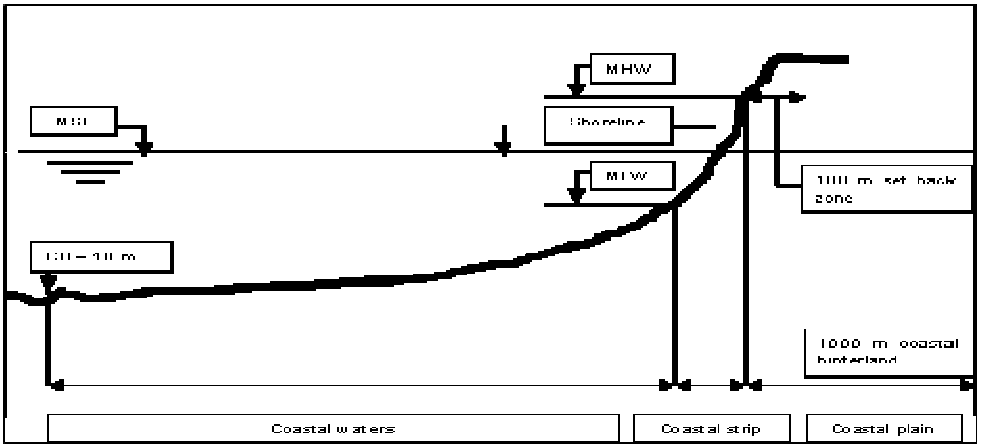
Stream	Catchment area (km²)	Transport (m³/yr.)
North of Barra	27	1,800-5,500
Oyster Creek	20	-
Cape Creek	3	-
Kotu Stream	65	4,500-9,000
Tanji River	145	10,000-30,000
Tujereng River	26	1,800-5,000
Kakima River	100	7,000-20,000

Source (Adapted from Coastal protection study, 2000)

Definition and boundary of the coastal zone

The Gambia has an 81km open coastline bisected into the North and South Banks by the River Gambia, which has its source some 680km upstream in the Fouta Djallon Highlands in Guinea.(UNDP, 2012). In The Gambia, there is no legal definition of the coastal zone or its boundaries. The Coastal Area Definition Study prepared for the National Environment Agency by EMSCO gives a review of definitions applied by various agencies in defining the coastal zone. The various definitions are summarized (fig 16**)** using the delineation of the Coastal Zone (Table 6**).** This shows that the various definitions are not consistent and in some instances base lines still have to be defined for a more precise definition.

Figure 18: Definition of characteristics dimensions of the coastal zone



Source (Coastal Protection study, 2000

Table 6:Delineation of the Coastal Zone

Reference	Seaward limit	Limit inter-tidal zone	Landward limit
International Law			
EEZ	200 NM		
Territorial limit	12 NM		
National Law			
Fisheries			
Artisanal fishing	7 NW from MLW	Between MLW and MHW	Not included
Licensed fishing	12 NM from MLW	Not included	Not included
Tourism			
TDA	Not included	Not included	800m from MHW

Banjul Port	Area bounded by the lines Buniadu point to St Mary in the West Point and Madiana Creek in the East	The whole inter-tidal zone in this area	Not specified
EMSCO Report	12 NM from baseline	Not specified	Atlantic Coast 1000m from MHW
Present report	12 NM from MLW or 10m depth contour	Between MLW and MHW	1000m from MHW

Source (adapted from Coastal protection Study, 2000)

Note: NM is the international Nautical Mile, 1852m, MHW= Mean High Water, MLW= Mean Low Water.

For the purpose of this research, the following boundaries are recommended:

- Coastal waters. Are wateris defined as the seaward area of the baseline, which may extend up to the territorial boundaries or the exclusive economic zone, depending on the issue under consideration. It is proposed to use the MLW mark as baseline. As of fisheries will be one of the coastal zone management issues the seaward boundary should be the limit of the territorial water.

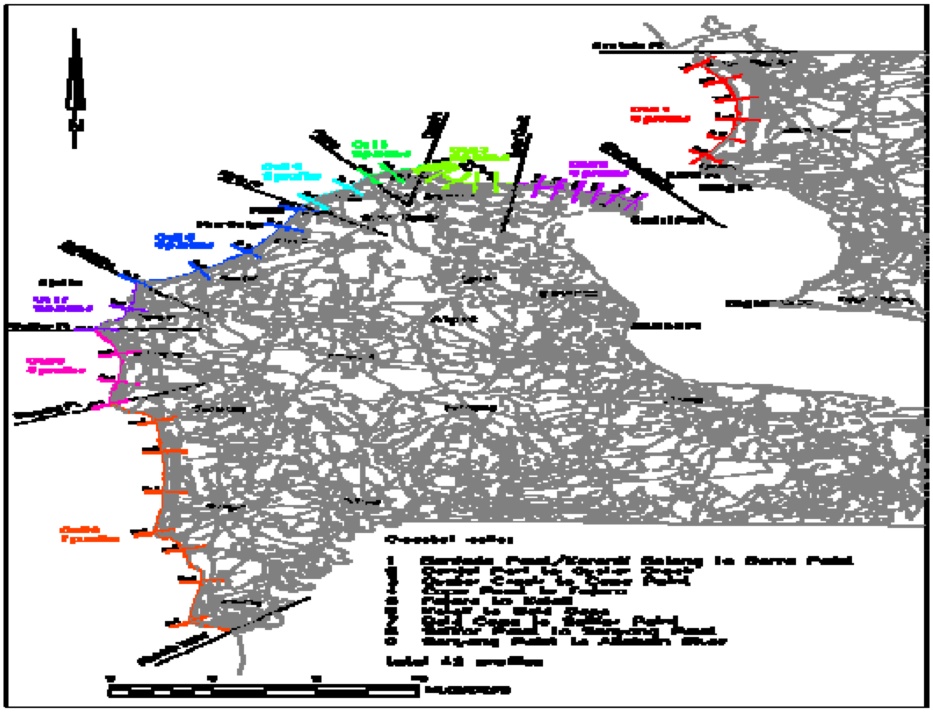
- The coastal strip. This is the inter-tidal area, the area where under normal wave conditions most of the sediment transport and related erosion and accretion processes are concentrated. These processes are responsible for the morfo-dynamic processes at a similar spatial scale. As such it is of main importance for the erosion problems. Moreover, most of the tourism and fish landing activities are concentrated in this area and sand mining takes place here as well, activities that may have a strong impact on these processes.

- The coastal hinterland. This is the part of the coastal plain used to accommodate a variety of social, economic and public activities. As this plain is part of the morfo-dynamic system, these activities should be controlled in order not to disturb the natural processes. In this respect the cross-shore transport of sand during high water and related erosion of cliffs and dunes is important. It is common to apply a setback zone landward of the MHW mark, where no permanent or semi-permanent structures are permitted. Depending on the observed erosion rates, countries apply different dimensions for the setback zone. UNEP recommends applying a width of 50 to 100 times the annual erosion rate, depending on the life time of the structures in the zone that should be safeguarded.

Hydro-sedimentary/ coastal cell description

The feasibility studies by Haskoning, (2000) divided the coastline of The Gambia into nine (9) cells on the basis of their geomorphic characteristics and vulnerability to sea-level rise impacts. According to the report, some of the delineation is based on the report on coastal profiles and management strategy of United Nations Environment Programme (UNEP) (UNEP/FAO/PAP, 1988). Below are highlights or description of the coastal cells:

Figure 19: Demarcation of coastal cells



Source (Haskoning, 2000)

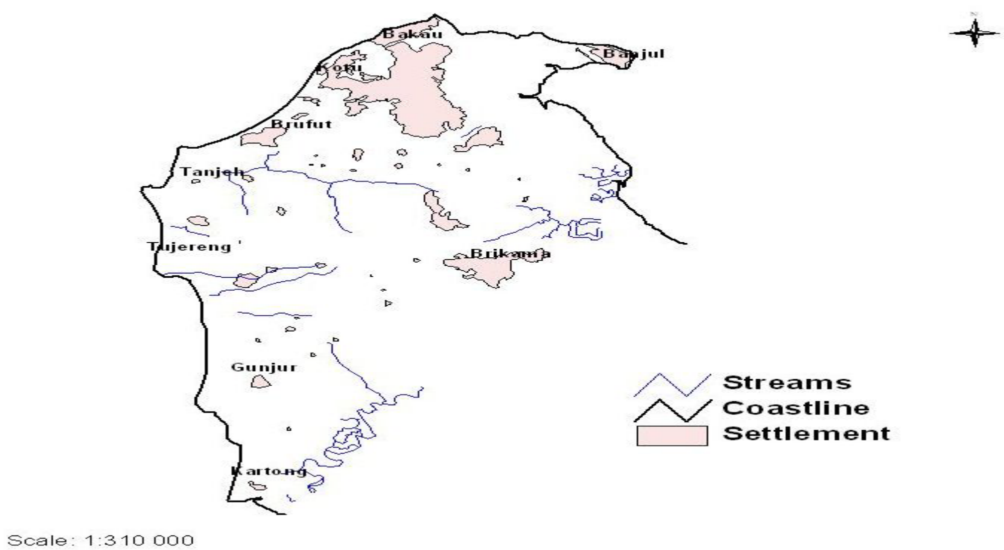
Apart from coastal cell 1(Buniadu point to Barra point), which is located on the northern coastline, the rest of the cells (2-9) are all located within the study area. Coastal cell 2(Banjul port to Banjul point and Oyster creek), south of ferry terminal is mainly port area, and north is sandy beach from the State house towards the lagoon. Cell 3(Oyster creek to Cape point), the main part of the shoreline is consist of large sandbars backed by mangroves. Cell 4(Cape point to Fajara), is the cliff coast with a few hotels, and fish landing site, Cell 5(Fajara to Kololi point), is tourism area, mainly hotels, and sand beach. Cell 6 (Kololi to Bald cape) features sandy beaches, less erosion, beach bars and restaurant and fish landing sites. Finally Cells 7-9(Bald cape to Kartung) consists of sandy beach, cliffs at Solifor point, and also concentration of mining sites.

4.1.2Location and Significance of Study Area: Southern Coastline

The River Gambia has divided the coastline into two: North and South. The Northern part starts from Barra to Buniadu point, while the Southern coastlineextends from Banjul to Kartung, and it is case study area of this research (see fig 20). The Southern coastline is densely populated compared to the Northern coast,the capital city; Banjul and Kanifing Municipal Council (one of the biggest Municipalities) are located within this area. In addition, a number of smaller towns and villages surrounded by their hinterland constitute the Western Division, covering the districts Kombo North and Kombo South. This region is the administrative and business center of the country and pays an important contribution to the national economy Bojang, (2006).

The coastal area is crucial from an economic, social and environmental perspective. The key drivers of existing livelihoods and future growth concentrated in the zone include agriculture, tourism, fisheries, mining, and biodiversity conservation and management. The Fishing and Tourism industries employ a significant percentage of The Gambian populace as well as making significant contributions to the GDP of the country. These activities are concentrated along the Southern coastline; a coastal-based tourism industry with over 40 hotels, the nine fish landing sites housing the fish processing facilities and agricultural activities. The details of the significance of the southern coastline are discussed below.

Figure 20: Map of the Southern coastline



Source: NEA, 2010

Tourism sector

Tourism is of vital importance to The Gambia, second to agriculture in its place in the economy. It is a major source of foreign exchange and comprises a significant proportion of GDP. It is an important source of wage earning employment, providing some 16,000 jobs (Tourism Master Plan, 2006). Travel and tourism plays an important role in the economic advancement of The Gambia. The industry has grown steadily over the years to become the second largest contributor to the socio-economic development in the country after agriculture, accounting for approximately 15% of the national gross domestic product (GDP) in 2011. It is also amongst the biggest foreign exchange earners as well as a major factor in the job market, offering an alternative source of income generation, infrastructure development and investment attraction.[57]

Fisheries sector

The territorial sea of The Gambian extends to 12 nautical miles with an Exclusive Economic Zone (EEZ) extending to 200 nautical miles. The seas off Gambia are located where two major oceanic currents converge along the coast of West Africa. One is the highest productive upwelling zone of the Canary Current Large Marine Ecosystem (CCLME). Cold and nutrient rich water flows southward starting from the seas off Mauritania and Senegal, attaining maximum effect on the Senegambia plateau in March/April. The other is the eastward flowing warm Guinea Current. The effects of these currents together with the trade winds which blow dominantly from the Sahara Desert westerly out over the Atlantic create intermittent upwelling

[57]www.euromonitor.com/travel-and-tourism-in Gambia/report).

along the coast of The Gambia. These upwellings, combined with the outflow of the Gambia River, provide the nutrients that fuel a bountiful marine ecosystem(Tobey, et al., 2009).

Fisheries play an important role in the national economy contributing an estimated 5% to GDP. The sector consists of two major domains: artisanal and industrial fisheries. The artisanal sub-sector is characterized by low levels of investment with operators from many dispersed, and often isolated, landing sites. This sector targets both the high value species (mainly to supply the industrial fish plants for the external market) as well as the lower value species for local consumption. It also provides employment opportunities for some 2000 people involved in fish harvesting and another 13,000-18,000 people involved in boat building, fish handling, processing, transportation and marketing activities(Haskoning, 2000).There are three fishery administrative areas: Atlantic/Marine Coast Stratum, Lower River Stratum and, Upper River Stratum. The Upper and Lower River Stratums are further divided into North and South Banks(Tobey, et al., 2009). The percentages of total artisanal fishery landings in the five stratums in 2007 are shown in table 8below.

Table 7: Distribution of total Artisanal landings by Stratum

Stratum	Percentage of total landings
Lower River South Bank	8.9%
Upper River South Bank	0.6%
Lower River North Bank	1.8%
Upper River North Bank	10.6%
Atlantic Coast	78.1%

Source: (Gambia Department of Fisheries, DOF 2007)

The total fish landed from both the artisanal and industrial sub-sectors were estimated at nearly 40,000 tons in 2006(FAO, 2007) and 47,000 tons in 2007(Gambia DOF, 2007). Out of this, the artisanal fishery contributed approximately 37,000 tonnes (93%) with about 3,000 tonnes (7%) from the industrial fisheries

Agriculture and horticulture sector

The agricultural sector is the most important sector of The Gambian economy. Contributing 30% of the Gross Domestic Product (GDP), providing employment and income for 80% of the population, and accounting for 70% of the country's foreign exchange earnings(Republic of The Gambia, 2011).[58] It remains the prime sector to raise income levels, for investment, to improve food security and reduce levels of poverty. The coastal area of The Gambia, like other parts of the country, has a mixed crop-livestock farming system on two distinct ecological zones (lowlands and uplands crop production) which are suitable areas for rice cultivation.

In addition, coastal areas are also the site of the most intensive horticulture production in the country dominated by small scale women gardeners who produce for the nearby urban communities. Nearly 88% of all women farmers in The Gambia are estimated to be engaged in individual or communal horticulture activities, although there are also a few commercial farms that mainly target the export market(IUCN, 2010).

In the Southern part of the coast from Banjul down to Kartung most of the agricultural activities are found in the area surrounding Brufut, Tanji, Tujereng, Sanyang and Kartung at a minimum distance of 150m of the HW shoreline. Horticulture crops include tomatoes, onions, cabbage, eggplant, okra, carrots, lettuce, beans, mangoes, cashew, papaya, cucumber. (see fig 21**)**

Figure 21: Major agricultural and horticulture settlements within the coastal area

[58]Programme for Accelerated Growth and Employment(PAGE)

Source (Bojang, 2006)

Minerals sector

In the coastal area placer deposits of heavy minerals- zircon, rutile and ilmenite occur in the raised beaches from Brufut to Kartung. The minerals occur as unconsolidated grains or within the sediments, which have been derived from parent rocks in the continental series as a result of weathering, transportation and deposition processes. These minerals, whose deposits occur in economic quantities, were mined for a short period in the 1950s(Bojang, 2006).

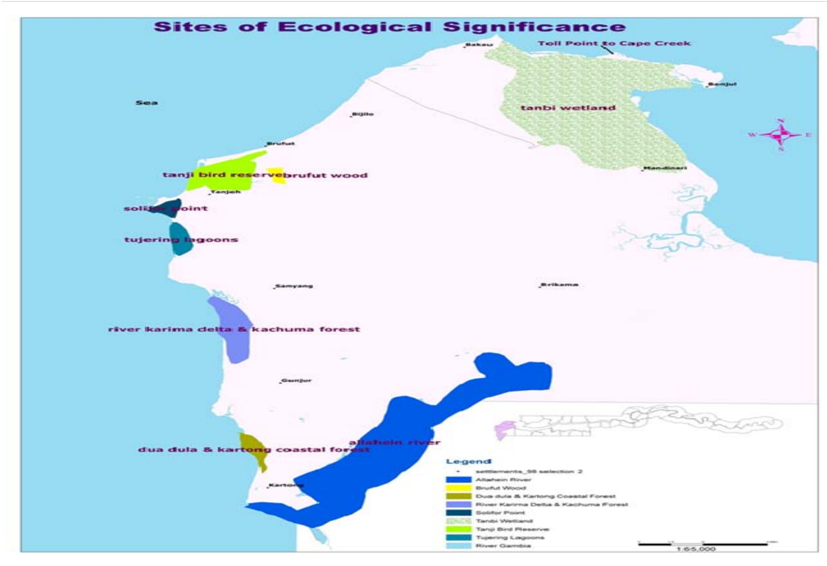
Construction sand and gravel are of low value, but are high volume commodities, which contribute significantly to the socio-economic development of the country. In the coastal zone, sand and gravel mining was extensive as the only designated site for sand extraction was at Bijilo, used since 1985. Prior to restrictions imposed on sand mining at Bijilo between 1985 to 1995, the estimated volume of sand extracted per year was approximately 100,000m^3 to 150,000m^{3}Haskoning,(2000). This had a serious environmental impact on the coastal area hence beach sand mining was stopped in Bijilo in December, 1995. Sand mining is now illegal at the site and the activity is only allowed in specially designated areas further inland EIA procedures and rehabilitation plans introduced by the National Environment Agency in collaboration with the Geological Department may help to reduce the environmental impacts of the mining.

Coastal and Marine habitats of high ecological value

The Southern coastal stretch from Banjul to Allahein River, in Kartung, consists of several coastal and marine habitats of high ecological importance. Although there is no comprehensive assessment to determine their ecological importance, according to a report by UNEP (1996), nine (9) sites of high ecological importance have been identified along the Southern coastline (see fig 22) .These areas include:

- Toll point to Cape Creek(mosaic of habitat types including coastal lagoon, mangrove, saltpan, coastal scrub and grassland, and freshwater ponds which form the Cameloo corner);
- Oyster creek mangroves swamp(to Mandanari point): mangrove swamp with fringing salt pan and grassland, some relic patches of woodland;
- Tanji/Karenti Bird Reserve: coastal lagoons, stabilized sand-dune with woodlands, scrubs and grassland component, freshwater swamp, river with fringing mangrove and saltpan dry woodland, offshore island with surrounding shallow reef;
- Brufut wood: relic patch of riverine woodland
- Solifor Point: coastal woodland/scrub, inshore reef, and laterite cliffs;
- Tujereng lagoons: coastal lagoon with mangrove saltpan fringe, also stabilized dune with grassland/scrub/woodland complex;
- River Kakima Delta-kachuma forest: outflow of the River Kakima. A mosaic of lagoons, mangrove, saltpan and stabilized dune vegetation, backed by a relic fringe of high coastal woodland(dominated by rhun palm;
- DuaDula to Kartung: coastal forest(rhun palm zone) merging to scrub-grassland in stabilized dune complex towards Kartung; and
- Kartung point to Allahein river mouth: coastal scrub/grassland on stabilized dune system, lagoon complex, river estuary and mangrove fringe. Also Folonko crocodile pool at Kartung village with relic patch of riverine forest.

Figure 22: Sites of ecological significance



Source (Camara, 2012)

It is important to highlight that protection of ecologically significant areas is critical to the long-term conservation of biological diversity. However, not all of the ecologically significant areas described above are protected. Some areas, such as Toll Point to Cape Creek and Oyster Creek mangrove swamp to Mandinari Point, form part of Tanbi Wetland Complex, a Wetland of International Importance (i.e.,Ramsar site) (Bakurin et al. 2010). Tanbi National Park is part of theTanbi Wetland Complex. Tanji/KarentiBird Reserve (Tanji and Bijol Islands Bird Reserve) is a Government protected area. Brufut Wood and Kartong Point to Allahein river mouth are under some form of local community protection, meaning that they are community forest areas. However, the remaining ecologically sensitive areas are not under any form of protection(Camara, 2012).

4.1.3Main Problems/Challenges of the Coast

As the population increases in the coastal zone, human activities become a significant factor in causing many coastal problems. Generally, speaking, there are four basic coastal problems within the southern coastline: 1) increase in sea-level rise-causing erosion 2) mining activities, 3) concentration of population, and 4) over-exploitation of resources.

Coastal erosion

Beach erosion is a significant problem along the southern coastline, threatening tourism facilities, cultural and historical sites (e.g. cemeteries), port and fishing facilities, State house and private properties. The activities primarily affected by erosion are agriculture, fisheries, and recreation.The most seriously threatened and impacted areas are the low lying areas such Banjul, the capital city, Cape point, Senegambia/Kairababeach hotel seafront, as well as cliff areas from Cape point to Fajara, where foreign embassies and some private properties are located. Pressure for development in this zone is generally much greater than elsewhere. The development, which has taken place, is believed to have accelerated beach erosion, which in some places is estimated to exceed two meters per yearHaskoning, (2000).The causes of erosion are both man-made and natural. The impact of people on coastal erosion may be a result of direct and indirect activities along the coastal zone or in the hinterland. The direct effects include the building of hard structures (e.g. seawalls, groynes, and breakwaters). Indirect effects include changes in water and sediment yield from the river system after the clearance of vegetation (e.g., mangrove deforestation). Some of the natural causes of erosion as highlighted in the coastal protection study conducted by Haskoning, (2000) are due to three reasons: 1) natural trend of erosion along the coast of The Gambia, due to an annual net sand loss from the coast in a longshore direction and the effect of sea-level rise.2) along the coast between Oyster creek and Banjul, the erosion is the result of the development of the sand-spit at Tool Point. Due to local accumulation of sand in the spit, the supply to the coast east of the spit is strongly reduced. Therefore at some distance east of the spit the eastward directed sand transport continues, the strong reduction of sand supply from the east causes erosion of the coast and 3) the observed large erosive trends in the last decades are for a large part (over 50%) due to sand mining from the beach.

Sand mining

Another problem that is common, not only along the southern coastline of The Gambia, but also other regions of the country as well are those that are related to unplanned and unmanaged mining activities. The Southern coastline is rich in terms of high sand deposits and other minerals such as zircon and ileminite, and this has attracted a lot of local sand mining companies, jobseekers, foreign investor and businessmen to the area. The coastal sand dunes are exploited for mainly building and construction purposes, as sand forms a great part of housing material in The Gambia.

This annual volume lost from the beach due to mining was similar to the volume lost due to the gradient in the long-shore transport along the entire coast of The Gambia.However, the deficit due to the gradient in the longshore transport is spread along the entire coast of Gambia, while the deficit due to sand mining was created very locally, over the a stretch of several kilometers around Bijilo(Haskoning, 2000).From 1985 until 1995, sand mining took place mainly between Kololi and Bijilo, and then became prohibited since 1996 soon after the Government transferred the activities to a site within the dune area in Sanyang and Kartung (see Fig 23**).** It was estimated during the 2000 Feasibility Study that volumes of 100,000 to 150,000 m³/yr. have been mined decade(s) before; this may even have been more. In the small coastal cells, sand mining from the beach may result in significant shoreline changes. Sand deficit created by sand mining will be spread over adjacent cells, resulting in overall shoreline changes.

Figure 23: Showing locations of sand mining sites in Kartung and Sanyang

Source (IUCN, 2010)

Population pressure

The issue of population increase, especially in the urban areas, is perhaps the most complicated problem faced by the Government of The Gambia. Between 1993 and 2003 the population of The Gambia grew by 2% per annum on average. The population within the study area has been growing by 3% per annum on average. It is projected to reach about 0.7 million persons in the year 2020 and in 2050 about 1.1million persons(IUCN, 2010)(Table 8). Most of the settlements along the Atlantic Ocean coastline depicted negative growth rates between 1993 and 2003. Hence, the average annual growth rate of settlement in this area was less than 2%. The lower growth rate is indicative of population mobility in which people would continue to move away from the coast land near shore to the nearby hinterland. Notwithstanding this outward mobility, the population of the study area is expected to reach 1.1 million in 2020.

Table 8: Projected distribution of population in settlement along the coastline and shoreline within a defined area of The Gambia, 2020 and 2050.

Locations	2003	2020	2050
Settlement along the Atlantic ocean shoreline	85,779	214,314	342,903
Settlement on the shoreline of the Lower mouth of the River Gambia	65,409	70,874	113,399
Settlement on the shoreline Upper mouth of the River Gambia	144,708	417,256	667,609
	295,896	702,444	1,123,911

Source: Gambia Bureau of Statistics, 2003

Compared to the North coast, the Southern coast is much more densely populated. The capital city, Banjul and the Kanifing Municipal Council are located here, which together with a number of smaller towns and villages surrounded by their hinterland, constitute the West Coast Region (WCR), covering the districts of Kombo North and Kombo South. This region is the administrative and business center of the country and pays an important contribution to the national economy(Bojang, 2006). High concentration of population is regarded as the underlying cause of most of the present problems, including those related to coastal resources.

Mangrove degradation and over-exploitation

Human uses of coastal resources has tended to accelerate, and in some instances adversely affect the natural structure of the shoreline and associated natural systems(Sulaiman, 1989). Many of the changes in the shorelines that result from overuse of coastal resources are far more severe than that caused by seasonal natural hazards (e.g., storms surges). Mangroves normally act as protective buffers for the land behind them. Without these coastal habitats, beaches are eroded more quickly(Sulaiman, 1989). In the case of mangrove utilization, there are two conflicting views. The first view is from those who consider mangroves as “waste lands”, ready and suitable for convert into more profitable economic development projects, such as agriculture, fish pond (aquaculture), settlements, fuel wood, building material, tourism facilities etc.,. In combination with natural forces these activities often exacerbate coastal erosion in many places and jeopardize opportunities for coasts to fulfill their socio-economic and ecological roles in the long term at a reasonable societal cost(FAO, 2007). This group favors the more obvious and immediate economic gains generated from the conversion of the mangroves, but they tend to ignore or be less sensitive to the impacts of the conversion (see figure 24). The second view is of mangroves as a unique coastal habitat for many wildlife species and, by virtue of location, as providing an effective natural and self-maintaining buffer against coastal erosion and tidal flooding. Because of their high productivity, the mangroves afford a vital role in sustaining the productivity of coastal and estuarine fisheries. Therefore, this group wants the resources protected and left undisturbed(Sulaiman, 1989). The former group favours more immediate economic gains without ecological consideration, the latter tends to select the long term ecological and socio-economic benefits derived from the conservation and rational utilization of the mangroves. However, the former group often dominates the latter; as a result many coastal problems become more complicated because of the lack of awareness of the environment.

Figure 24: Mangrove degradation

Source (NEA, 2011)

Along the Southern coastline, thereare only a few mangrove forests available in the area,. The mangrove ecosystem found in Tanbi Wetlands National Park, is not only important in protection of the Capital city, Banjul but is also high in biodiversity and many coastal communities surrounding the park are utilizing the resources for their daily livelihood through fishing, and Oyster collection. Other small mangroves are at Tanji, situated inland behind the sand-spit at the estuary of theTanji River and at Kartung although they are not directly situated at the Atlantic coast.

4.2 Future state/baseline scenarios of Southern coastline

Introduction

Extreme events such as torrential rains, storms (wind, thunder and dust), drought, cool spells, heat waves, intra-seasonal drought and erratic rainfall patterns have become more frequent, with devastating effects in The Gambia. These have been impacting on the country for decades and collectively, they make climate change a burden to national development(Ampomah, et al., 2012). Each year thousands of people are displaced, with millions of Dalasi (Gambian currency) worth of property damage (including houses, bridges and roads). The IPCC (2013) projected that some of these climate hazards are likely to get worst in the years ahead and this scenario would significantly increase coastal risks and affect local livelihoods. This section gives a summary of the climate change baseline scenarios and their impact on the coastal environment as well as socio-economic impact on the population in The Gambia.

4.2.1 Climate Change projections

Data from the mid-1940s up to date reveal a decreasing trend in rainfall and length of the rainy season and in an increase in temperatures (Republic of the Gambia, 2010). Since the mid-1960s, the mean annual temperature increased on average by 0.21°C per decade and the mean monthly rainfall during the rainy season decreased on average by 8.8mm per decade((McSweeney, et al., 2012). It is obvious that the climate is altering and these changes are having and continue to have severe impacts. One of the vulnerable continents to changes in climate is Africa, and The Gambia will be especially affected (Government of the Gambia, 2010).

The Gambia already needs to deal with diverse climate hazards such as torrential and unseasonal rainfall, floods, sea-level rise, coastal erosion, storms, cold and heat waves, drought, fire and pests. Some of these impacts are expected to occur more frequently, and be more powerful and widespread in the future. In general, mean annual temperatures are expected to increase between 3 and 4.5°C by 2075(Government of the Gambia, 2010).The projected warming rate will be higher in land regions than in coastal regions. Climate projections further show a considerable increase in the frequency of hot days and night and a decrease in the frequency of cold days and nights. Model projections for mean annual rainfall are highly variable, but indicate, averaged over the country, a decreasing trend in particular during the rainy season(McSweeney, et al., 2012). Considering the amount of total annual rainfall in heavy events, climate models show an overall increasing trend but seasonally dependent increases and decreases(McSweeney, et al., 2012). The frequency and severity of extreme events like wind, rain-and dust storms and droughts will increase in the short term, while sea-level, coastal erosion and land cover changes will increase in the long term(Government of the Gambia, 2010). As Gambia is a low-lying country, it will be especially affected by the rising sea-level, which will entail problems like flooding.

Global sea-level rise is mainly caused by thermal expansion of the oceans (due to an increase in water temperature), melt-water from ice caps and glaciers entering the ocean and melt-water from polar ice sheets (Church etal., 2008). There have been various predictions of future sea-level trends and lots of debate about it, but for the purpose of this research the focus is on the work done by the IPCC, because they are an International scientific body responsible for assessing scientific information on climate change. Generally, projections of future sea-level are done by two basic approaches: linear and non-linear (accelerating) sea-level trend (Mather, 2009). There are different ways of doing projections; either by using gauges, projection based on a temperature and sea-level rise relation as proposed by (Ramstorf, 2009) and projections using global climate models such as done by the IPCC. Projections for temperature change and sea-level using climate models for the end of the 21st century are made in the IPCC Fourth Assessment Report (2007) for different scenariosdescribed as follows:

The acronym SRES refers to the scenarios described in the IPCC Special Report on Emissions Scenarios (IPCC, 2000). The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) related to development pathways; which cover a wide range of demographic, economic and technological driving forces and resulting GHG emissions. The SRES scenarios follow (IPCC, 2007):

- The A1 pathway assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies.
- A1 is further divided into three groups that describe alternative directions of technological change: fossil intensive (A1F1), non-fossil energy resources (A1T) and a balance across all sources (A1B).

- B1 describes a convergent world, with a global population similar to A1, but with more rapid changes in economic structures toward a service and information economy.
- B2 describes a convergent world, with an intermediate population and economic growth, where local solutions to economic, social, and environmental sustainability are emphasized.
- A2 describes a world with high population growth, slow economic development and slow technological change.

Table 9 shows the predicted values (IPCC, 2007) for the different scenarios detailed above. The predictions are highly dependent upon the future scenarios chosen and there are significant variation in SLR estimates and thus a large confidence interval. As the future scenarios are still an unknown being somewhat conservative with SLR estimates is prudent.

Table 9: Projected global average surface warming and sea-level at the end of the 21st century

Case	Low	High
B1 scenario	0.18	0.38
A1T scenario	0.2	0.45
B2 scenario	0.2	0.43
A1B scenario	0.21	0.48
A2 scenario	0.23	0.51
A1F1 scenario	0.26	0.59

Source (Adapted from IPCC, 2007)

The aforementioned climatic changes have been exacerbated with rising sea levels. Sea level rise predictions made for The Gambia started in the mid 90's.Brown et al. (2011) used the Dynamic

Interactive Vulnerability Assessment (DIVA) model to project sea-level rise in The Gambia. They projected a sea level rise (in comparison with 1995 levels) of 0.13 m in 2025, 0.35 m in 2050, 0.72 m in 2075 and 1.23 m in 2100. Jallow et al. (1996) used the Aerial Videotape-assisted Vulnerability Analysis (AVVA) to assess the vulnerability of the coastal zone of The Gambia to sea-level rise. They predicted that a 1 meter sea-level rise in The Gambia will lead to inundation of about 92 km² of the coastal zone. It has been estimated that about 50% (47 km²) of the land loss to inundation will come from the sheltered coast (Government of The Gambia 2007); Shoreline retreat is projected to vary depending on topography, between 6.8 m in cliff areas to about 880 m in flatter and sandier areas (Jallow et al. 1996). In the event of a 1 meter sea-level rise, without adequate protection measures, the city of Banjul is projected to be lost in the next 50-60 years because a large proportion of the city is below 1 meter (Jallow et al. 1996). Moreover, mangrove systems on St. Mary's Island in Kombo St. Mary (KanifingMunicipality) and those on the north Bank from Barra to Buniadu Point are also projected to be lost (Government of the Gambia, 2007)

4.2.2 Climate change impacts on environment

The adverse impacts of climate change are evident in The Gambia and are characterized by rising sea levels resulting in flooding in the coastal zone, salt water intrusion, storm surges and coastal erosion. Moreover,erratic and irregular as well as more intense rainfall causes flooding and associated soil erosion as well as periodic drought resulting in soil acidification. Climate

change poses a serious threat to low-lying countries. Assessments of vulnerability to climate

change have revealed that The Gambia is one of the most vulnerable countries to sea-level rise (Balk et al. 2007, Jaiteh and Sarr 2011).The coastal areas of The Gambia are affected by climate change and variability mainly through coastal erosion owing to increased wave activity and

physical drowning of low-lying areas as sea level rises.

This result iscoastline recession and the physical loss of ecosystems and the services they provide. The problem is considered to be exacerbated by the increase in sea levels and the frequency of storm surges. The Southern and Northern coastal zones consist of low-lying coastal areas and heavy infrastructural development; government buildings/offices and businesses are more prone to the impacts of sea level rise. These areas are the Greater Banjul Area, North Bank, Kombo North, Kombo South, Kombo Central and Lower Niumi. Coastal erosion has prevailed in the coastal areas of the country for the past four decades. The Southern coastal region experiences alarming rates of recession estimated on average at 2m/yr. in some locations. Studies indicate that areas around the Bijilo Beach are receding at a rate of 4m/yr. (ICAM, 1998).

A 1-meter sea level rise is projected to drown over 8.7% of the total land area of the country including the port and capital city of Banjul, as well as a host of critical facilities including 25.5 km of paved roadway in the greaterBanjul and all harbors and ferry landing sites along the Gambia River (Jaiteh and Sarr 2011). The expected sea level rise in meters for various parts of the city of Banjul and the impacts of sea level rise on the city, its suburbs and main roads and nearby mangrove swamps (spawning grounds for fish and natural tubs) are shown below

Figure 25: Impact of sea level rise on Banjul

Source (UNDP 2012)

Sea-level rise would also have a serious effect on lowland agricultural production. Saline water intrusion has destroyed many farmlands making a large proportion of farming households poorer. The biggest threat of saline water intrusion into the River Gambia comes from sea-level rise. Short-term rice production may be the most affected by saline water intrusion, constituting

64% of all cropland that will be inundated by 1 meter sea level rice (GOTG 2007). This could result in decreased rice production and impede the achievement of The Gambia National Agricultural Investment Program (GNAIP). A 1 meter sea level rise could inundate over 61% of the current mangrove area and over one-third of swampland (Jaiteh and Sarr 2011). However, this could potentially create new wetlands and mangrove growing areas (Jaiteh and Sarr 2011). Moreover, the coastal and marine environment of The Gambia, which harbors globally significant species of organisms and habitats of high ecological importance, may be highly affected by climate change. These ecosystems are very important for the artisanal coastal fisheries industry, serving as spawning grounds for juvenile fish species.

4.2.3 *Climate change impacts on socio-economics and population*

The Gambia is one of the top ten countries in the world with the highest share of population living within lower elevation coastal zone (LECZ) (Bakurin et al. 2010). The projected sea level rise of Brown et al. (2011) for The Gambia, using the DIVA model projected that, with a sea-level rise of 0.35 m in 2050, 76,000 people will be flooded per year and with a sea-level rise of 1.23 m in 2100, 137, 000 people will be flooded per year (see table 10)(Brown et al. 2011). The total cost of sea level rise for The Gambia combining costs of forced migration, land loss, salinization, sea floods and river floods is US$71.9 million per year for 2050 and US$313.4 Million per year for 2100 (Brown et al. 2011).

Table 10: Gambia’s sea level rise scenarios and their impacts

	2015	2050	2075	2100
Relative sea level rise (since 1995)(m)	0.13	0.35	0.72	1.23

Total cost of residual damage (USD million/yr.	1.2	71.9	113.4	313.4
Population flooded (thousand/yr.)	4.0	76.0	126.5	137
Land loss (submerged) (km2/yr.)	0.0	34.3	113.4	9.8
Net land loss (erosion) (km2/yr.)	0.1	0.1	0.2	0.4
Sea flooding cost (USD million/yr.)	1.2	10.0	51.6	146.4

(Source: adapted from UNDP 2012)

Climate change impacts could potentially be severe because they exacerbate other factors which have increased vulnerabilities in the coastal zone. Other factors affecting vulnerability of the coastal area include (i) uncontrolled and unplanned urbanization (ii) haphazard planning of the coastal area (iii) unsustainable agricultural and oyster culture practices resulting in habitat degradation; coastal vegetation ecosystems such as the mangroves which are spawning grounds for the variety of fish species and (iii) uncontrolled and non-sustainable sand mining. It is believed that the sand used in the construction of the Tourism Industry was taken from nearby beaches; records from the Ministry of Trade reveal that approximately 100,000 to 150,000 m³ of sand was mined from the Bijilo sand mining site(UNDP, 2012).

CHAPTER 5- THE GAPS IN AND NEEDS FOR TO SEA-LEVEL RISE ADAPTATION IN THE COASTAL ZONE OF THE GAMBIA

Introduction

As highlighted in the Gambia Environmental Action Plan (GEAP)(UNEP/FAO/PAP, 1998).The coastal zone is identified as an“… important natural and economic resource which if utilized in an appropriate manner will yield important economic benefits. Uncontrolled sand removals from the beach, and unplanned tourist development along the coastline are serious problems which need to be stopped. Yet there is a lack of basic technical information on coastal dynamics necessary for effective management of the coastal zone"(UNEP/FAO/PAP, 1998).In addition, as discussed in the previous chapters, some challenges of the coastal zone include: the high population density of The Gambia is along the coast, where employment possibilities are greater by far than in the rest of the country, mainly because of the tourism sites and government institutions. Pollution of the beaches caused mainly by fish processing on the beach within the artisanal sector, litter and sewage from the tourism industry is also a major concern. In addition, the depletion of groundwater resources and the issues of salt water intrusion are areas of concern in the coastal area.

However the key issues in the coastal area is the absence of an effective land-use planning and development control systems. Both are needed to rationalize the development of land, to coordinate with infrastructure provision and to ensure protection of the environmental resources, all in the interest of sustainable development of the Gambia coast.This section reviews the legal and institutional framework for coastal zone management and climate change. It also highlights previous and existing coastal protection measures implemented by Government and private and business ownerand suggested options tomitigate the effects of sea-level rise.

5.1 Existing coastal and Climate Change adaptation strategies and activities

5.1.1 Existing legal and institutional framework for coastal zone management

The first Gambia Environmental Action Plan (GEAP I) prepared by National Environment Agency in collaboration with the key relevant stakeholders and the public was adopted in 1992 and the second version (GEAP II) (NEA, 1992; 2010) was recently reviewed and adopted in 2010. The GEAP was intended to provide a legislative and policy framework for the management of The Gambia's environment. It identified the major environmental issues of concern and proposed Government actions to address them. In addition GEAP is an umbrella framework which serves to avoid duplication and segregation in the various national action programmes. The National Environmental Management Act (NEMA) 1994 is the principal piece of legislation for environment management in The Gambia. However, the matter of sound environmental planning and management as enshrined in the NEMA, is cross sectoral and cannot be treated in insolation of the other legislation relevant to other phenomena that comprise the environment.The enactment of the NEMA led to the creation of National Environment Agency (NEA) and the National Environment Management Council (NEMC).

It is important to highlight that the roles and responsibilities of the NEMCand NEA are not specifically restricted to coastal zone management; such issues form part of their general mandate. However, NEMA specifically empowers the NEA to regulate activities undertaken in the coastal zone, by stating that the express permission of the Agency is required for the conduct of activities within the coastal zone. It further empowers and imposes an obligation on the NEMC “to make regulations and guidelines for the management of the environment of the coastal zone, rivers and other wetlands and in particular may provide for:

(a) “The developments of an overall management plan of the coastal zone taking into account the various sectoral interests;

(b) Measures for the control of coastal erosion;

(c) The conservation of mangrove ecosystems on the basis of the principle of optimum sustainable yield;

(d) The harvesting of the minerals of the coastal zone including sand, clay, shells and restoration of the mineral sites;

(e) The environmentally sound development of tourism resources especially the orderly and planned development of building structures along the coast;

(f) Containment of oil spill emergencies;

(g) The management of freshwater wetlands;

(h) Containment of salt water intrusion into rivers, aquifers and agriculture lands.And

(i) The exploitation of the offshore areas including the continental shelf, the territorial sea, and the exclusive economic zone”.

NEMA also provides that the NEMC may declare protected zones in any area of the coastal zone, river, or wetland and exclude or restrict human activities, if it thinks that such an area is at great risk from unsustainable human activities; or is of ecological, cultural, or aesthetic significance. These stipulations clearly envisage a framework for an effective and sustainable management of the coastal zone.

Some of the key gaps identified in the legal framework of coastal zone management are:

1. Since its enactment in 1994, these specific provisions of the NEMA relating to the management of the coastal and marine environment have not been given any legal effect, as the envisage guidelines and regulations have not been issued. Because of the lack of the relevant regulatory framework, the NEA has not also devised a permit system for the regulation of socio-economic activities within the coastal zone. The only legislative action, on coastal zone management undertaken by the NEA under NEMA is the establishment of the Coastal and Marine Environment Working Group (CMEWG). This is a non-advisory body; with no decision making power that deliberates on coastal issues in accordance with its mandate and advises the NEA. The NEMC makes final decisions on policy relating to coastal zone management. The Working group is multi-sectoral and cuts across all sectors that have a stake in the management of the coastal area.
2. There is currently no single institution charged with the Management of the coastal zone in The Gambia.The NEMA stipulates that a Technical Advisory Committee (TAC) should be established as an advisory body to the National Environment Agency on Coastal Zone Matters.The TAC is now a Technical Working Group, the Coastal and Marine Environment Working Group (CMEWG), consisting of various institutions all with a specific mandate in respect to the Coastal Zone. The NEA recently added Non-Governmental Organizations to the Working Group. Non-Governmental Organizations usually elicit, encourage and promote local leadership better than their governmental counterpart institutions. This might be due to the non-biased nature of their

operations as a result of non-political motives. Responses of governmental counterpart

institutions could at times be affectedby the existing political order. The meetings of the working Group creates a forum for the exchange of ideas on different aspects of Coastal Zone Management. The main task of CMEWG is to:

(i) To formulate review and revise policies relating to all coastal, marine and fluvial activities;

(ii) To advise the NEA and the Government on matters arising on the sustainability, protection, development and monitoring of the coastal, marine and fluvial environment; and

(iii)To form and guide the work of task forces on issues that may arise relating to coastal and riverbank erosion, marine and fluvial environment, and sand mining.

More recently, The UNDP- supported Disaster Management Policy has brought Disaster Management Issues such as climate change and its impacts into the limelight and has introduced adaptive mechanisms at the community level. The Policy advocates for efficient response mechanisms to disaster management and developing an institutional framework and building capacities at the National, Regional and local levels to respond to disasters in a timely fashion.

3. For The Gambia, inadequate institutional capacities hinder the implementation process of the aforementioned policies in the coastal zone. With the emergence of climate change it become evident that institutions are ill equipped to address its adverse impacts; these national policies and framework largely ignore the new dimensions of threats that are associated with more consistent and gradual climate change effects, such as sea-level rise increasing inundation, dynamic changes in precipitation, and higher salinity.

5.1.2 Existing legal and Institutional management framework on climate change

Commitment of The Government of The Gambia to combat climate change has started with its ratification of the UNFCCC in 1994 and the Kyoto Protocol in 2005. Since its ratification of the convention, at the national level, The Gambia has taken very important steps to mitigate the effects of climate change. Two documents namely, the Initial National Communication of the Republic of The Gambia (INC) to the UNFCCC was prepared in 2003 and the National Adaptation Program of Action (NAPA) on Climate Change in 2007 (UNDP, 2012). In addition to the two documents, a plan for National Appropriate Mitigation Actions (NAMA and draft Second National Communication (SNC) report) was prepared in 2012. Also a Designated National Authority (DNA) for the Clean Development Mechanism was also established (Camara, 2013). The assessment on investment and financial flows to address climate change in the water, energy, forestry and agriculture sectors has also been completed. These assessments highlighted national policy implications for addressing climate change (Camara, 2013).

The Gambia's SNC provides a quantitative assessment of the country's own greenhouse gas emissions and developed plausible scenarios for assessing the potential impacts of projected climate change on the national economy. The impacts of climate change on crop production, forestry, fisheries, range lands and livestock have been assessed. Public sector institutions, private sector entities, development partners and civil society organizations were all engaged during preparation, review and validation. Both cabinet and legislative approval was gained. (Camara, 2013).The national communications include The Gambia's 2000 national inventory of greenhouse-gas emissions and the mitigation options it has identified to reduce them. The Programme for Accelerated Growth and Employment (PAGE) recommends the development of the Gambia Low Carbon Development Strategy (LCDS), and the mainstreaming of climate change into national development plans, programmes and policies.

The NAPA consists of three broad sectors namely, the economic sector, the natural resources sector and the social sector. It critically re-examines the role of climate on societal and natural systems and is implemented through institutional arrangements at the central, regional and community levels (Republic of The Gambia 2007b). The NAPA is in line with other development frameworks such as the Poverty Reduction Strategy Paper (PRSP II) and the PAGE, the CPD and the MDGs. The Gambia's main PRSPII provides a framework for medium to long term socioeconomic development. The long term goal of PRSP II is to eradicate poverty by significantly increasing national incomes through stable economic growth and reducing income and non-income inequalities through several poverty interventions. PRSP II feeds into the PAGE; Pillar 1 and 5 of the PAGE on Accelerating and Sustaining Economic Growth and Reinforcing Social Cohesion respectively, lays emphasis on addressing Climate Change and Disaster Reduction. The NAPA shares a common objective with the MDGs; to provide food security and enhance sustainable livelihoods of those engaged in Agriculture, Livestock and Fisheries sectors (NAPA, 2007).

The existing institutional arrangement for the implementation of the NAPA or climate change issues in The Gambia is visualize in three levels; i) central (Policy Focal Point- The Ministry of Environment, Parks and Wildlife, and the National Climate Committee); ii)regional (Regional Development Committee and Change Committee) and iii) community(Ward Development Committees and Village Development Committees) (NAPA, 2007). At the Central level, the Ministry of Forestry, Parks and Wildlife Management is the focal point for all policy and technical issues regarding climate change executed by the National Climate Committee (NCC) chaired by the Director of Water Resources (Focal Point for UNFCCC). At the Regional level, the Regional Coordinating Committee (RCC) will have overall regional policy and technical oversight of all climate change related issues. Its technical coordination function is provided by the Climate Change Committee chaired by the Governor. At the Community level, the community level institutions are the entry point for community development activities and will therefore be responsible for the day-to-day implementation management and administrative functions.

The gaps/barriers in implementing coastal climate change adaptation strategies includes:

1. Limited understanding of climate change and its coastal impacts amongst decision-makers and technical staff of institutions in charge of coastal management;

2. Shortage of information and data, particularly with regards to coastal processes, forecast sea-level rise, meteorological conditions and forecast climate change;

3. Limited financial resources: international standards for coastal protection are very expensive, and the national budget is not large enough to cover the anticipated cost;

4. Shortage of scientific and engineering capacity needed to measure and understand basic coastal and ocean processes, to identify, plan, design and implement coastal protection measures;

5. Limited organizational capacity: the lack of organization within communities means the traditional consultative and decision-making mechanism no longer function effectively. In particular, this tends to undermine the operation and maintenance of investments.

5.2 Needs for climate change adaptation and mitigation (Mitigation options)

In the coastal areas, climate change-induced adverse impacts such as sea-level rise, and increase in frequency and intensity of tropical cyclones and storm surges, pose a major challenge for developing countries in implementing appropriate, affordable, and cost-effective adaptation measures. It is important to recognize that climate change adaptation presents a fundamental challenges to managing the coastal resources and should be mainstreamed into coastal development at all levels(Saleem Khan, et al., 2012).

According to the definition by IPCC (2007), climate change an adaptation is adjustments in human or natural systems in response to actual or expected climatic variation, with a view to moderating harm or exploiting beneficial opportunities. The UNDP-UNEP (2011) describes adaptation as an area of growing concern and engagement for many developing countries. The myriad and uncertain effects of a changing climate pose significant risks for developing and achieving the Millennium Development Goals (MDGs).

5.2.1 Coastal protection measures (existing and previous strategies)

Coastal erosion and accretion are common natural processes on most shoreline of the world. In The Gambia, there is a trend of erosion along the coast caused by sediment loss by alongshore transport to the south, to the river Gambia which acts as a sediment trap and on the other hand by sea-level rise. The natural erosion rate of the above mechanisms is generally small. However, because of human interference in different coastal processes, erosion rates are higher at certain locations such as tourist areas and the capital city, BanjulHaskoning, (2000).

Measures to combat the coastal erosion have been implemented since the mid-fifties. Most of them implemented, either by the private sector or by the Government, were on an ad-hoc basis. In 1957 groynes, constructed with rhun palm tree piles and concrete panels were constructed west of Banjul. Later, similar protection measures were placed at several places along the coast between Cape Point and Banjul. Most of them have become ineffective, due to poor design or lack of maintenance. In the nineties, coastal erosion of The Gambia coast became a more serious threat, especially in the capital city, Banjul and around the Tourism Development Area (TDA). As popular tourists'destination during the winter season, the beaches are of utmost importance for The Gambia. Some of the past interventions by Government and some private land and business owners to address coastal erosion along the Southern coastline are elaborated below in the sections.

Coastal Protection Project (RoyalHaskoning)

In the past years, the Government of The Gambia has implemented hard and soft engineering techniques to minimize or control rates of coastal erosion at strategic locations of the Gambian coastline. However those interventions in the past were done on a piecemeal basis. A more holistic approach was taken in 2003, when USD$20MCoastal Protection Project was awarded to a Dutch firm (Royal Haskoning). Before the works began feasibility studies was carried out in 2000 and proposed measures implemented at strategic locations of the Gambia coastline. The works consisted of beach nourishment and the redistribution of the sand spit at Banjul, placing 5 groynes at Cape Point, a T-groyne at Bakau and beach nourishment at KololiBeach (see fig 26)

Figure 26: Royal Haskoning coastal protection intervention sites

Source (Haskoning, 2000)

Palm groynes and gabion baskets (Banjul Cemeteries)

These are the oldest form of coastal protection measures used in The Gambia during the colonial period and are still evident along the coastline. Today, these structures were mainly built along the coastline in Banjul to protect the Muslim cemeteries and part of the Christian cemetery which suffered serious floods during the spring tides in 1957(IUCN, 2010).Between 1958-1968, after the palm groynes were built it was reported that the groyneswere remarkably successful and within a very short time, sand rapidly built-up in the area. However, due to lack of maintenance, the structures could have served much longer, as they require maintenance at ten- year intervals.

In replacement of the old palm groynes,the UNDP funded coastal protection project (UNDP Poverty alleviation Strategy program) funded the coastal stretch of 160m along the coastline adjacent to the Muslim Cemetery at a cost of USD 400,000. A sea wall/revetment was built using gabion baskets filled with the laterite and granite boulder stones. **(**See figure 25**)**

Figure 27:Gabions and palm groynes at the Muslim cemetery and Scout HQ in Banjul

Source (Royal Haskoning, 2000)

Beach nourishment (Banjul port and Senegambia/Kairaba beach hotels)

The beach nourishment was part of the Coastal Protection Project in 2003, awarded to the Dutch firm, Royal Haskoning under the ADB funded project. The targeted areas for the nourishment includes Banjul port area close to the State house and Atlantic hotel as well asthe Sea front of Senegambia and Kairaba Beach hotels to reclaim significant areas lost to coastal erosion. An equivalent of 1,400m³ of offshore dredged sand was used along a stretch of approximately 3km to protect the capital city, cemeteries and the main highway linking the capital city of Banjul to the rest of the country, (Haskoning, 2000).

Figure 28: Coconut plantation at the nourished beach and ferry terminal in Banjul

Source (Drammeh, 2012)

At Senegambia and Kairaba sea front, 1,000,000m³ of offshore dredged sand was pumped along the shore covering a length of approximately 1.5km. The function of the nourished beach is to protect the infrastructure behind the beach and act as an erosion buffer (Haskoning, 2000). The nourishment has also spread out and fed adjacent coastal stretches during the process of reaching a final stable profile under the present wave and tide regime at the location.

In front of the two storm water drains the beach level has been lowered in order to allow for free flow of the storm water towards the sea during the rainy season. The nourished beach at this site decreased at a rate of between 2-3m annually due to increased wave energy at this site, and also the poor quality of the sand used for nourishment (see fig 29-30).

Figure 29: Senegambia and Kairaba hotel after the beach nourishment in 2004 and current state in 2010

Source (Haskoning, 2004)

Revetment and T Groynes at Cape point and Bakau

At Cape Point beach, a 300m long rock revetment was built with five rock groynes. The revetment was built with an under layer of basalt rock, grading 10-60kg, placed on geotextile. The under layer of the revetment is covered with an armour layer of basalt rock, grading 100-500kg. The specific weight of the rock is close to 2,900kg/m³, the upper berm is situated at the level of CD+3.50 with an extended splash berm, which connects the laterite rock protection placed on the slope above the revetment. The toe berm was lifted to run over the laterite shoal at the Cape point's bend to reduce the length of the slope and smoothly connects to the most northern sea groynes. (See figure 31).

The northern groyne has a length of 120m while the length ofthe remaining four groynes at southern groynes is 100m each. These five groynes and a revetment were constructed at Cape Point to protect the Hotel industry (particular, former Sunswing hotel, Cape point hotel and Ocean Bay hotel) from erosion, and instead of an expected infill of 50,000m³, excavations to be carried out to construct the groynes at design level, a considerable infill of the new beach pockets was done by nature in less than half a year ((Haskoning, 2000)(see figure 30)

The T-groyne was constructed in Bakau to protect infrastructure and fishing activities located along the coast. It consists of an under layer of rock grading 60-100kg which is placed underneath the 2-5 ton section of the T at the sea side(Haskoning, 2000). The landside of the root of the T-groyne has two sections, one section connecting the sea side of the T-groyne, at a level of CD+ 1.50m, constructed with basalt rock 300-1000kg and another section connecting the land side, constructed with literate rock 60.300kg. The latter slopes from CD+1.50m to approximately CD+3.50m at the connection with the cliff (Haskoning, 2000).

Figure 30: Constructed groynes at Cape point hotel

Source (NEA, August, 2009)

Figure 31: Constructed revetment close to Sunswing hotel

Source: (Haskoning, 2000)

Coastal protection measures by private land and business owners

Apart from the Government and donor-funded projects to address coastal erosion along the Southern coastline, there are other protectionmeasures undertaken by private landowners, Foreign Embassies and hoteliers whose office building business and settlements are threatened by coastal erosion and storm water. Most of these private interventions are happening within the cliff coast between Cape Point and Fajara. The retreat of the cliffs due to wave action is not a continuous but a stepwise process. Governed by hydrodynamic and geotechnical phenomena, waves are undercutting the toe of the cliff slides until the cliff becomes geotechnically instable and a significant part of the cliff slides off. Several years may pass without significant cliff retreat, while in one year a retreat of several meters may occur. On the basis of detailed aerial photographs of 1946 and 1993 it can be observed that on average the cliff has retreated in that period over a distance of 20 to 30m, indicating an average retreat rate of 0.4 to 0.6m/yr. At some locations no significant retreat was found (0m/yr.), while at one location, a retreat of 40m was measured (0.9m/yr.)(Haskoning, 2000). The properties located on the cliff are not only threatened by the undercutting of the cliff by wave action, but also by storm water from upland causing erosion. The two options of coastal protection implemented by the private land and business owners includes seawalls and sandbags and they are briefly described below:

The First seawall is built on top of the cliff, by the French Embassy from the top of the cliff to the bottom using the cement blocks. Inside of each of these two walls, on large drainage pipe has been built into lead all the run-off from the top of the cliff to the sea(see fig 32). The second seawall was constructed at the base of the cliff, along the length of the property belonging to a business man (BasiruJawara) to protect the cliff from erosion through wave action. The edge of the base wall is constructed in a manner such that the storm water is being diverted into the sea at this point, which is causing erosion of the wall there (see fig 33).

Figure 32: Cliff erosion at the fence of the French Embassy

Source (NEA, 2012)

Figure 33: Sea wall protecting a house on top of the cliff

Source (NEA, March 2012).

The third sea wall was built by the management of African Village hotel in 1986. The wall is comprised of interlocking cement blocks measuring 2 x2 x3 meters, placed on top of each other. The area between the wall and cliff has been filled with beach sand to serve as an elevated beach.

Due to the heavy weight of the cement blocks, they are able to dissipate the wave energy and further prevent erosion.

Figure 34: Constructed wall around artificial beach at African Village hotel

Source (NEA, 2012)

A fourth sea wall was built by businessman (Amadou Samba) from the perimeter fence of the compound at the top of the cliff down to the beach. The entire cliff is covered with concrete, thus preventing any form of cliff erosion. At the bottom of the cliff, the wall is made thicker and serves to dissipate the wave energy. Some natural rock boulders left inside the sea adjacent to the property serve as breakwaters. All the run-off from the top of the cliff is led inside drainage pipes to the beach (see fig 36).Finally, Senegambia and Kairaba beach hotel both sea wall and sand bag intervention were done at the seafront before the coastal protection project started in 2003(see fig 36).

Figure 35: Seawall at Amadou Samba's residence and run-off gullies close by

Source (NEA, March 2012)

Figure 36: Sand bags and sea wall at the front of Senegambia/Kairaba hotel

Source (NEA, 2000 and 2009)

5.2.2 *Recommended management and adaptation options*

Assessing coastal erosion can be done by visual observation and through discussions with inhabitants to ascertain its degree and when it started. However, determining the causes of coastal erosion and which coastal protection options should be used requires a comprehensive study of coastal processes. Generally, options for combating coastal erosion are traditionally twofold, namely hard engineering and soft engineering. These solutions have at least two hydraulic functions to control waves and littoral sediment transport. For the problem of coastal erosion and flooding in some keys area within the study area, the following options are evaluated based on the present situation at the southern coastline of The Gambia.

The options were assimilated from various references (Bijl, 2011)(Geldenhuys, 2011)(FAO, 2007)and they are categorized below:

1. *Do nothing*

Doing nothing amounts to the base case and involves letting nature run its course without assisting land owners in any way. It amounts to implementing reactive rather proactive measures. This option is only suitable if no other economically or environmentally feasible alternatives, which reduce the risk, exist or if the location is not considered critically vulnerable. In this case study instances of flooding and coastal erosion could lead to very high economic damages and due to the criticality of the infrastructure behind the beach such as the Capital city (Banjul) and other major hotels and infrastructure along the Southern coastline. It is unlikely to be a suitable option on its own for the long term for this location, but will be kept in as a “theoretical” option.

2. *Seawalls*

These are generally rigid structures protecting hinterland infrastructure and keeping the coastline (of the specific location) in place (keeping the line).In some instances sea walls also contain non-rigid parts such as armour units which dissipate wave energy in front of them. Their presence also scars the very landscapes that are trying to save; however they are probably the second most traditional method used in coastal management. Whereas a seawall could be feasible at some location in the study area as a final line of defence it is not a preferred solution for this area. Although it is observed that a few seawall have been constructed by private land and business owner in the study area to protect their settlements and hotels.

3. *Revetments*

These are non-rigid structures generally consisting of rock rip rap or concrete armour units, slabs or blocks normally placed on an angle on banks which absorb wave energy. They could also consist of geotextile bags, gabions or vegetation. Most revetments do not significantly interfere with the longshoretransport of sediment. Since the wall greatly absorbs the energy instead of reflecting, it erodes and destroys the revetment structure; therefore, major maintenance will be needed within a moderate time of it being built.This will be greatly determined by the material the structure was built with and the quality of the product. This could be a protection solution for the study area, as it has been used in the coastal protection project by Royal Haskoningin 2003 at Cape Point beach hotel, although because of its visibility, it might cause visual impact detracting significantly from the tourist potential of the beach.

4. *Groynes*

These are structures made of wood, rhun palm, concrete or rock, generally constructed to the shoreline which aims to trap sediment from longshore transport. Beach materials build up on the down drift side, where littoral drift is predominantly in one direction, creating a wider and a more plentiful beach, therefore enhancing the protection for the coast because the material filters and absorbs the wave energy. However, there is a corresponding loss of beach material on the up drift side, requiring that another groynebe built there. Moreover, groynes do not protect the beach against storm-driven waves and if placed too close together will create currents, which will carry sand material offshore. It is increasingly viewed as detrimental to the aesthetics of the coastline.

Many experts consider groynes to be a “soft” solution to coastal erosion because of the enhancement of the existing beach, while other did not consider it to be a coastal protection solution, but rather a form of coastal management. Although groynes construction creates a problem know as Terminal Groyne Syndrome, which prevents longshore drift from bringing material to other nearby places or shifts the problem downstream, it could be considered in the study area, since it has been the oldest form coastal protection in The Gambia since the colonial period, and also recently during the last coastal protection project by Royal Haskoning.

5. *Detached breakwaters*

These are offshore structures, made of enormous concrete blocks and natural boulders that are sunk offshore to alter wave direction and to filter the energy of waves and tides. The waves break further offshore and therefore reduce their erosive power. This leads to wider beaches, which absorb the reduced wave energy, protecting cliff and settlements behind. These structures are generally a solution for a highly erosive coast with a longshore transport gradient. A detached breakwater is generally constructed from rip rap or concretearmour units. This option could be considered in the study area, especially between Cape point and Fajara, where cliff erosion is quite visible. Also the breakwaters will be helpful in combination with beach nourishment at Senegambia and Kairaba.

6. *Beach replenishment/nourishment*

Beach nourishment is one of the most popular soft techniques of coastal defence management schemes. This involves importing sand on the beach and piling it on top of the existing sand. The imported sand must be of a similar quality of the existing beach material so it can integrate with the natural processes occurring there, without causing any adverse effects. This option is generally seen to have substantial recreational and tourism benefits. This could be a good option for the case study area, especially at the sea-front of Kairaba and Senegambia hotel, where nourishment has been done recently (although it was not the best success story, due to number of reasons, including the quality of the sand used, absence of breakwaters, and high wave energy.

7. *Coastal re-vegetation in muddy coastline environments*

In muddy coastal environments or within the tidal zones of estuaries, mangroves forest and other indigenous shrub species are commonly found. Most erosion in these zones is attributable to the removal of the mangroves and other trees. To overcome this problem, replanting is necessary because these trees can regenerate and serve as coastal defence structures. This is considered as a possible option for the study area, especially in Tanbi wetlands National Park (surrounding the capital city), Tanji river estuary, and Kartung where mangroves have been cleared in the past years.

8. *Dune stabilization and rehabilitation*

Sand dunes are unique among other coastal landforms as they are formed by wind rather than moving waters; they represent a store of sand above the landward limits of normal high tides where their vegetation is not dependent on the inundation of seawater for stability. They provide an ideal coastal defence system; vegetation is vital for the survival of dunes because their root systems bind sediments and facilitate the build-up of dune sediment via wind baffle.Dune stabilization or rehabilitation is considered to be an effective “natural” protection measure. This could be considered a possible option especially at rehabilitated sand mining sites and untouched sand dunes.

9. Setbacks and zoning mechanism

Setbacks requirements are standards that protect structures from hazards or create buffers between structures or uses by preventing development a minimum distance from a baseline, often the shoreline. Coastal setbacks are often designed to prevent damage to infrastructure from flooding and erosion. The distance from the baseline is typically calculated either as a fixed number or is based on an algorithm, such as the average erosion rate over the economic life of the structure. Alternatively, for coastal areas which have conflicting activities and population pressures, it is difficult to decide which management techniques might be applicable and acceptable to all resource users

10. Improve role of Local government

Much of the success of coastal resources management depends largely on the results achieved in the lower levels of Government. Local governments also are the most immediately concerned with coastal problems due to the direct effect on their citizens. However, they are usually reluctant to take action because of limited authority and capacity. To overcome this trend, a change in the delegation of decision-making authority is required. Decentralization could give the local government more authority and responsibility.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This review aimed to assess and develop recommendation for adapting to climate change induced sea-level rise in Southern coastline of The Gambia. Climate change induced sea-level rise has been recognized as a significant threat to low-lying coastal areas around the world since the issue of human-influenced global climate change emerged in the 1980s (Barth and Titus, 1984). The concentration of people and their assets, including many of the world's major cities along the coasts, makes them hazardous locations as a result of their exposure to coastal storms with large waves, hurricanes, and associated flooding (Kron, 2008) is a major coastal issue in the 21st century, partly because many of the World's built assets, infrastructure and highly ecologically sensitive areas are located in the coastal areas. Literature review shows that there are two major driving forces behind sea-level rise: thermal expansion and global ice melt. Thermal expansion is a result of warming ocean waters; as the ocean heats up, it expands. The Greenland and Antarctic ice sheets, which make up most of the ice covering Earth's surface, are melting, contributing to rising seas. Both driving forces are impacted by temperature- the warmer the earth becomes, the more sea level will rise. Sea level rise is not the only climate impact threatening coastal communities. Combined with expected increase in storm intensity and changing precipitation patterns, we expect sea-level rise to lead to an increase in coastal erosion, coastal inundation, saltwater intrusion, and flooding.

Accelerated sea-level rise and storm surge pose serious threat to coastal habitat, biodiversity and socio-economic activities in the coastal zone of The Gambia, particularly in the Southern coastline, especially in Banjul- where some parts of the capital city are less than 1m above sea-level. Also other major socio-economic and cultural activities such as tourism, artisanal fisheries, coastal settlement, cultural and historic sites, habitats for turtle nesting and migratory species are all threatened. The effects of climate change, combined with past human interventions (sand extraction, degradation of coastal environment) have increased the vulnerability of the coastal zone of The Gambia. In addition, in view of the scientifically robust projection of additional and accelerating sea-level rise in the future, vulnerability and adaptation is an increasing central concern for low-lying coastal countries like The Gambia. Therefore, the goal of this review is to increase the understanding of politicians and decision makers regarding the socio-economic impact of climate change induced sea-level rise in The Gambia as well as assess the approaches, policy options, available tools and best practices, in the increasing resilience of coastal communities and ecosystem to accelerated sea-level rise especially in Southern coastline of The Gambia, where the major socio-economic development have taken place.

Based on the review of case studies on coastal erosion, adaptation strategies to sea-level at both regional and international level as well as different tools and approaches used in coastal vulnerability assessment and adaptation, several important lessons has been learnt:

- Firstly the review identified widely accepted approachesto vulnerability assessment, including tools, methods, handbooks, and guidelines developed by different international bodies, research institutions, and NGOs in the field of environment and climate change. It is apparent that even though the different approaches and tools use similar language and seek to further the process of adaptation, they need to be selected carefully as they are designed for different purposes and do not target the same users or situations.
- Secondly, it is important to bear in mind that most of the approaches and tools are not simple and straight-forward; their usage requires training and skillful facilitators who are knowledgeable in the required field. Significant data collection and/or significant resources might also be required.Although access and availability of methods and tools for adaptation is not a limitation, there is limited guidance available on how to select the most appropriate approaches for a given location.
- Thirdly, the review shows that the coastal and marine areas are considered to be very highly productive in terms of their contribution to the socio-economic, cultural and environmental issues such as tourism, fisheries, recreational, and ecosystems good and services from coastal ecosystems. However, the latest sea-level rise projections from the IPCC Fifth Report, reveals that the rate of sea-level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. In this regard,despite the importance of coastal areas, sea-level rise induced climate change will continue to threaten these areas, thereby causing problems like coastal inundation, saltwater intrusion and coastal erosion. This phenomenon causes impacts of loss of land with economical, societal or environmental values, destruction of natural sea defenses(usually a dune system), sometimes as a result of a single storm event, which in turn results in flooding of the hinterland; undermining of artificial sea defences, potentially also leading to flood risks.

Coastal erosion is a natural process where waves and currents or wind remove sediments from the beach. An eroding coast suffers from an imbalance of sediments where the removal is more than the supply of sediments. The factors which are driving coastal erosion trends in the case study countries, and thus changing coastal geomorphology, can be categorized as either due to natural and man-made activities or both. The natural factors such as wave action, current, and sea-level rise depict the normal behaviour of the coastal system. The man-made factors such as constructing coastal engineering structures- mainly dam construction upstream of the major rivers in West Africa, which trap sediments before they reach the coast and therefore contribute to reduce the sediment budget available on the coast. Sand mining and harbour related dredging activities also remove every year millions of tons of sediments from the riverbed. Other man-made activities include oil exploitation, vegetation clearing contributed to the accelerated coastal erosion along the coast of West Africa. These activities are a direct cause of shoreline erosion, damaging to the beach fauna and flora, ruinous to beach aesthetics, and frequently causing environmental damage to other coastal ecosystems associated with the beach such as wetlands.

- Fourthly, the lessons learnt from the case study countries in relation to past coastal erosion interventions have demonstrated that options for combating coastal erosion are traditionally twofold, namely hard engineering protection structures and soft engineering options. Both options have at least two functions to control waves and littoral sediment transport; however in applying the solutions, their underlying principles should be well understood, otherwise it will lead to failure, and resulted in environmental and socio-economic problems owing to improper designand construction.The literature show such problems in case study countries, where hard engineering options implemented through Government and donor projects, provide local solutions which do not address the underlying cause of erosion (shortage of sediment) and generally accelerates the problem down-drift the coastal protection. It is also noted that the coastal erosion measures were implemented locally in specific places in piece meal management schemes, which were not effective in the long-term. A combination of hard and soft options has become more popular recently because of cost-effective and optimum results in slowing down erosion process with a limited impact on natural coastal processes rather than when used single option.
- Fifthly, a review of the literature shows that, for sea-level rise adaptation strategies to work effectively they need to be backed up by appropriate policies and regulations for their implementation; otherwise it will lead to failure at the long-term. This has been

noted in some case study countries, who have implemented successful coastal protection and management measures with good policies. However, coastal governance, public awareness and involvement of the private stakeholders, local authorities seems to be low, and it should necessary to create a dialogue towards a concerted management of coastal zone.

In conclusion, sea-level rise induced climate change is of great concern for The Government of The Gambia, due to its socio-economic impacts on the tourism industry, fisheries, agriculture and coastal biodiversity, which all contribute significantly to the development of the country and the livelihood of the communities, who depend on those resources for daily lives. There is all evidence that the climate is warming, and sea-level will continue to rise in future.

6.2 RECOMMENDATIONS

Climate changes are inevitable and adaptation to unavoidable impacts requires evaluation of existing strategies and policies for implementation. Sea-levels haverisen observably in the past century, and scientists forecast that sea-level rise will continue for centuries, even if we stop emitting greenhouses gases now. As a result, coastal areas will be subject to increasing riskof inundation and erosion. Recommendations for the southern coastline of The Gambia are as follows:

1. **Recommended policies and strategy**

- Develop Integrated Coastal Zone Management (ICZM) policy

Currently,the management responsibility of the coastal zone is divided among several institutions having a stake in the coastal areas. The roles of the institutions are guided by their different mandates, and there are usually conflicts of interest between the stakeholders while operating within the coastal zone. Therefore to avoid conflict and strengthen coordination among stakeholders, in order to manage the coastal resources effectively, Integrated Coastal Zone Management is needed through adoption of an integrated or joined up approach towards the many different interests in both the land and marine components of the coast.

- Develop a climate change and sea-level rise strategy

Previous vulnerability assessment conducted shows that Banjul-capital city of The Gambia is highly vulnerable to sea-level rise, as some parts of the city are less than 1m above sea-level. This highlights the importance of planning for future sea-level rise scenarios for The Gambia. In this regard there is need to build on past vulnerability studies in order to develop sea-level rise strategy for the entire coastal zone and outcome of which will determine areas of low, medium and high priority for future protection against rising sea-level.

- Review of the National Environment Management Act (NEMA)

The NEMA empowers the National Environment Agency to regulate activities in the coastal zone, but since its enactment in 1994, these specific provisions of the Act relating to the coastal and environment has not been given any legal effect, as the envisage guidelines and regulations have not been issued. Because of the lack of the relevant regulatory framework, the NEA has not also devised a permit system for the regulation of socio-economic activities within the coastal zone. The only legislative action on coastal zone management undertaken to date by NEA under NEMA is the establishment of the Coastal and Marine Environment Working Group (CMEWG). Therefore it is relevant to review the existing NEMA, and strengthen the section on coastal zone management to guide the activities within the coastal zone.

- Wetlands and mangrove policy

Coastal ecosystem (including wetlands and mangroves) are highly diverse ecosystems that provide a variety of goods and services, including flood protection, livelihood, water purification, wildlife habitat, recreation, migratory routes and carbon sequestration: however, despite their importance coastal ecosystem are at risk from sea-level rise and over-exploitation by humans and also under-valued or ignored in traditional economic analyses. In this regard since The Gambia is signatory to the RAMSAR Convention on Wetlands, ABIDJAN Convention to coastal and marine environment as well asthe three Rio Conventions (CBD, UNFCCC, UNCCD), there is need to develop wetlands and mangrove policy to understand their environmental values and protect these fragile areas from unsustainable utilizations of the resources and future development on natural lands that are immediately adjacent to wetlands.

2. Capacity building/public awareness on climate change

There is often limited knowledge and understanding on sea-level rise and climate change and adaptation concepts and their implication at local level. Climate change is a new phenomenon with potential risks but limited reaction of policy makers. The capacities for adaptive planning, informed policy development and climate proof programming are often weak. Therefore capacity building will help to understand climate change adaptation concepts, be able to effectively and meaningfully contribute to the debate on climate change adaptation in the policy process and apply the concept of climate change adaptation within the context of sustainable development. As a matter of priority, the policy makers and politicians should who plays great part in debating and approving legislations and national budget should be capacitated on climate change issues and their impacts on socio-economic development of the country.

3. <u>Coastal erosion management strategies</u>

- Regulate sand mining- The large extraction of beach sand from the mining areas permanently removes sediment that would otherwise feed beaches elsewhere along the coast. If this sand is released and subsequently transferred alongshore, it could provide significant additional buffer to dune erosion. Therefore, all mining sites need to go through the EIA process as outlined in the NEMA, with management plan regulating the volume of sand to be extracted and restoration plans to implement at the abandoned mining sites.
- Establishment and creationof coastal setbacks and buffers-There are number of tourism and fisheries infrastructure as well as private and public properties located along the coastlines which are at risk of future impacts of sea-level rise. It is therefore recommended to establish setback to guide future development especially in areas with less development. Usually the distance of setback are determined or calculated using the average erosion rate.

  Creating buffers zone between human developments and natural resources, especially around wetlands, will provide a valuable form of adaptation to changes in sea-level, both in their benefit to human and natural systems. Based on the annual erosion rate in some areas along the coastline (between 2-4m) it is important to maintain recommended distance of 150m from the high water mark as suggested by Royal Haskoning, during the feasible studies, however, this distance will be subjected to change according to future erosion rates.

- Restrict the type of erosion control- Lessons learnt from the past interventions have demonstrated that hard-engineering protection structures such as groynes and seawalls built by Government, private land and business owners along the coast only provide very local solutions which do not address the underlying root cause of erosion.There is a need to regulate/restrict the kind and location of coastal protection structures to be built by home owners in order to minimize damage to adjacent properties and the coastal ecosystem. Where necessary mitigation fees to compensate the public for impacts, including recreational opportunity caused by the structures.
- Public awareness and involvement is key in coastal erosion control and management. The coastal communities and the public should be sensitized on the causes, effect of erosion and how human interventions aggravate the situation. Therefore local communities need to be train on mangrove planting in degraded coastal areas to reduce coastal erosion and also enhance their livelihood options.

4. Coastal research and monitoring

- Conduct vulnerability assessment-The southern coastline falls within the jurisdiction of three local municipalities (Banjul City Council, Kanifing Municipal Council and Brikama Area Council). Therefore Local governments or regional planning agencies should conduct detailed studies to better understand the potential impacts of sea-level rise in their communities to allow appropriate policy formulation and action.
- Regular monitoring and baseline studies on coastal dynamics, geomorphology, bathymetry and erosion rates will help in understanding the root causes of erosion and design appropriate intervention measures to reduce erosion.
- The Coastal and Marine Environment Unit of the National Environment Agency should be well trained on coastal zone management, and provide them with the necessary equipment to do their job properly.

5. **<u>Build coastal resilience disaster risk reduction</u>**

- Green infrastructure plays a major role in the mitigation and adaption to climate change. It contributes to strengthening ecosystem services and supports the central role that biodiversity plays in reducing the impact of, and adapting to climate change and livelihood of the communities. Therefore degraded coastal ecosystem (dune, wetlands etc.) require restoration using mangroves, and other coastal plants to protect communities from storm surge and sea-level. In addition, cost-effective "green infrastructure" to help absorb storm water runoff, while beautifying communities (a growing list of communities across the country are investing in green infrastructure- like roadside plantings, expanded tree pits, parks, green roofs, and porous pavement- to keep pollution out of urban waterways.

6. **<u>Interagency coordination</u>**

- Interagency coordination for protection and management of marine and coastal resources needs to be reorganized to minimize incompatible uses of funding and to increase efficiency.
- Synchronizing the planning and implementation of programs affecting marine and coastal resources also need to be fostered at all government levels.
- Establishing an integrated program to control destructive activities such as overfishing, illegal mining, and unsustainable cutting of mangroves is essential.

6.3 SUMMARY-PRIORITY ACTIONS

A major challenges facing our planet and its resources in the 2st century is the changing climate; its impacts on our life sustaining resources and ability to adapt to the change. Scientific consensus based on an overwhelming body of evidence, indicates that global climate is changing, and that it is caused in large part by human activities. According to the recent Fifth Assessment Report of the IPCC indicates that the rate of sea-level rise since the mid- 19th century has been larger than the mean rate during the previous two millennia. Over the period 1901-2010, global sea-level rose by 0.19(0.17 to 0.21) (IPCC, 2013). Ocean thermal expansion and glacier mass loss are very likely the dominant contributors to global mean sea-level rise the 20th century. It is very likely that warming of the ocean has contributed 0.8(0.5 to 1.1 mm of sea-level change during 190-2010(IPCC, 2013). Urgent actions is needed at all levels of Government, as well as by industry communities and individuals to reduce carbon emissions and lessen the extent of climate change, and to begin to adapt to the effects of climate change. Even with such actions, The Gambia and the rest of the nations and world will experience increasingly serious and damaging physical, ecological, social and economic effects in the decades ahead.

Previous research by UNEP (1998) and Jallow et al 1996 shows that The Gambia is ranked among the top ten countries in the world threatened by sea-level rise. It is projected that 92km^2 of land in the coastal zone of The Gambia will be flooded and covered by the sea as a result of only a 1meter rise in the present water level of the sea. The implications will include saline intrusion in agricultural production areas, ground water contamination, loss of biodiversity, and accelerated coastal erosion.While uncertainty remains when it comes to determining the exact way that climate change induce sea-level rise will affect the coastline of The Gambia in the future, however that uncertainty should not result in paralysis or lack of action. Planning for climate change is fundamentally a risk management strategy, similar to an insurance policy against an uncertain future.

Experiences from the case studies have revealed that processes of adaptation to climate change and sea-level rise in both human and natural systems are very complex and dynamic, and often involves numerous assessments depending on existing conditions. The success of any policy depends on the ability to address the natural resilient to the change, financial considerations, the local capacity to deal with the effects of the change, effective planning policies, which depends on data and informed decisions. The goal of this review is to increase the understanding of politicians and decision makers regarding the socio-economic impact of climate change induced sea-level rise in The Gambia as well as assess the approaches, policy options, available tools and best practices, in the increasing resilience of coastal communities and ecosystem to accelerated sea-level especially in Southern coastline of The Gambia, where the major socio-economic development have taken place.

In view of the vulnerability of the coastal zone of The Gambia to climate change induce sea-level rise, and also considering the importance of the coastal zone in contributing to the socio-economic of The Gambia. The Recommendations highlighted above are summarized below in order of priority for action by the Government of The Gambia:

Priority 1: Capacity building/public awareness on climate change.

Priority 2: Review and/or develop policy on climate change, coastal zone management, wetlands and mangrove conservation.

Priority 3: Coastal research and monitoring.

Priority 4: Coastal erosion management strategies

Priority 5: Interagency coordination in coastal resources management.

Priority 6: Build coastal resilience/ disaster risk reduction

CHAPTER 7:BIBLIOGRAPHY

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