MODELLING THE EFFECT OF PREDICTED SEA LEVEL RISE ON TOURISM FACILITIES ALONG THE COAST OF ACCRA, GHANA

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March 2011

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Enschede, The Netherlands, March, 2011

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente and the Faculty of Renewable Natural Resources of the Kwame Nkrumah University of Science & Technology in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Geo-information Science and Natural Resource Management.

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ABSTRACT

Recent sea-level rise has mostly been attributed to global warming and this process is expected to continue for centuries. The extent of the impact of sea level rise on tourism in Ghana is unknown though there are predictions that some prominent tourism facilities are at risk. This research assessed the potential impact of Enhanced Sea Level Rise (ESLR) for different IPCC scenarios on tourism facilities along the coast of Accra. Shorelines for 1974 and 2005 were extracted from ortho photos and topographic maps and vulnerability for tourism facilities calculated. Mean sea level measurements indicated an average rise of 3.3mm/yr. whilst the shoreline eroded by as much as 0.86m/yr. Predictions for Ghana showed 10cm, 23.4cm and 36.4cm sea level rise for 2020, 2060 and 2100 respectively with 1990 as base year. Modelled predictions for the years 2020, 2060 and 2100 based on A2 (enhanced regional economic growth) and B2 (more environmentally focused) IPCC scenarios indicated that 13 tourism facilities are at risk to sea level rise. Out of the total number of tourism facilities at risk, 31% cannot physically withstand the event of sea level rise hazard. In terms of socio-economic vulnerability, accommodation facilities are the most susceptible. Salinization and sanitation problems along the coast will adversely affect tourism.

Keywords

Mean sea level, Intergovernmental Panel on Climate Change (IPCC) scenario, Vulnerability, Coast of Accra, Tourism facilities.

ACKNOWLEDGEMENTS

I thank God Almighty for His continuous grace and guidance through this fairyland.

I acknowledge the Ghana Tourist Board for granting me study leave and ITC capacity fund for providing the funds for my study. I am grateful to my supervisors Drs Joan Looijen, Drs Michel Damen, Mr John Ayer, Louis Addae-Wireko and Professor Oppong for their constructive ideas, comments and encouragement during my research work. Thanks to the staff of ITC (NRM Department) and KNUST GISNATUREM for their varied contribution to the completion of this programme. I am also thankful to the Survey Department of Ghana for the data given me for this research.

To my course mates it has been wonderful knowing you especially the musketeers. I am also appreciative to Mr Paintsil of Survey Department, Dr Appeaning Addo, Kwame, Wahab and the GIS Lab (Oceanography) University of Ghana, Legon.

Finally, I am enormously grateful to my close family and loved ones for their patience and continuous encouragement through this course and research. Thanks for being there when the going was so tough.

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1. INTRODUCTION

1.1. Background

Several studies have been conducted in recent years showing that the effect of climate change has become a challenge (Rahmstorf *et al.*, 2007; IPCC, 2007a). Research indicates that the recent acceleration in sea-level rise is due to global warming (Rahmstorf *et al.*, 2007) and this is expected to continue for centuries (Nicholls *et al.*, 2007). Sea level rise has been associated with greenhouse gases emission, melting of the polar ice in Greenland and Antarctic, and thermal expansion of the sea due to temperature rises (Wigley & Raper, 1987). The Intergovernmental Panel on Climate Change (IPCC) predicted that global warming will lead to a sea level rise of approximately 0.6 m by 2100 (IPCC, 2007a).

Sea level rise could have adverse effect on different sectors and infrastructure along the coast. The most vulnerable sectors being the coastal communities, coastal defences and the ports, and coastal tourism infrastructures (Snoussi *et al.*, 2009). Climate variability and change, coupled with human-induced changes, may also affect ecosystems e.g., mangroves and coral reefs, with additional consequences for fisheries and tourism (IPCC, 2007b).

Although the actual extent of the areas to be affected by sea level rise is unknown, it is evident that such rises in sea levels could cause coastal erosion and extensive coastal inundation, which will lead to coastal habitat destruction, loss of property and lives. Sea level rise could increase the socio-economic and physical vulnerability of coastal cities and may cost up to 14 per cent of GDP in coastal countries (IPCC, 2007b).

Africa has an economic benefit of about 3% of the world's tourism (IPCC, 2007b; WTO, 2005; Appeaning Addo, *et al.,* 2008). Most of these tourism facilities are located along the coasts and are thus vulnerable to sea level rises (McLeman & Smit, 2004).

Risk assessment of enhanced sea level rise on the vulnerability of coastal areas is important for sustainable coastal and tourism development which must be done in an environmentally, socially and culturally sensitive manner (Miller, 2001). Thus spatial mapping of coastal risk areas and tourism facilities in Ghana will give a better understanding of risk patterns towards mitigation and coastal prevention measures (Stanchev*, et al.,* 2009). It is therefore important to identify tourism facilities and infrastructure that might be affected by predicted sea level rise on the coast of Ghana.

1.2. Problem Statement

Studies have shown that Ghana's shore experience a significant wave height of about 1.2m, with relatively long wave periods between 10seconds and 15seconds and tidal range of 0.6m and 1.3m (AESC, 1988; Appeaning Addo, *et al.,* 2008). Though, the Accra local sea level, rises in conformity with the historic global trend of 2 mm/yr., this is expected to increase to approximately 6 mm/yr. in the 21 century (Appeaaning Addo, *et al.,* 2008; IPCC, 2007a). The shoreline of Accra has shown a mean erosion rate of 1.13m/yr. due to acceleration of sea level rise resulting in 82% of the coast being eroded and the rest either accreting or stable (Appeaning Addo, *et al.,* 2008). This is likely to put coastal infrastructure and other assets at risk.

The implication could be adverse effect on the tourism industry since most of the prominent tourism facilities in Ghana are located along the coast. Despite predictions and evidence of coastal erosion, such as the loss of the Ada beach and Fort Prinzenstein in Keta, limited studies have been carried out on the potential impacts of sea level rise on the coast and tourism facilities along the coast of Ghana.

1.3. Justification

The extent of the impact of sea level rise on tourism in Ghana is yet unknown though Appeaning Addo, *et al*, (2008) and others have predicted that certain prominent tourism facilities could be at risk (Boateng, 2006). Ghana's tourism industry is the fourth highest foreign exchange earner and the fastest growing industry with a potential of becoming the nation's first foreign exchange earner. Though, a number of tourism facilities and conservation sites, heritage and historical monument are located within 200m from the shoreline (Boateng, 2006) the likelihood for more developments in these areas cannot be underscored. Prominent facilities such as the current official residence and office of the President of Ghana (Christianborg Castle), Kwame Nkrumah Mausoleum, and Labadi Beach Hotel (the only five star hotel), Elmina Castle, Cape Coast Castle, many forts such as Ussher Fort and James Fort and the abandoned port in James town (Accra) now a fishing harbour are all located within the shoreline protective buffer of 60 to 90meters recommended by the Ghana Water Resources Commission (WRC, 2008) and within 200m from the shoreline. Hence the importance to undertake research on the effect of sea level rises on tourism facilities along the coast of Ghana

1.4. Objectives

The objectives of the research are divided into main and specific objectives:

1.4.1. Main Objectives

The main aim of this research is to assess the potential impact of Enhanced Sea Level Rise (ESLR) for different IPCC scenarios on tourism facilities along the coast of Accra, Ghana.

1.4.2. Specific Objectives

The specific objectives are:

- To analyse the trend of sea level rise over the past thirty (30) years based on historic data for Ghana.
- To map potential impact of sea level rise on coast of Accra.
- To identify and classify the elements at risk for tourism.
- To assess and map the potential physical and socio-economic impact of ESLR on the different classes of tourism facilities at risk for selected IPCC scenarios.

1.5. Research Questions

The formulated questions to meet the above objectives are:

- What has been the sea level rise over the past 30 years?
- How much beach has been lost over the past 30 years?
- How much of the coast of Accra is impacted by the different scenarios?
- Is there any relationship between the past 30 year's sea level rise in Accra and the predicted IPCC global scenarios?
- What tourism facilities are at risk for the different elevation categories?
- What is the physical vulnerability for the affected tourism facilities?
- What is the socio-economic vulnerability for the affected tourism facilities?

1.6. Working Definitions

Some basic terms used in the research are as follows:

- **Mean sea level** (MSL): is the average height of sea surface (the average point between the mean high tide and mean low tide (water heights) of the sea surface) with respect to a local land benchmark. MSL means the "still water level"—the level of the sea with motions such as wind waves averaged out—averaged over a period of time such that variations caused by waves and tides are mostly removed.
- **Beach:** the sandy part of the coastline where people can sit and or use for recreation.
- **Tourism Facilities***:* A Tourism facility is viewed by many as the tourism industry (Crouch & Ritchie, 1999). For the purpose of this research, tourism facilities comprises accommodation facilities (hotels, resorts, lodges), food services (restaurants, night clubs, pubs, bars) and tourist attractions (heritage sites, historical monument, recreational facilities, beaches, lagoons, Ramsar sites)
- **Shoreline/coastline:** The part of the shore/coast which shows the high water mark from the high tide.
- **Elements at Risk***:* Tourism facilities exposed to inundation from the sea level rise hazard. Tourism facilities that may be affected or impacted by the inundation due to the hazard (sea level rise).
- **Hazard**: Hazard as defined by the UN-ISDR (2004) "is a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. This event has a probability of occurrence within a specified period of time and within a given area, and has a given intensity."
- **Vulnerability:** It is the exposure to risk and an inability to avoid or absorb potential harm (Pelling, 2003). In this case the tourism facilities that will be damaged by inundation due to the hazard (sea level rise).
- **Risk:** Risk is defined by the equation:

  Risk = Hazard * Vulnerability * Amount of elements at risk

1.7. Special Report on Emission Scenarios (SRES) Storyline and scenario family

The IPCC Sea-Level Rise (SLR) predictions uses four scenarios based on the Special Report on Emission Scenarios (SRES) for socio economic issues namely A1, A2, B1 and B2 which accounts for uncertainties in modelling parameter for land ice, permafrost and sediment deposition. All the scenarios were equally valid with no assigned probability of occurrence. The following explains the storyline and scenario family used in the prediction of SLR:

- The A1 storyline and scenario family considers a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter and introducing new and more efficient technologies rapidly.
- The A2 storyline and scenario family emphasizes a very heterogeneous world, regionally oriented towards a more fragmented economic growth.
- The B1 storyline looks at global population as in the A1 storyline and a converging world with rapid changes in economic structures toward a service and information economy.
- Whiles B2 storyline and scenario family puts emphasis on local solutions to economic, social and environmental sustainability and focuses on environmental protection and social equity. The population component of both A2 and B2 scenarios are continuously increasing (IPCC-TGICA, 2007).

In the case of developing countries like Ghana where there is the urgent need to solve socio-economic, environmental, increasing population growth and sustainable tourism issues, the IPCC SRES scenarios A2 and B2 for SLR predictions was considered appropriate for the research.
The SLR for the A2 which is more economically fragmented and the B2 scenario more environmentally inclined of which every economy and country will like to attain were used to model the effect on tourism facilities along the coast of Accra.

2. MATERIALS AND METHODOLOGY

2.1. Study Area

The study area is within the coastal zone of Greater Accra Region of Ghana. Ghana has a total length of about 539km coastline, mostly low, sandy shore supported with plains and several rivers and streams running into the sea. Greater Accra is the region hosting the political capital and economic city of Ghana. It is the smallest region but densely populated with about 3,909,764 based on the 2010 population census figures (Ghana Statistical Service, 2011).

The study area (Figure 2.1) explores the coast around Accra which lies between latitudes 5.626 ° N and 5.487° N, longitudes 0.1014 ° W and 0.371° W; approximately 48km long. Accra has an equatorial type of climatic condition prevailing along the coast and characterized by dry and wet seasons. The average temperature for this area is 28^{o} Celsius with less temperature variations. The predominant wind direction in Accra is of southwest monsoons.

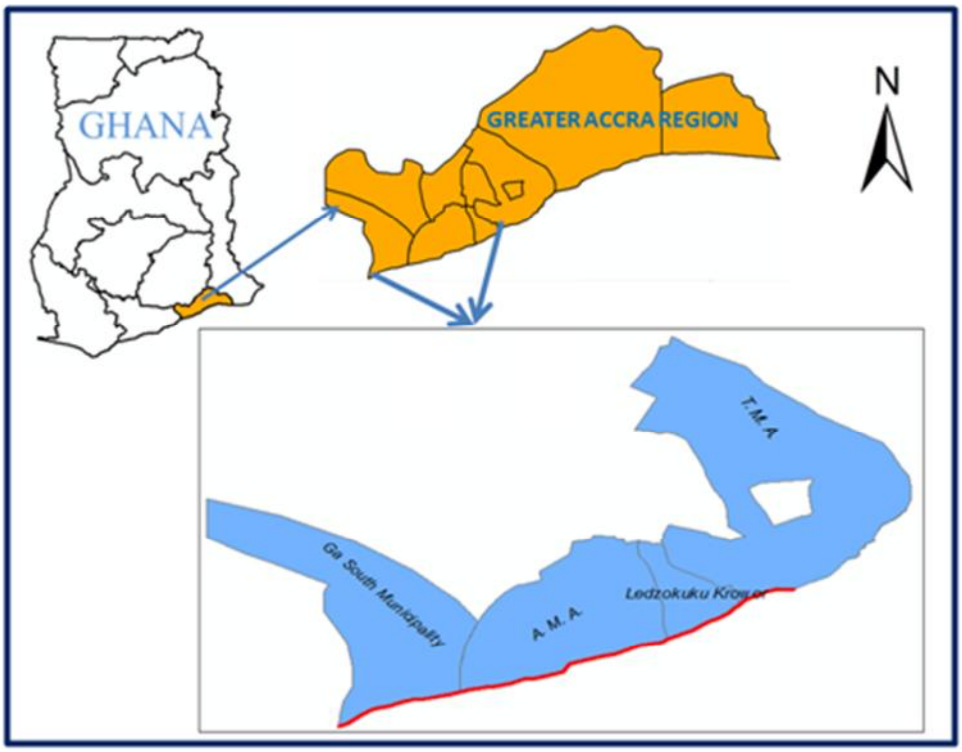


Figure 2. 1: Study area:
Coast of Accra (in Red) covering the, four districts in Greater Accra region

Accra is generally a low lying area with successions of ridges, slopes and occasional rocky headlands. Most developments in this area are found on cliffs. The area of study is most active in business activities with developments and prominent tourism facilities sited along the coast. Forts, lighthouse, museums, hotels, restaurants and active beaches are all in this area and contribute both socially and to the tourism industry. This area has four lagoons, namely: Sakumo I (or Densu Lagoon), Sakumo II, Kpeshi and Korle. The

Sakumo I and II are recognized as world tourism sites known as Ramsar sites. The Ramsar sites have many different species of birds and fishes.

The study area was sub-divided into three (3) geomorphic regions (Table 2.1). The sub-divisions as adopted from Appeaning Addo, *et al.* (2008), are (1) western- 19.1 km from Bortianor to Jamestown; characterized by sandy beach and moderate slope with some lagoons (2) Central- 14.4km from Jamestown to Teshie; predominantly coarse sand with moderate slope and exposed rocks in low to moderate slope and (3) Eastern- 14.6km from Teshie to Sakumo lagoon; coarse sand and rocky between Nungua and Sakumoanya (Sakumono).

Table 2. 1: Geomorphic Zones
(Adopted from Appeaning Addo *et al.*, 2008)

Geomorphic Region	Sub-Region	Description
Eastern 14.6km from Sakumo lagoon to Teshie	A	Stratified lithology, Retard erosion, shore protection, low volume beaches, relatively deep offshore profiles& high cliffs, dotted exposed rocks substratum
Central 14.4km from Teshie to Jamestown	B	Retard erosion, shore protection structures Sandstones, cliffs of varying heights, bay, headland, jetties
Western 19.1km from Jamestown to Kokrobite	C	Low lying barrier ridge, Cliff, steeply sloping seabed, densely populated, lagoons

The study considered an extent of five hundred metres (500 m) inland where most of the tourism facilities are sited. A reconnaissance field survey was used to identify and classify the three (3) geomorphological units in conformity with table 2.1. Information from the survey was used to stratify the areas to represent different classes of elevations and different tourism facilities were sampled from these areas using purposive sampling methods.

2.1.1. Tectonic activities along the coast

The effect of tectonic activities along the coast is crucial for SLR in Accra. For example, earthquakes have been known to occur in the locality of Accra over the past recent years with the major shocks experienced in 1906, 1939 and 1969. The 1939 incidence recorded the most severe shock of m=6.5. Although most of the shocks centred in Accra, strong effects were reported along the coast. In 1911 the eastwards effect of earthquake in Accra resulted in Lome, a neighbouring country experiencing a trough tidal wave (Blundell & Banson, 1975).

Juner (1941) reported on the 1939 earthquake that Accra experienced earthquake along the coast in 1862 and probably some aftershocks 1863. Various shocks, tremors, were experienced in 1906, 1907, 1911 and

1914 to 1933. Between 1933 and 1935 cracks developed in government buildings mostly sited along the coast of Accra though no shocks were felt. These indicated that the coast of Accra is prone to earthquakes and may be affected by seismic activities and subsidence. Severe storm surges and waves could seriously impact on areas of Accraian formation (sandstones and shale) cliffs which may cause erosion and subsidence as there has been evidence of historic subsidence (Blundell & Banson, 1975). Tectonic activities may cause land displacement resulting in adverse effect on tourism facilities along the coast.

2.2. Materials Used

Data collection was done based on the three geomorphic zones. Within each geomorphic zone a five (5) kilometres stretch was considered and shoreline positions were taken to verify the position of the shoreline from the images. Both primary and secondary data were collected for the purpose of this research.

2.2.1. Primary data

Spatial locations of tourism facilities within the area of study were taken using a GPS (Garmin GPSmap 60CSx) to identify and verify the location of facilities on the ortho photo and Google images. Spot heights (elevation measurements) of facilities were taken along the coast looking at the variations of height from the shore to the facility with the help of a surveyor from the Ghana Survey Department. Interviews were conducted with management of tourism facilities and policy makers for information on awareness of sea level rise, mitigation and preparedness strategies for sea level rise.

Shoreline position measurements were taken with the Garmin GPS. A GPS point was taken for the shoreline at the high water mark visualized and determined from high tide using a 500m grid interval determined from the Google image. This was used to verify the shoreline position.

2.2.2. Secondary data

Year 2005 ortho photographs for the study area were available from the Ghana Survey Department for the delineation of shoreline. Google images used to identify tourism facilities along the coast were obtained from ITC. Topographic maps and mean tidal data from the Takoradi tide gauge from 1930 to 1994 were obtained from the Ghana Survey Department to analyse the trend of Mean Sea Level (MSL). Tidal data from 2006 to 2009 were downloaded from the Proudman Oceanographic Laboratory (database) website. Attribute data on tourism facilities were obtained from the Ghana Tourist Board to determine the types and number of tourism facilities within the study area.

2.3. Research Methods

In general the following methods were used to achieve the objectives of the research: analysing the trend of past Mean Sea Level (MSL) data; delineating the shoreline using ortho photos and topographic maps and calculating the rate of change; and then modelling the effect of sea level rise using predicted scenarios and assessing physical and socio-economic implications.

2.3.1. Interviews

Management and/or operators of tourism facilities were interviewed to obtain data on the socio-economic aspects, opinions on change in beach width and mitigation plans and policies for the perceived hazard. Structured questionnaires were used for the interviews. Purposive sampling methods was used for the collection of interview data which were coded in excel and interpreted. Informal interviews and personal observations were also applied. Two questionnaires were used one for the management of the tourism facility operators and the other for policy makers.

2.3.2. Analysing trend of MSL

Ghana as a whole has two points for recording tidal data - Tema and Takoradi harbours. The Tema harbour gauge which is closer to Accra has broken down and has since 1982 not recorded any data. Takoradi harbour recorded tidal data until its final breakdown in 1994. However a new tidal gauge was installed at the Takoradi harbour in 2004 and has recorded data since 2006. Tidal data over the past years from this location was used for this research. Tidal data is recoded by the Survey Department for the Ghana Ports and Harbour Authority. Tidal data collated from the Survey Department of Ghana was analysed with regression and trend analysis methods using statistical software (Excel and Minitab) and used to determine the sea level rise for the past 30 years.

2.3.2.1. Shoreline Delineation:

There are a variety of techniques for delineating the shoreline by automatic and manual means. This includes the digitizing of shoreline from aerial photographs, digital ortho photogrammetry and topographic maps (Ryu, *et al.,* 2002; Fenster, *et al.,* 1993; Fletcher*, et al.*, 2003). Historic shorelines positions were digitized from digital ortho photos (Fletcher, *et al.*, 2003; National Academy of Sciences, 1990; Moore 2000). Selected 2005 ortho photos, Google images and 1:2500 topographic maps were used to determine the shoreline position for the area. The shorelines from 1974 topo map and 2005 ortho photos were used to determine change in coastline (beach width and area) over the past 30 years due to sea levels.

The high water mark was used to define the shoreline position (Pajak & Leatherman, 2002). The high water mark was determined from the image as (Figure 2.2- Image A) visually and the shoreline digitized accordingly as shown in (Figure 2.2- Image B). It was however challenging digitizing the shoreline at rocky areas but this was done with experience and observation during field study.

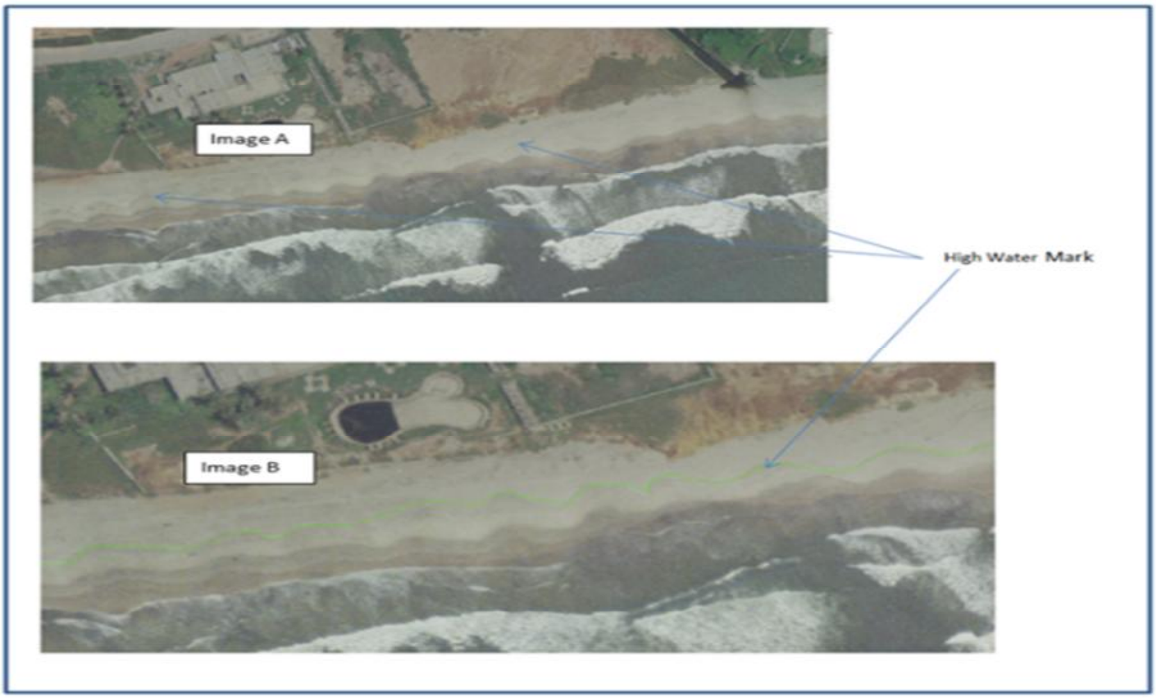


Figure 2. 2: Visualization and delineation of shoreline (green line)

Shoreline positions could be influenced by the tide at the time of acquisition of ortho photos and the visualization and determination of the High Water Mark. The ortho photos were georectified before use; however errors due to tidal fluctuations were not accounted for or calculated. These errors were not calculated since the acquisition of the ortho photos was regardless of tidal cycle.

2.3.2.2. Calculating shoreline rate of change:

The change in beach width was determined by first calculating for the shoreline rate of change. The change in beach width was calculated with the shoreline rate of change as the product of the number of years of change being investigated. The shoreline rate of change indicated the width of beach taken away or eroded per year.

Calculation of shoreline rate of change from historic shorelines was done using a variety of methods. Common techniques used for calculating coastline/shoreline rate of change includes end-point-rate, average rates, linear regression, jack knife and weighted linear regression methods (Morton, *et al.,* 2004; Crowell, *et al.*, 1991; Dolan, *et al.*, 1992). Due to limited availability of data, the End-Point-Rate (EPR) of change method was applied in the study. The EPR computation is flexible and requires only two shorelines for the calculation of the shoreline rate. In this case shorelines for 1974 and 2005 were used. A baseline was created perpendicular to the shorelines and transects casted (Dolan, *et al.*, 1991; Crowell, *et al.,* 1997; Theiler, *et al.,* 2005, Appeaning Addo, *et al.,* 2008; Theiler, *et al.*, 2009; Maiti & Bhattacharya, 2009) from the baseline across the shorelines at equal intervals of 100metres. The result, shoreline rate of change was used to determine the change in beach width over the past 30 years.

2.4. Predicted ESLR for Accra

Sea level rise (SLR) and its impact on the coastal zone is unequivocal. It has been predicted that global mean sea levels will increase up to approximately 6ocm by 2100 (IPCC, 2007). This will have some impact on the coast since relative SLR is perceived to have a multiple effect of about 50 to 200 times the level of rise on the coast. The assessment of the natural hazard posed by SLR is crucial for tourism activities along coastal areas. The aim of the hazard assessment is to identify which areas are prone to SLR in the Accra coast. Estimates of SLR from the IPCC predicted SLR graph (Figure 2.3) is shown for the years 2020, 2060, 2100 for scenarios A2 and B2.

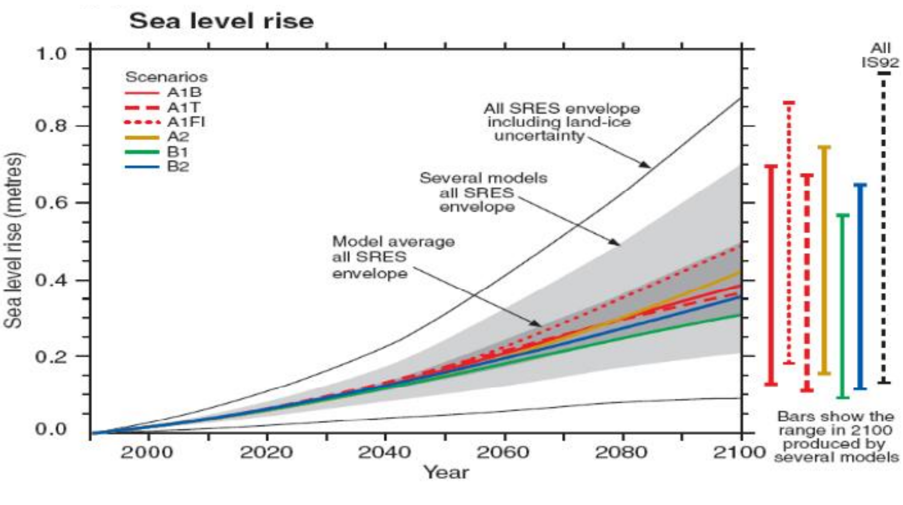


Figure 2. 3: IPCC Sea Level Rise (SLR) graph
(Source: Union of Concerned Scientists, 2010).

Ghana SLR scenarios were predictions based on the linear trend and extrapolated for the years 2020, 2060 and 2100 after which the SLR was determined and shown in table 2.2.

Table 2. 2: Predicted Ghana Sea Level Rise Scenarios (Base year 1990)

scenarios	**Sea Level Rise (SLR) Predicted (cm)**		
	2020	**2060**	**2100**
Ghana	10.02	23.38	36.74

2.4.1. Maps of predicted enhanced SLR (ESLR) - Hazard Zone

Digital Terrain Model (DTM) was generated using contour map (Spot heights) with 2 metres intervals. The DEM with the different IPCC and Ghana scenarios of sea level rise were used to model the impact of SLR on the coast. A hazard map of the impact of ESLR on the coast of Accra was generated for the different scenarios using equation 2.1 to model the hazard zone.

$$Y = \frac{X}{X_r} \times S_r \qquad 2.1$$

where:

S_r= Shoreline rate of change
X = predicted SLR
X_r= Local rate of SLR
Y = Hazard Distance from shoreline

The formula describes a linear relationship between the rate of sea level rise and the shoreline rate of change (recession rate). It was assumed that the current rate of SLR resulted in a particular shoreline rate of change thus a rise in sea level will result in the ratio of that rise and the shoreline change. The formula was based on the assumption from Bruun, (1962) that Sea-level rise is a cause of shoreline erosion. The assumptions were that:

- Winds and waves are the same as period in review
- Storms are as the years in review
- No extreme event and
- Other conditions along the coast remain constant

The trend of sea level rise (SLR) for Ghana based on historic mean sea level data was compared with the IPCC sea level rise scenarios and reviewed.

2.5. Identified and categorized tourism facilities

Different tourism facilities were identified from Google image and 2005 ortho photographs. These different tourism facilities were categorized into three groups: Accommodation, Food Services and Tourist Attraction. The categorization was done based on Ghana Tourist Board database on tourism facilities and field visitation. The various facilities identified were within the 500 m radius of the study area. Coordinates of these tourism facilities were taken upon visits to the facilities and used to establish the location of the tourism facilities from the Google and ortho photos. These categorised facilities were further classified based on different elevation classes: low, moderate and high. The elevation classes were derived from the height measurements taken at locations of tourism facilities. Identified and categorized tourism facilities were mapped.

2.6. Physical and Socio-economic impact

Elements at risk are properties and economic activities that are exposed to hazard in a particular area at a given time. Using the elevation measurement from the field, the elements at risk were derived with the base year of 1990. The average sea level for 1990 was determined and the various levels of sea rise for the different scenarios 2020, 2060 and 2100 were used to calculate for the elements at risk. The equation 2.2 was used to determine the facilities at risk and those with negative values were classified as facilities at risk and mapped using ArcGIS.

$$E@R = Elev - (SL + SLR) \qquad 2.2$$

where:

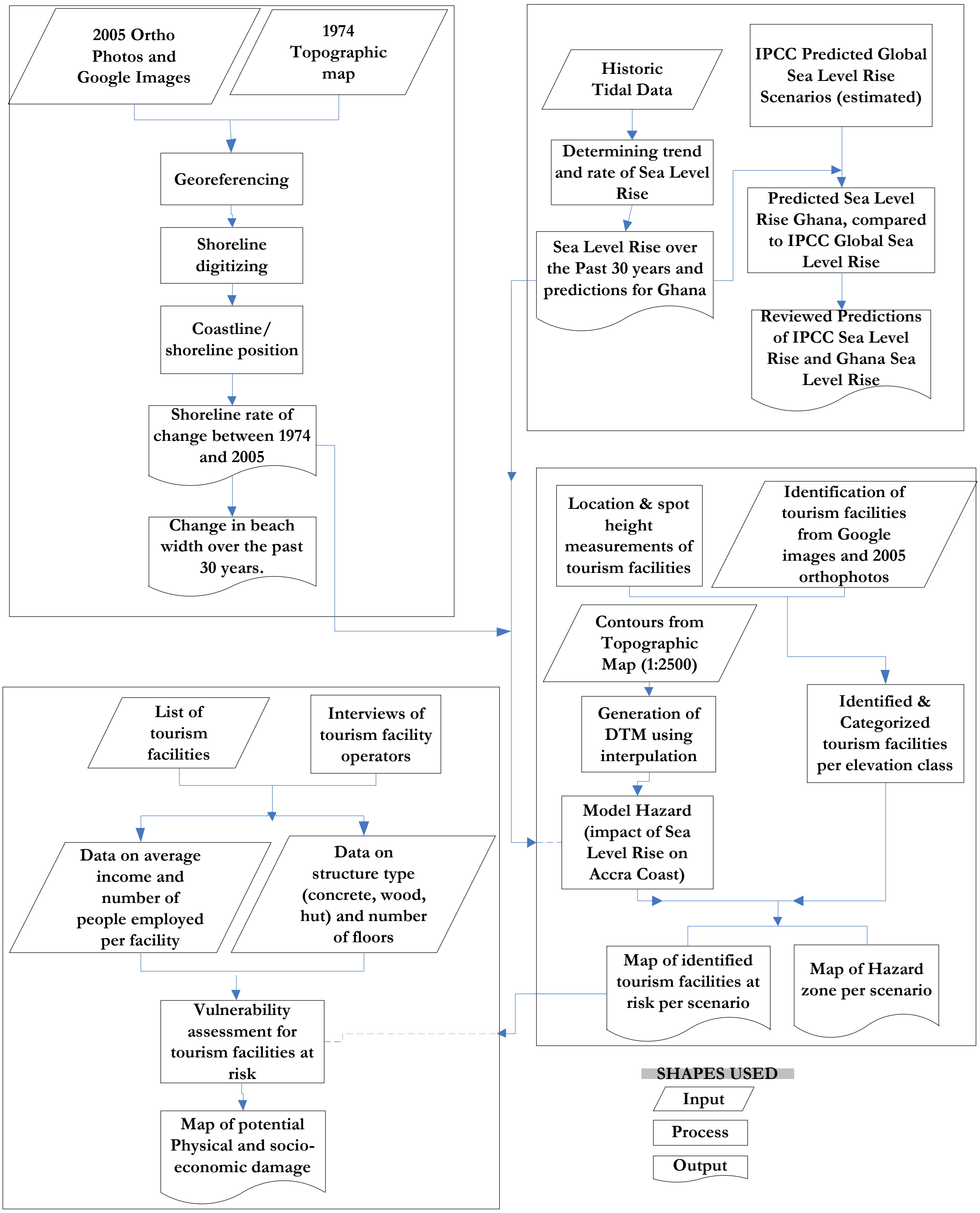
E@R is Elements at risk (tourism facilities at risk)
Elev is elevation (height of facility above mean sea level)
SL is the Average Sea Level for the base year
SLR is the sea level rise (rise for different scenarios)

Maps of identified and categorized tourism facilities were overlaid on the predicted ESLR model of the IPCC scenarios and that of Accra (Hazard zone) for different year to come up with potential vulnerable Tourism facilities map due to ESLR. Different tourism facilities at risk for different scenarios were mapped using ArcGIS.

Inundation maps were created using DEM generated from contours and sea level scenarios. A TIN was generated from elevation measurements (spot heights) for the coast from the topographic map (1:2500) and verified with field data spot heights. The TIN was converted into a raster and used as the DEM for the coast of study.

The semi-quantitative technique was used to express vulnerability. These were numerical values which were merely relative indications, but did not have a direct meaning to damage or expected losses. Also vulnerability was expressed in a relative sense for physical and socioeconomic. This were classified into low, moderate and high and used to map vulnerable tourism facilities. The socio-economic implications from the vulnerable tourism facilities were assessed by assigning numeric values 1, 2, and 3 to low, medium and high vulnerability respectively. Vulnerability for economic and number of people were determined and used to assess the socio-economic vulnerability of tourist facilities.

2.7. Methodological Flowchart



3. RESULTS AND ANALYSIS

3.1. Analysis of the trend SLR over past 30 years based on historic data

Ghana as a whole has two point for recording tidal data, Tema and Takoradi harbours. The Tema harbour gauge which is closer to Accra has broken down and has since 1982 not recorded any data. Takoradi harbour recorded tidal data until its final breakdown in 1994. However a new tidal gauge was installed at the Takoradi harbour in 2004 and has recorded data since 2006. Tidal data over the past years from this location was used for this research. Tidal data is recoded by the Survey Department for the Ghana Ports and Harbour Authority.

Analysing the mean sea level data collected from the Survey Department, showed that the sea levels increased steadily from 1930 but showed a decreasing trend between 1973 and 1994 (Figure 3.1 and 3.2). As indicated above also, there were some periods of no recorded data due to a breakdown in recording equipment. Rahmstorf, *et al.,* 2007, has established a direct relationship between sea level and temperatures, so temperature recordings could also confirm the trend in sea level changes. However, it was possible to estimate trend by using past historic data from 1930 to 1969 (40years) to analyse sea level trends. Figure 3.1 and figure 3.2 below shows monthly and annual mean tidal heights as recorded from Takoradi. The trend shown in the graph for 1973 through 1994 confirms the effect of averaging insufficiently recorded information within this period. From the graph there is a gap from 1994 to 2004 showing periods of no recorded data.

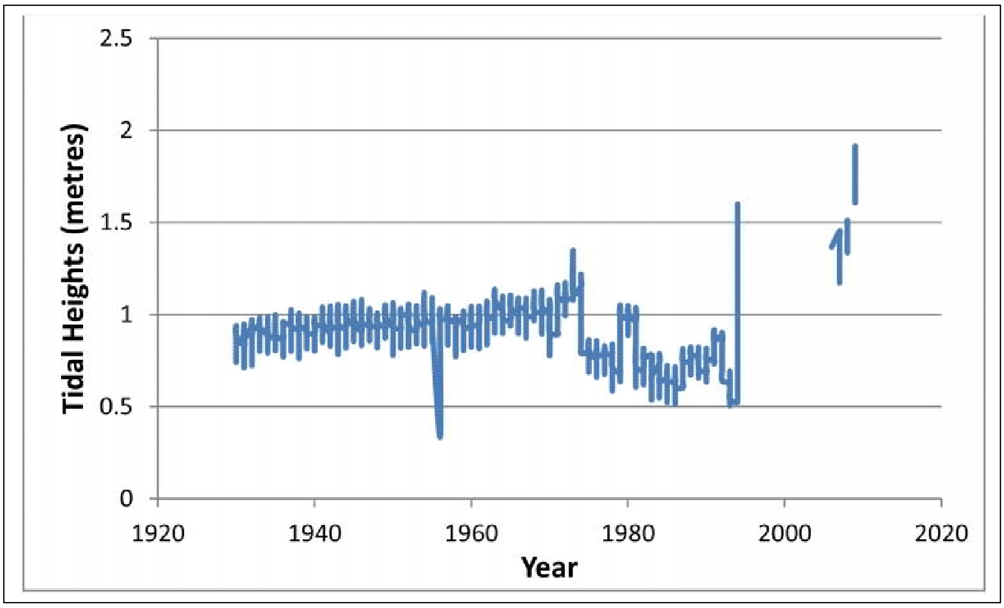


Figure 3. 1: Monthly Mean Tidal Heights at Takoradi

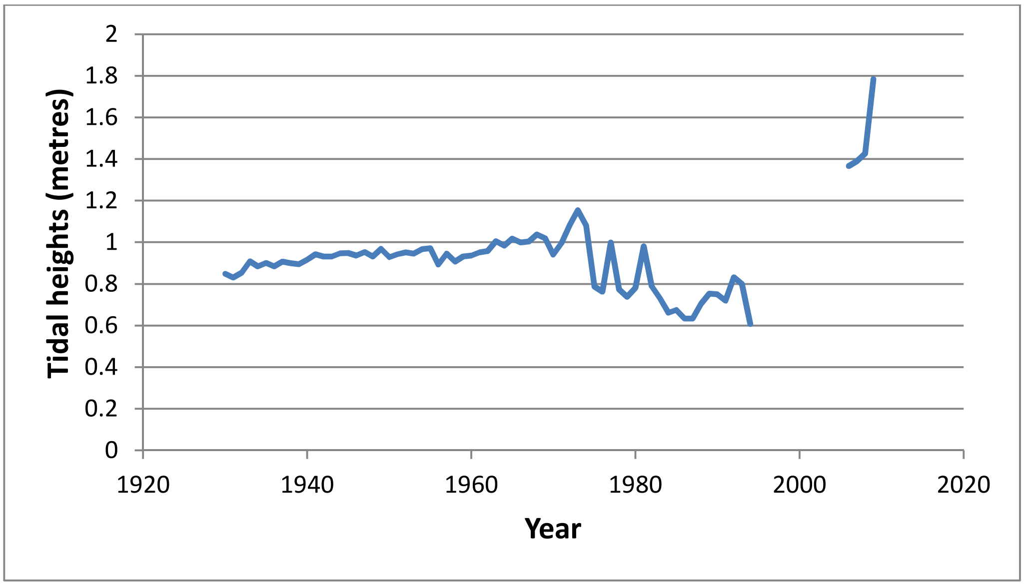


Figure 3. 2: Annual Mean Tidal Heights at Takoradi

Historic data from 1930 to 1969 (40years) was used to derive trend of mean sea levels. Linear regression (ordinary least squared method) has been proven to give better results for predicting shoreline using mean sea level data (Crowell, *et al,*. 1997; Honeycutt, *et al.,* 2001). A linear regression for the 40years (1930-1969) data used, indicated an average rate of sea level rise per year of 3.34mm at 95% confidence interval. The analysis indicated that 70% variation of the data could be explained by the model. The trend model had a mean absolute percentage error of 2%. This means that the model averagely deviates from the data used for the trend analysis and future predictions by 2% (Figure 3.3). The fitted trend equation 3.1 was as follows:

$$Yt = 0.869190 + 3.34 \times t \qquad 3.1$$

where:
Yt = Average mean sea level,
t = year/period,
3.34 = rate in millimetres.

The graph figure 3.3 shows an incresing trend from 1931 up to 1955, after which there was a dip up to 1960 and then an increase. The dip in the MSL trend model from 1955 to about 1960 may have been due the construction of the Tema Port during the same period.

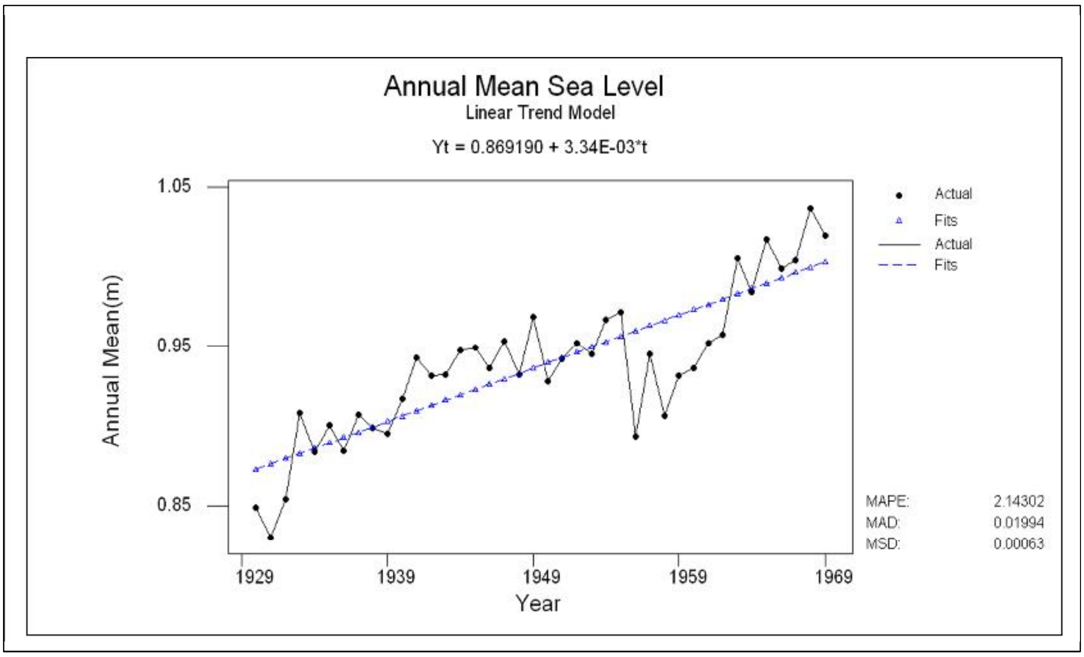


Figure 3. 3: Linear Trend Model for Annual Mean Sea Level

Figure 3. 4 shows a graph of annual mean sea level data plotted against predicted mean sea levels. From the graph, the predictions are close to the actual tidal data. Following the predicted pattern then, tidal levels for the past 30 years should range between 1m and 1.15m with an average of 1.09m and sea level rise of 10cm.

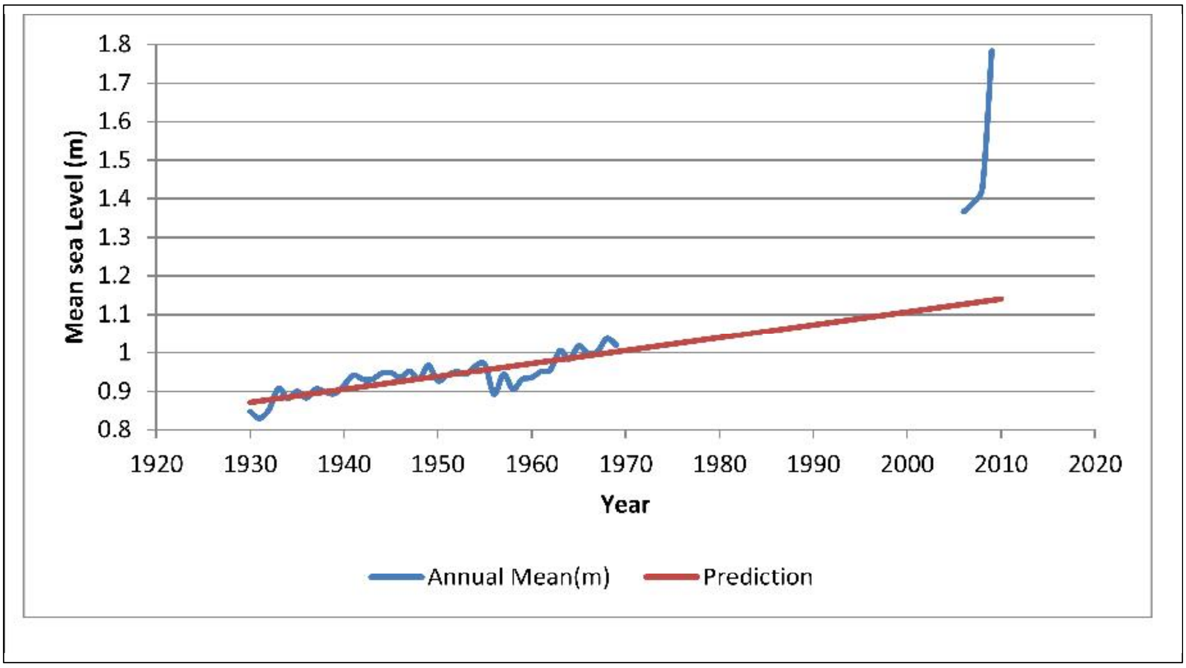


Figure 3. 4: Annual Mean Sea Level Data and Predicted Mean Sea Levels

However a wide difference occurred between the prediction and the data collected for the years 2006 to 2009. This could be due to some seismic activities or the occurrence of subsidence in the area where the tidal gauge is located. Indeed in the year 2004 (Joseph, *et al.*, 2006) it was recorded that the coast of Ghana had an after effect of the 26 December tsunami which occurred in the Indian Ocean resulting in a lowering of the sea level of about 15cm. The high levels of sea levels for the subsequent years could be an after effect of that extreme event.

3.1.1. Review of IPCC predicted SLR for Different scenarios with Ghana's scenarios

Both IPCC scenarios applied the Atmosphere-Ocean General Circulation Models (AOGCM) techniques for the sea level scenarios. Ghana scenarios of sea level rise predicted were a little higher than the IPCC scenarios. The predictions did not include climatic conditions. B2 scenarios SLR for 2100 seem to be closer to the Ghana scenario 2100 with a difference of about 1cm. The IPCC scenarios gives global measurements while the Ghana scenarios are more specific. This indicates that on the average sea levels are rising in conformity with the B2 scenario. Thus more environmental friendly activities may contribute to reduce greenhouse gasses and climate change effects on the sea levels.

3.1.2. Change in beach width over the Past 30 Years

3.1.2.1. Calculating shoreline rate of change:

The EPR was used for the calculation of shoreline movement between the years 1974 and 2005. Example of transects casted for the calculation with equal interval of 100m from a baseline perpendicular to the shorelines used (Figure 3.5).

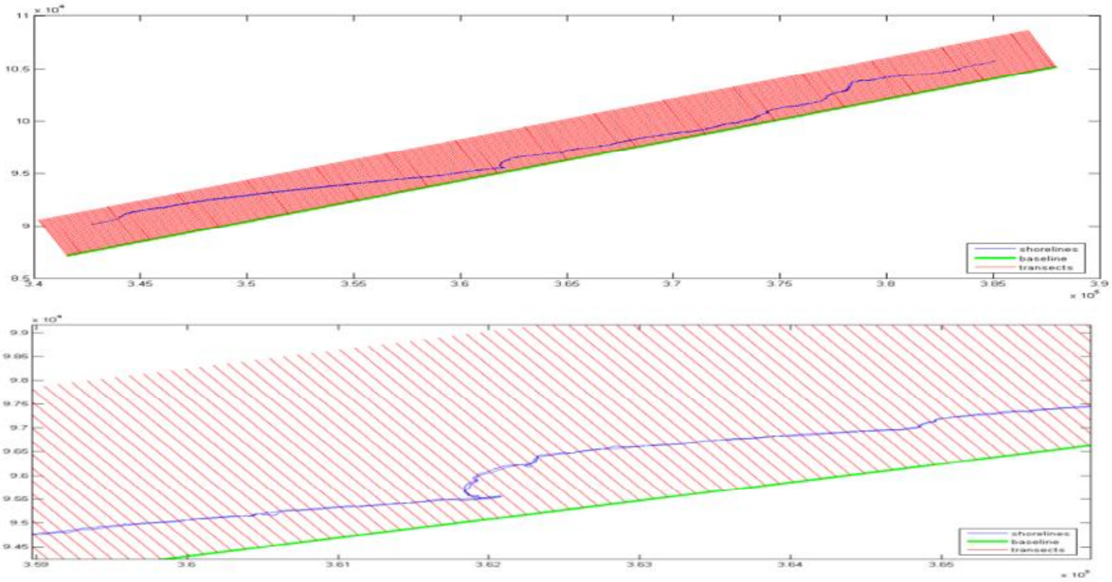


Figure 3. 5: Shorelines with transects 100 metres interval

The shoreline rate of change was calculated with the rate of erosion being 0.86 m/yr. and a standard deviation of +/- 0.7. The rather high standard deviation accounts for the variations in the shoreline of approximately 48km. The varying geomorphic profiles of the coast revealed that the shorelines had different rates of change the rates ranging from -3.6m to 1.6m. The negative value indicated that the shoreline was moving inland (erosion) and positive means the shoreline is moving offshore that is gaining more beach or land. These high variations in the differences in the shorelines accounts for the rather high standard deviation. The shoreline rate of change was then used to calculate for the change in beach width per year and the past 30 years.

The results show that the beach of Accra eroded at an average rate of 0.86m per year over the past years. Thus by this rate of 0.86m/yr., by 2010 beach width would have reduced at an average of approximately

25m. This might not be the same for all areas along the coast. Areas around the Bortianor and Dansoman in the western zone are prone to this reduction.

3.2. Potential impact of enhanced sea level rise on coast of Accra.

The relative sea level rise for the years 2020, 2060 and 2100 for the different scenarios was estimated from the predicted IPCC sea level rise graph (Union of Concerned Scientists, 2010) for scenario A2 and B2. The estimated levels of rise from the different IPCC scenarios A2 and B2 and years 2020, 2060 and 2100 were used as the hazard for this research (Table 3.1). The relative sea level rise for Ghana scenario was determined from predictions of historic mean sea level data with the base year 1990 as per the IPCC scenarios. Table 3.1 show the predicted sea level rise for the various scenarios and years.

Table 3. 1: Predicted sea level rise for global IPCC and Ghana scenarios based on 1990 levels

			Enhanced Sea Level Rise (ESLR) (cm)		
Year	Return Period	Probability of Hazard	A2	B2	GH
2020	30	0.33	5	5	10.0
2060	70	0.014	20	20	23.4
2100	110	0.009	42.5	35	36.7

The potential hazard map was derived from the description and formula in section 2.4.1. Figure 3.6 –A shows the hazard zone for A2 scenarios, figure 3.6 – B shows the hazard zones for Ghana scenarios and figure 3.6 –C shows the hazard zone B2 scenarios all in the central zone of the study area. The red lines indicate the 2100 scenario shoreline, the yellow 2060 shorelines, green 2020 shorelines and blue the base shorelines for 1990.

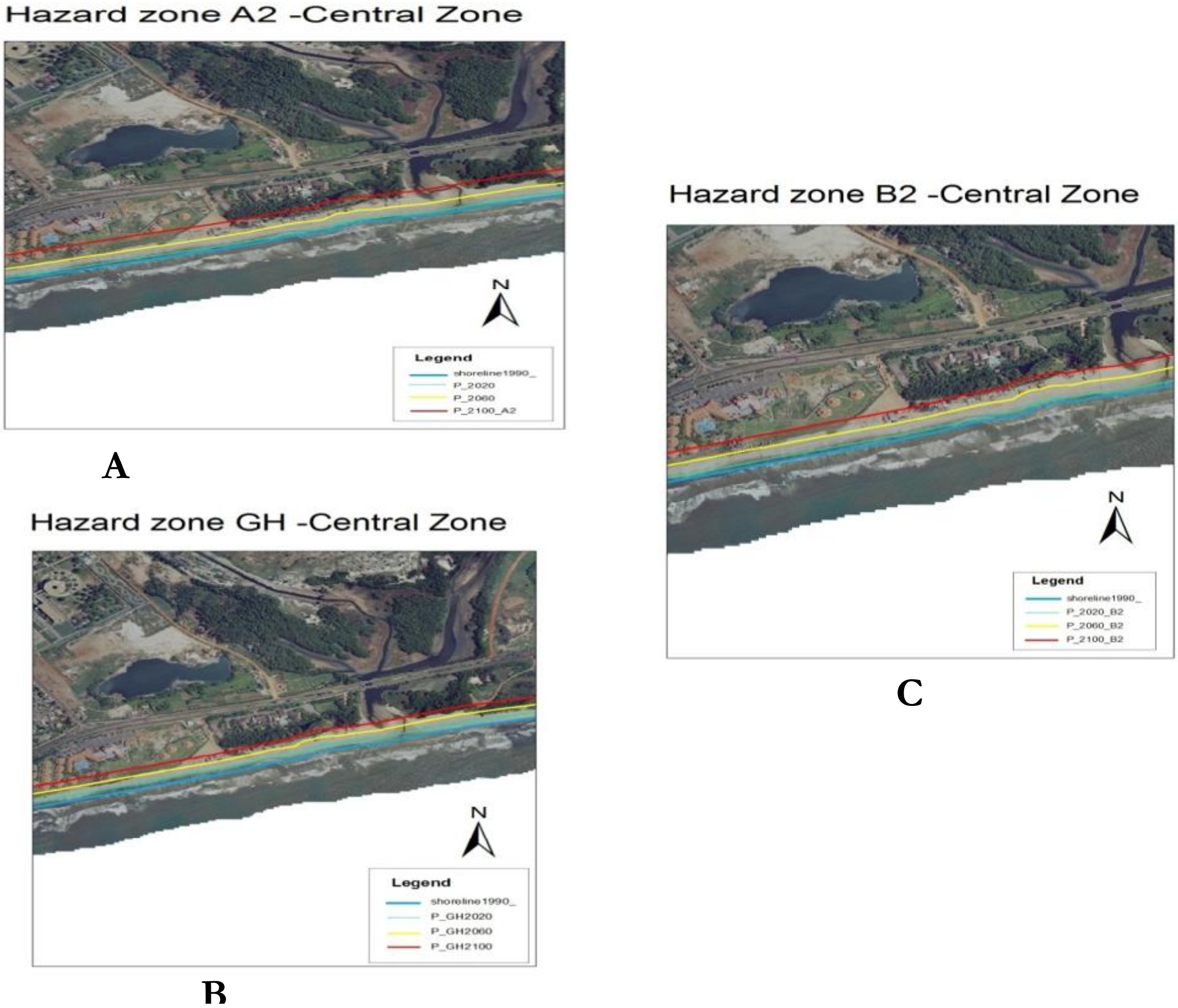


Figure 3. 6: Hazard zone for the central zone of the study area for the different scenarios

The results show that for the A2 and B2 scenarios the shoreline will retreat about 13 m, 52m and 109 m for the years 2020, 2060 and 2100 respectively. For the B2 scenario, the Accra shoreline would probably retreat approximately 90 m by the year 2100 unless Ghana embarks on a more environmentally friendly mitigation practices that will reduce the effect of anthropogenic activities. Table 3.2 shows the length of coastal land and area to be affected by the hazard for the different scenarios. For scenarios A2 and B2 land of about 38m more will be lost by 2060 and approximately 58m land loss by 2100 within the another period of 40yrs for A2 scenario. The length of land loss measures the same for the years 2020-2060 and 2060-2100 forty years interval each respectively for B2 and Ghana scenarios.

Table 3. 2: Differences in length and area for the various SLR scenarios on the coast of Accra

Scenarios	Distance (m)	Area (m^2)	Δ Length (m)	Δ Area (m^2)
A2_2020	12.9	619.2	12.9	619.2
A2_2060	51.5	2472	38.6	1852.8
A2_2100	109.4	5251.2	57.9	2779.2
B2_2020	12.9	619.2	12.9	619.2
B2_2060	51.5	2472	38.6	1852.8
B2_2100	90.1	4324.8	38.6	1852.8
GH_2020	25.8	1238.4	25.8	1238.4
GH_2060	60.2	2889.6	34.4	1651.2
GH_2100	94.6	4540.8	34.4	1651.2

3.3. Identification and classification of elements at risk for tourism

3.3.1. Categorized Tourism Facilities by elevation classes

Tourism facilities identified were categorized into accommodation, food services and tourist attraction facilities and further grouped per elevation class (Table 3.3). Accommodation facilities were comprised of mainly hotels and lodges, food services included restaurants and drinking bars and tourist attractions comprise of attractions and potential attractions such as forts, lagoons and beaches. The identification and classification used coordinates and elevation measurements from the field and expert knowledge described in the methodology. The categorized facilities by elevation are represented in tables 3.3, 3.4, 3.5 and 3.6.

Table 3. 3: Elevation classes

Elevation class	Elevation/Height (metres)
Low	$E_l \leq 5$
Moderate	$5 < E_m \leq 15$
High	$15 < E_h \leq 22$

A total of 39 tourism facilities were identified within the study area based on recognized facilities by the Ghana Tourist Board. Sixteen of the facilities were accommodation facilities; seven were of food services and sixteen tourist attraction. All food services were found to be within the lower elevation range less that 5m above mean sea level (Table 3.4). Accommodation facilities were located on varying elevation classes with 50% found to be on the lower elevation (Table 3.5). Approximately 63% of tourist attractions were located within the lower elevation comprising beaches and lagoons (Table 3.6). Within the coastal extent of 500 m from the shoreline 64% of the tourism facilities were found to be in the low elevation class (less than 5 m above MSL), 31% in the moderate elevation class and 5% were in high elevation class above 15 m. Facilities in the low elevation class were considered to be more at risk to any inundation.

Table 3. 4: Categorized Food Services Facilities

Food Services Facilities				
Elevation Class1 (Low elevation)				
No.	**Name of Facility**	**Elev (m)**	**Type of Facility**	**Rating**
1	Bojo Beach Resort	1	Food Service	grade 1
5	Bahdoosh Bar	3	Food Service	grade 3
6	Boshe Ba Beach Resort	3	Food Service	grade 3
7	Pink House Bar	3	Food Service	grade 3
2	La Tawala	4	Food Service	grade 2
3	Osekan Restaurant	4	Food Service	grade 2
4	Harbin	4	Food Service	grade 2

Table 3. 5: Categorized Accommodation Facilities

Accommodation Facilities				
Elevation Class1 (Low elevation)				
No.	**Name of Facility**	**Elev(m)**	**Type of Facility**	**Rating**
1	Ramada Hotel	1.01	Accommodation	3 Star
2	Sobamba Coastal Resort	1.01	Accommodation	budget
3	Ave Maria	2	Accommodation	1 Star
4	Labadi Beach Hotel	2	Accommodation	5 Star
5	Big Milly Backyard	3	Accommodation	budget
6	Flander Beach Resort	3	Accommodation	budget
7	New Hotel	3	Accommodation	budget
8	La Palm Royal Beach Hotel	4	Accommodation	4 Star
Elevation class2 (Moderate elevation)				
9	Next Door	6	Accommodation	budget
10	Club 1900 Guest House	7	Accommodation	budget
11	Diplomat Beach Hotel	10	Accommodation	1 Star
12	African Royal Beach Hotel	11	Accommodation	2 star
13	Afia Beach Hotel	14	Accommodation	1 Star
14	Beach Cumber	14	Accommodation	budget
Elevation class3 (high elevation)				
15	Ocean Sky Hotel	20	Accommodation	budget
16	Friends Guest House	22	Accommodation	budget

Table 3. 6: Categorized Tourist Attraction facilities

Tourist Attraction Facilities				
Elevation Class1 (Low elevation)				
No.	**Name of Facility**	**Elev(m)**	**Type of Facility**	**Rating**
1	La Community Beach	-1	Tourist attraction	beach
2	Densu Lagoon	0	Tourist attraction	lagoon
3	Kpeshie Lagoon	0	Tourist attraction	lagoon
4	Lagoon (Mighty Beach)	0	Tourist attraction	lagoon
5	Sakumo Lagoon	0	Tourist attraction	lagoon
6	La Pleasure Beach	0.36	Tourist attraction	beach
7	Accra Beach (behind Independence Square)	0.9	Tourist attraction	beach
8	Shaba Beach Nungua	1	Tourist attraction	beach
9	Art Gallery	4	Tourist attraction	art gallery
10	Mighty Beach	5	Tourist attraction	beach
Elevation class2 (Moderate elevation)				
11	Independence Square	8	Tourist attraction	attraction
12	Lighthouse	9.44	Tourist attraction	attraction
13	James Fort	11	Tourist attraction	attraction
14	Ussher Fort	14	Tourist attraction	attraction
15	Kwame Nkrumah Mausoleum	15	Tourist attraction	attraction
16	Kpeshie Mangrove		Tourist attraction	

3.3.2. Elements at Risk

The tourism facilities at risk to the SLR per scenarios are highlighted in grey (Tables 3.7, 3.8 & 3.9). These are represented per tourism facility category. There was no difference between the SLR scenarios except in terms of height of sea level rise. Beaches, lagoons and mangroves are mostly at risk with the minimum rise of 5cm in sea levels. In total 13 facilities are at risk to the SLR for the various scenarios and years. One (1) out of the seven food service facility is at risk, two (2) out of the sixteen accommodation facilities and nine (9) out of the sixteen tourist attractions at risk most of which are lagoons.

Table 3. 7: Table with Food Services at risk to SLR (hazard in cm) highlighted in grey for the different scenarios and years

No.	Name Facility	Type of Facility	Rating	Structures	Floors	Elev_cm	A2_2020	A2_2060	A2_2100	B2_2020	B2_2060	B2_2100	GH_2020	GH_2060	GH_2100
1	Bojo Beach Resort	Food Service	grade 1	Concrete	1	100	-9.66	-24.66	-47.16	-9.66	-24.66	-39.66	-34.72	-48.08	-61.44
2	La Tawala	Food Service	grade 2	Concrete/ wood	1	400	290.34	275.34	252.84	290.34	275.34	260.34	265.28	251.92	238.56
3	Osekan Restaurant	Food Service	grade 2	Concrete	1	400	290.34	275.34	252.84	290.34	275.34	260.34	265.28	251.92	238.56
4	Harbin	Food Service	grade 2	Concrete	1	400	290.34	275.34	252.84	290.34	275.34	260.34	265.28	251.92	238.56
5	Bahdoosh Bar	Food Service	grade 3	Concrete	1	300	190.34	175.34	152.84	190.34	175.34	160.34	165.28	151.92	138.56
6	Boshe Ba beach Resort	Food Service	grade 3	wood/bamboo	1	300	190.34	175.34	152.84	190.34	175.34	160.34	165.28	151.92	138.56
7	Pink House Bar	Food Service	grade 3	Concrete	1	300	190.34	175.34	152.84	190.34	175.34	160.34	165.28	151.92	138.56

Table 3. 8: Table with Accommodation facilities at risk to SLR (hazard in cm) highlighted in grey for the different scenarios and years

No.	Name Facility	Type of Facility	Rating	Structures	Floors	Elev_cm	A2_2020	A2_2060	A2_2100	B2_2020	B2_2060	B2_2100	GH_2020	GH_2060	GH_2100
1	Ramada Hotel	Accommodation	3 Star	Concrete	1	100.8	-8.86	-23.86	-46.36	-8.86	-23.86	-38.86	-33.92	-47.28	-60.64
2	Sobamba Coastal Resort	Accommodation	budget	Concrete	1	101	-8.66	-23.66	-46.16	-8.66	-23.66	-38.66	-33.72	-47.08	-60.44
3	Ave Maria	Accommodation	1 Star	Concrete	3	200	90.34	75.34	52.84	90.34	75.34	60.34	65.28	51.92	38.56
4	Labadi Beach Hotel	Accommodation	5 Star	Concrete	2	200	90.34	75.34	52.84	90.34	75.34	60.34	65.28	51.92	38.56
5	Big Milly Backyard	Accommodation	budget	Concrete	1	300	190.34	175.34	152.84	190.34	175.34	160.34	165.28	151.92	138.56
6	Flander Beach Resort	Accommodation	budget	Concrete	1	300	190.34	175.34	152.84	190.34	175.34	160.34	165.28	151.92	138.56
7	New Hotel	Accommodation	budget	Concrete	1	300	190.34	175.34	152.84	190.34	175.34	160.34	165.28	151.92	138.56
8	La Palm Royal Beach Hotel	Accommodation	4 Star	Concrete	3	400	290.34	275.34	252.84	290.34	275.34	260.34	265.28	251.92	238.56
9	Next Door	Accommodation	budget	Concrete /hut	1	600	490.34	475.34	452.84	490.34	475.34	460.34	465.28	451.92	438.56
10	Club 1900 Guest House	Accommodation	budget	Concrete	2	700	590.34	575.34	552.84	590.34	575.34	560.34	565.28	551.92	538.56
11	Diplomat Beach Hotel	Accommodation	1 Star	Concrete	2	1000	890.34	875.34	852.84	890.34	875.34	860.34	865.28	851.92	838.56
12	African Royal Beach Hotel	Accommodation	2 star	Concrete	3	1100	990.34	975.34	952.84	990.34	975.34	960.34	965.28	951.92	938.56
13	Afia Beach Hotel	Accommodation	1 Star	Concrete	2	1400	1290.34	1275.34	1252.84	1290.34	1275.34	1260.34	1265.28	1251.92	1238.56
14	Beach Cumber	Accommodation	budget	Concrete	1	1400	1290.34	1275.34	1252.84	1290.34	1275.34	1260.34	1265.28	1251.92	1238.56
15	Ocean Sky Hotel	Accommodation	budget	Concrete	3	2000	1890.34	1875.34	1852.84	1890.34	1875.34	1860.34	1865.28	1851.92	1838.56
16	Friends Guest House	Accommodation	budget	Concrete	1	2200	2090.34	2075.34	2052.84	2090.34	2075.34	2060.34	2065.28	2051.92	2038.56

Table 3. 9: Table with Tourist Attractions at risk to SLR (hazard in cm) highlighted in grey for the different scenarios and years

No.	Name Facility	Type of Facility	Structures	Floors	Elev_cm	A2_2020	A2_2060	A2_2100	B2_2020	B2_2060	B2_2100	GH_2020	GH_2060	GH_2100
1	La Communal Beach	Tourist attraction	sandy beach	0	-122.103	-231.763	-246.763	-269.263	-231.763	-246.763	-261.763	-256.823	-270.183	-283.543
2	Densu Lagoon (Estuary)	Tourist attraction		0	0	-109.66	-124.66	-147.16	-109.66	-124.66	-139.66	-134.72	-148.08	-161.44
3	Kpeshie Lagoon	Tourist attraction	water	0	0	-109.66	-124.66	-147.16	-109.66	-124.66	-139.66	-134.72	-148.08	-161.44
4	Lagoon (Mighty Beach)	Tourist attraction	water	0	0	-109.66	-124.66	-147.16	-109.66	-124.66	-139.66	-134.72	-148.08	-161.44
5	Sakumo Lagoon	Tourist attraction	water	0	0	-109.66	-124.66	-147.16	-109.66	-124.66	-139.66	-134.72	-148.08	-161.44
6	La Pleasure Beach	Tourist attraction	sandy beach	0	36	-73.66	-88.66	-111.16	-73.66	-88.66	-103.66	-98.72	-112.08	-125.44
7	Accra Beach (behind Independence Square)	Tourist attraction	sandy beach	0	90	-19.66	-34.66	-57.16	-19.66	-34.66	-49.66	-44.72	-58.08	-71.44
8	Shaba Beach, Nungua	Tourist attraction	sandy beach	0	100	-9.66	-24.66	-47.16	-9.66	-24.66	-39.66	-34.72	-48.08	-61.44
9	Art Gallery	Tourist attraction	Concrete	2	400	290.34	275.34	252.84	290.34	275.34	260.34	265.28	251.92	238.56
10	Mighty Beach	Tourist attraction	sandy beach	0	500	390.34	375.34	352.84	390.34	375.34	360.34	365.28	351.92	338.56
11	Independence Square	Tourist attraction	Concrete	1	800	690.34	675.34	652.84	690.34	675.34	660.34	665.28	651.92	638.56
12	Lighthouse	Tourist attraction	Concrete	3	944	834.34	819.34	796.84	834.34	819.34	804.34	809.28	795.92	782.56
13	James Fort	Tourist attraction	Concrete	1	1100	990.34	975.34	952.84	990.34	975.34	960.34	965.28	951.92	938.56
14	Ussher Fort	Tourist attraction	Concrete	2	1400	1290.34	1275.34	1252.84	1290.34	1275.34	1260.34	1265.28	1251.92	1238.56
15	Kwame Nkrumah Mausoleum	Tourist attraction	Concrete	1	1500	1390.34	1375.34	1352.84	1390.34	1375.34	1360.34	1365.28	1351.92	1338.56
16	Kpeshie Mangrove	Tourist attraction	marsh	0	0	-109.66	-124.66	-147.16	-109.66	-124.66	-139.66	-134.72	-148.08	-161.44

Different tourism facilities are displayed with different elevations in metres – height above local mean sea level (Figure 3.7 & 3.8).

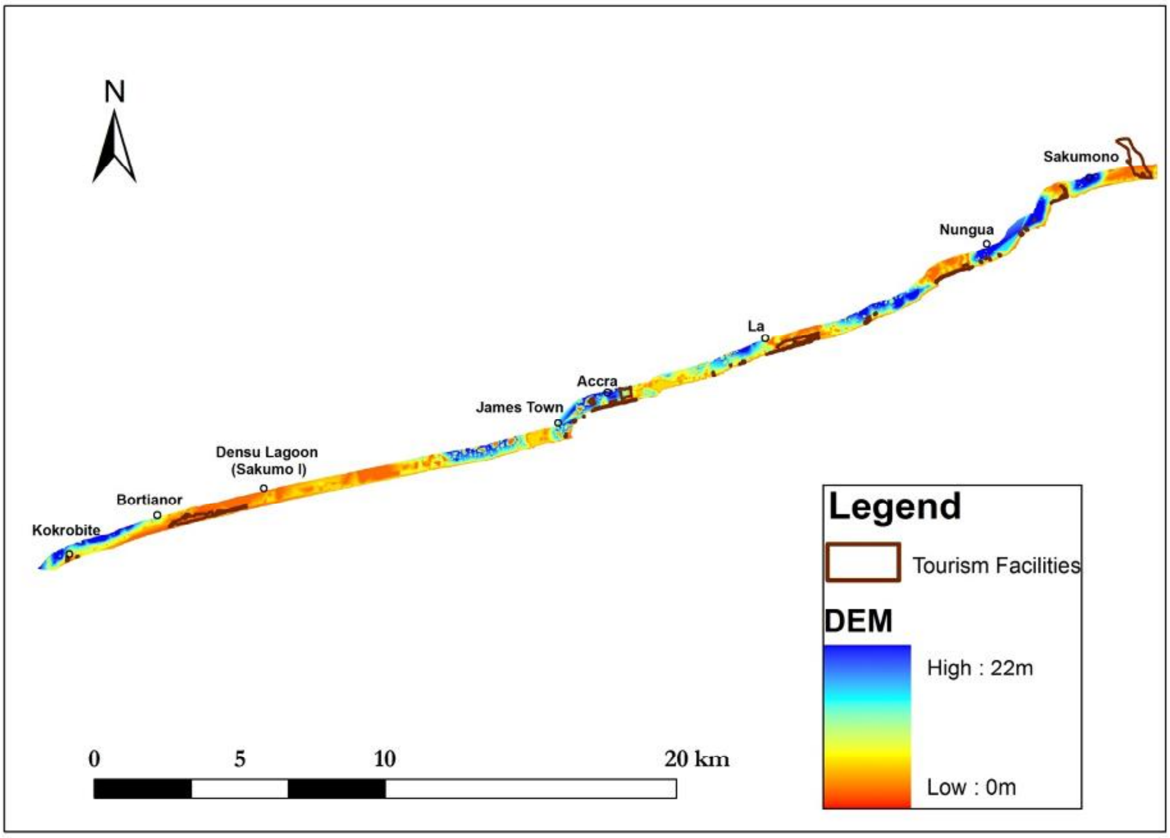


Figure 3. 7: Categorized tourism facilities per elevation class

Tourism facilities displayed on the High elevation (Red and Yellow), Moderate (Light Blue) & Low (Blue) areas of the coast.

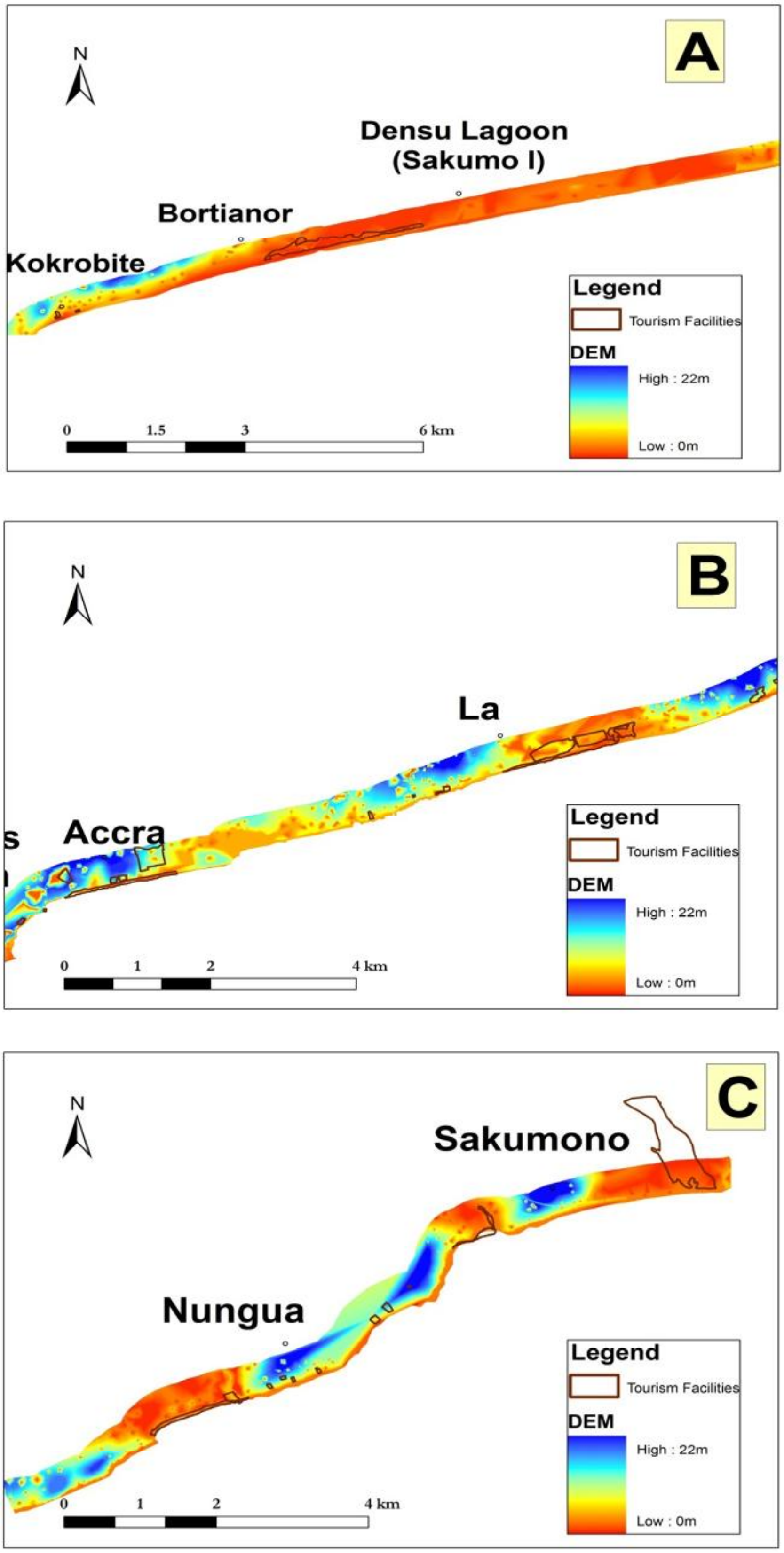


Figure 3. 8: Categorized tourism facilities per elevation class for western, central and eastern zones

A: western zone of the study area; **B:** central zone; and **C**: eastern zone.
Tourism facilities in the High elevation (Red and Yellow), Moderate (Light Blue) and Low (Blue) for different zones.

3.4. Assessment of potential physical and socio-economic impact of ESLR on the different classes of tourism facilities at risk

"Risk Analysis is the use of available information to estimate the risk caused by hazards to individuals or populations, property or the environment, from a hazard. Risk analyses generally contain the following steps: definition of scope, danger (threat) identification, estimation of probability of occurrence to estimate hazard, evaluation of the vulnerability of the element(s) at risk, consequence identification, and risk estimation" (van Westen & Kingma, 2009). The risk for the tourism facilities was analysed semi qualitatively with the formula as referred in the section 1.6.

Risk classes for tourism facilities at risk were developed based on the following:

- *High risk*: Facilities seriously affected or impacted by sea level rise. Facilities are completely inundated and/ or destroyed. Facility cannot be used or not operational for more than 7days.
- *Moderate risk*: Facilities partially affected by the sea level rise. Facilities are partly inundated. Water reaches facility but not completely destroying facilities or items. However facility cannot be used for purpose within 24hours to 7days.
- *Low risk*: Facility is likely to be or not to be affected by sea level. This may be due to erosion or other effects from extreme events.

Generally vulnerability as defined by UNDRO, (1991) is "The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage)" (UNDRO, 1991). *Vulnerability* here is the structural damage/collapse/ destruction to facilities caused by inundation, damage to contents of facilities, loss of employment and income from operations.

Based on the definition of the UNDRO1991 the vulnerable facilities were calculated with the codes for the different physical vulnerability in table 3.14 from equation 3.2.

Degree of Physical vulnerability = elevation + structure type + Nr_floor 3.2

Description of Structure type:

- **Beach** is the sandy part of the coastline where people use for recreation and is highly exposed to the hazard SLR.
- **Hut** is a wooden structure partially enclosed with a concrete floor.
- **Wood** is a wooden or bamboo structure fully enclosed.
- **Concrete** is facility with concrete walls/fence or concrete structure and fully enclosed.

From interview and observation on the field there were no tourism facilities with hut and wood above one floor. Therefore vulnerability for huts and wooden structures above 1 floor was not taken into account. Naturally beaches were considered highly vulnerable to SLR. In view of the above vulnerability was not calculated for beach, and hut and wooden constructions with 2 floors and above.

The semi-quantitative technique was used to express vulnerability. These were numerical values which are merely relative indications ranging between 0 and 2, but do not have a direct meaning of expected losses. Also in this case vulnerability is expressed in a relative sense. The numerical range for the physical vulnerability (Table 3.10) was derived from the aggregate of the codes for structure type and number of floors. Codes were assigned for structure type and number of floors (Table 3.11 & 3.12) with values 2, 1 and representing highly vulnerable, moderately vulnerable and less vulnerable respectively. These codes were assigned subjectively considering the degree of susceptibility for all the tourism facilities per structure types since number of floors is not the same.

The numeric range for which the degree of physical vulnerability was classified as shown in table 3.10 were values derived from summing the value of the codes for structure type and number of floors resulting in Table 3.13. The classes show how much vulnerable a particular facility may be. For example a facility structure type of hut and on a 1 floor will result in a value of 4 (i.e. aggregate of codes for 1 floor (2) and structure hut (2) as shown in table 3.14).

Table 3. 10: Numerical range for which the vulnerability of a facility is high, moderate or low.

Degree of Physical vulnerability	Numerical range
High	>=4
Moderate	2-3
Low	0 to 1

Table 3. 11: Codes for the different physical attributes

Structure Type	Code
Beach	2
Hut	2
Wooden construction	1
Concrete	0

Table 3. 12: Codes for number of floors

Number of Floors	Code
0	2
1	2
2	1
>2	0

Table 3. 13: Physical vulnerability codes

Structure type	Number of floors			
	0	1	2	>2
Hut	4	4	N/A	N/A
Wooden construction	3	3	N/A	N/A
Concrete	2	2	1	0

Table 3. 14: Degree of physical vulnerability for the different attributes

	Physical Vulnerability code	Degree of physical vulnerability
Beach	4	High
Hut	4	High
Wooden construction	3	Moderate
Concrete	0 -1	Low

The degree of vulnerability was classified into high, moderate low because some tourism facilities within the same area will have different susceptibility rate. Table 3.14 shows the degree of physical vulnerability for the different characteristics.

3.4.1. **Potential Physical Impact on tourism facilities at risk**

The potential physical impact on tourism facilities vulnerable to the SLR are highlighted and represented per tourism facility category in tables 3.15, 3.16 and 3.17. The dark grey indicating high physical vulnerability, light grey is moderate physical vulnerability and white low vulnerability.

Out of the total number of tourist facilities at risk, 31% of these facilities are highly physically vulnerable to SLR and 51% moderately vulnerable. Eight (8) of the accommodation facilities are moderately vulnerable and eight (8) less vulnerable to the SLR. Out of the seven (7) food services facilities at risk all are moderately vulnerable. From a total of sixteen tourist attraction facilities made up of beaches, lagoons and mangrove ten (10) of these facilities are highly vulnerable, three (3) moderately vulnerable and the rest (3) less vulnerable.

Table 3. 15: Physical vulnerability of Accommodation facilities: Light grey (moderately vulnerable) and white (less vulnerable)

No.	Name of Facility	Type of Facility	Rating	Structures	Floors	Floor value	Structural value	Vulnerability
1	Ramada Hotel	Accommodation	3 Star	Concrete	1	2	0	2
2	Sobamba Coastal Resort	Accommodation	budget	Concrete	1	2	0	2
3	Ave Maria	Accommodation	1 Star	Concrete	3	0	0	0
4	Labadi Beach Hotel	Accommodation	5 Star	Concrete	2	1	0	1
5	Big Milly Backyard	Accommodation	budget	Concrete	1	2	0	2
6	Flander Beach Resort	Accommodation	budget	Concrete	1	2	0	2
7	New Hotel	Accommodation	budget	Concrete	1	2	0	2
8	La Palm Royal Beach Hotel	Accommodation	4 Star	Concrete	3	0	0	0
9	Next Door	Accommodation	budget	Concrete/hut	1	2	0	2
10	Club 1900 Guest House	Accommodation	budget	Concrete	2	1	0	1
11	Diplomat Beach Hotel	Accommodation	1 Star	Concrete	2	1	0	1
12	African Royal Beach Hotel	Accommodation	2 star	Concrete	3	0	0	0
13	Afia Beach Hotel	Accommodation	1 Star	Concrete	2	1	0	1
14	Beach Cumber	Accommodation	budget	Concrete	1	2	0	2
15	Ocean Sky Hotel	Accommodation	budget	Concrete	3	0	0	0
16	Friends Guest House	Accommodation	budget	Concrete	1	2	0	2

Table 3. 16: Physical vulnerability of Food Services facilities; (moderately vulnerable)

No.	Name of Facility	Type of Facility	Rating	Structures	Floors	Floor value	Structural value	Vulnerability
1	Bojo Beach Resort	Food Service	grade 1	brick	1	2	1	3
2	La Tawala	Food Service	grade 2	Concrete/wood	1	2	0	2
3	Osekan Restaurant	Food Service	grade 2	Concrete	1	2	0	2
4	Harbin	Food Service	grade 2	Concrete	1	2	0	2
5	Bahdoosh Bar	Food Service	grade 3	Concrete	1	2	0	2
6	Boshe Ba beach resort	Food Service	grade 3	wood/bamboo	1	2	1	3
7	Pink House Bar	Food Service	grade 3	Concrete	1	2	0	2

Table 3. 17: Physical vulnerability of Tourist Attraction facilities; Dark grey (highly vulnerable), Light grey (moderately vulnerable) and white (less vulnerable)

No.	Name of Facility	Type of Facility	Structures	Floors	Floor value	Structural value	Vulnerability
1	La Community Beach	Tourist attraction	sandy beach	0	2	2	4
2	Densu Lagoon (Estuary)	Tourist attraction	water	0	2	2	4
3	Kpeshie Lagoon	Tourist attraction	water	0	2	2	4
4	Lagoon (Mighty Beach)	Tourist attraction	water	0	2	2	4
5	Sakumo Lagoon	Tourist attraction	water	0	2	2	4
6	La Pleasure Beach	Tourist attraction	sandy beach	0	2	2	4
7	Accra Beach (behind Independence Square)	Tourist attraction	sandy beach	0	2	2	4
8	Shaba Beach, Nungua	Tourist attraction	sandy beach	0	2	2	4
9	Art Gallery	Tourist attraction	Concrete	2	1	0	1
10	Mighty Beach	Tourist attraction	sandy beach	0	2	2	4
11	Independence Square	Tourist attraction	Concrete	1	2	0	2
12	Lighthouse	Tourist attraction	Concrete	3	0	0	0
13	James Fort	Tourist attraction	Concrete	1	2	0	2
14	Ussher Fort	Tourist attraction	Concrete	2	1	0	1
15	Kwame Nkrumah Mausoleum	Tourist attraction	Concrete	1	2	0	2
16	Kpeshie Mangrove	Tourist attraction	marsh	0	2	2	4

3.4.2. Potential Socio-Economic Impact on tourism facilities at risk

Socio- economic impact was derived by analysing the socio economic attribute data of the potential vulnerable facilities derived in the previous section. The average income that will be lost per hazard scenario and type of facility was calculated and analysed.

The average income for the various facilities was classified with the assumption that the more the income the higher the vulnerability. The vulnerability classes were determined based on data collected from the field and classified as follows:

- **Low vulnerability:** The annual income class ranging GHC 4,000 – GHC 100,000
- **Moderate vulnerability:** The annual income class ranging GHC 100,000 – GHC 1,000,000
- **High vulnerability:** The annual income class above GHC 1,000,000

The numeric values 1, 2, and 3 were assigned to low, medium and high vulnerability respectively as described above and a vulnerability table prepared and mapped (Table 3.18). The average income was the multiplication of the rate by the number of guests expected. This was multiplied by 12 (no. of months in a year) to get annual income. The number of guests expected was derived by multiplying the occupancy rate by the capacity of facility.

Table 3. 18: Economic vulnerability classes and numeric codes

Economic vulnerability	Annual income class range in GHC	Numeric code
High	>1,000,000	3
Moderate	100,000 – 1000,000	2
Low	4,000 – 100,000	1

The average income for beaches was calculated with estimates of capacity of 2000 people and 50% occupancy rate per beach. This occupancy is assumed to be only on holidays. The 13 national holidays for Ghana was employed for the annual income calculation. It was assumed that the beaches are only occupied only on holidays since during this period the beaches are fully occupied and can be quantified. Calculation of the annual income for beaches was the product of the occupancy by the rate (gate fee) ranging between GHC2 and GHC5. The average income value for the beaches was determined and used for the analysis.

To determine socio economic vulnerability the social vulnerability was first determined from the number of employees and classified into semi qualitative form (Table 3.19). Socially Low vulnerability means number of people employed is less than twenty (20), moderate is between 20 and 100 employed and high being above 100 and numeric values 1, 2 and 3 were assigned for calculation purposes. A matrix of economic and social vulnerability was created (Table 3.20) to determine the socio-economic vulnerability and classified as shown in table 3.21. The socio economic vulnerability was given as the product of the semi qualitative value given to the social and economic vulnerability. The susceptibility of facility to both economic and social vulnerability was rated low, moderate and high depending on the amount and number of people that will be lost (Table 3.21).

Table 3. 19: Employment vulnerability classes and numeric codes

Employment vulnerability	Number of Employee Range	Numeric code
High	>100	3
Moderate	20 – 100	2
Low	<20	1

Table 3. 20: Matrix used to determine socio-economic vulnerability.

Economic vulnerability	Employment vulnerability	Low	Moderate	High
	×	1	2	3
Low	1	1	2	3
Moderate	2	2	4	6
High	3	3	6	9

Table 3. 21: Socio economic vulnerability classes

Socio-economic vulnerability	Numeric range
Low	0-1
Moderate	2-4
High	6-9

Accommodation:

The economic vulnerability for accommodation only relates to income gained per current occupancy rate. This did not include other gains from other sources of income by the accommodation facilities. The analysis showed (Tables 3.22) that four accommodation facilities are highly economically vulnerable to SLR of a total amount of GHC 34,913,424.00 for each year of hazard. Moderately vulnerable facilities will lose an amount of GHC 557,760.00 and the less vulnerable accommodation facilities an amount of GHC 232,008.00 to the SLR hazard. Appendix 4 image A & B displays some of the accommodation facilities economically vulnerable. In total the tourism industry will lose approximately GHC 35,703,192.00 from direct income accrued by the accommodation facilities from guests when such a hazard occurs. Number of guests that will be lost per day is approximately 404 and may increase to 1,616 guest loss within a month. Socio-economically, four (4) out of the 11 facilities are highly vulnerable, 3 are moderately vulnerable and 4 has low vulnerability. A total of over 400 employees and about GHC 34,913,424 will be lost to facilities that are highly vulnerable.

Food Services:

The food services assessed showed high economic vulnerability to any SLR as shown in table 3.23 and would lose an amount of GHC 5,443,200.00 and moderately vulnerable socially, rendering 100 people unemployed for the period of the hazard. Socio economically the food services would be moderately vulnerable since the number of employees for most of such facilities is not many (Appendix 3).

Tourist Facilities:

Table 3.24 shows the seven (7) tourist attractions which have low social vulnerability in terms of the number of employees to lose jobs. One of these facilities had high economic vulnerability with GHC 4,858,560.00 and the other 6 had low economic vulnerability which included five beaches which will lose a total of GHC 231, 532.00 per year and depicted by maps in Appendix 4C. Averagely 2000 visitors will be lost per beach per holiday. The socio-economic vulnerability for tourist attractions is mostly low shown in the table (Appendix 2) and maps (Appendix 5C). This is due to the fact that most of these facilities assessed are beaches though important facilities are not economically valued and this was estimated using only 13 public holidays. Lagoons and mangroves were not assessed for socio- economic vulnerability. These facilities which are mostly natural provide a wide range of social and economic value to the communities, visitors and other industries which are not yet well quantified thus the less value. Socio-economic vulnerability could be high if tourist attractions are properly valued.

Table 3. 22: Economic vulnerability for Accommodation facilities in grey scale ranging from dark scale as the high vulnerability.

Name of Facility	Type of Facility	Grade	Occupancy Rate	No. of Rooms	Rates GH¢	No. of Guests	Income/Day	Ave. Monthly Income	Ave Annual Income	Insured	Vulnerability
Friends Guest House	Accommodation	budget	0.15	18	30	2.7	81	2268	27216	No	1
Club 1900 Guest House	Accommodation	budget	0.4	5	60	2	120	3360	40320	No	1
Next Door	Accommodation	budget	0.7	11	25	7.7	192.5	5390	64680	No	1
Beach Cumber	Accommodation	budget	0.99	10	30	9.9	297	8316	99792	No	1
Ocean Sky Hotel	Accommodation	budget	0.4	11	80	4.4	352	9856	118272	Yes	2
Diplomat Beach hotel	Accommodation	1 star	0.1	24	200	2.4	480	13440	161280	Yes	2
Big Milly Backyard	Accommodation	budget	0.6	46	30	27.6	828	23184	278208	Yes	2
Afia Beach Hotel	Accommodation	1 star	0.9	80	101.25	72	7290	204120	2449440	Yes	3
Ramada Hotel	Accommodation	3 star	0.42	140	172.5	58.8	10143	284004	3408048	Yes	3
Labadi Beach Hotel	Accommodation	5 star	0.9	104	375	93.6	35100	982800	11793600	No	3
La Palm Royal Beach Hotel	Accommodation	4 star	0.8	152	422.5	121.6	51376	1438528	17262336	Yes	3

Less Vulnerable
Moderately Vulnerable
Highly Vulnerable

Table 3. 23: Economic vulnerability for Food Services facilities in grey scale ranging from dark scale as the high vulnerability.

Name of Facility	Type of Facility	Grade	Occupancy Rate	Capacity	Rates GH¢	No. of Guests	Income/ Day	Ave. Monthly Income	Ave. Annual Income	Insured	Vulnerability
La Tawala	Food Service	grade 2	0.6	2000	3.5	1200	4200	117600	1411200	Yes	3
Bojo Beach Resort	Food Service	grade 1	0.4	6000	5	2400	12000	336000	4032000	Yes	3

Less Vulnerable
Moderately Vulnerable
Highly Vulnerable

Table 3. 24: Economic vulnerability for Tourist Attractions in grey scale ranging from dark scale as the high vulnerability.

Name Of Facility	**Type Of Facility**	**Grade**	**Occupancy Rate**	**Capacity**	**Rates GH¢**	**No. of Guests**	**Income/ day**	**Ave Monthly Income**	**Ave Annual Income**	**Insured**	**Vulnerability**
Accra Beach (behind Independence Square)	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	No	1
La Communal Beach	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	No	1
La Pleasure Beach	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	No	1
Mighty Beach	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	No	1
Shaba Beach, Nungua	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	No	1
Ussher Fort	Tourist Attraction	attraction	0.4	20	1.5	8	12	336	4032	No	1
Art Gallery	Tourist Attraction	attraction	0.3	800	60.25	240	14460	404880	4858560	No	3

Less Vulnerable
Moderately Vulnerable
Highly Vulnerable

3.4.3. Awareness

Accommodation facilities are the dominant tourism facilities along the coast. Out of the facilities management interviewed 72% were accommodation facilities and 28% for food services and other facilities made up 28%. Quite an appreciable number of operators of tourism facilities had some kind of awareness on sea level rise. 64% of the respondents had knowledge about sea level rise and climate change whiles about 29% of these operators knew nothing about sea level rise or climate change. Though small this cannot be ignored. About 7% of the operators along the coast had the view that there was no sea level rise. Some of these tourism facilities like la Tawala restaurant and Beach Comber had gained some beach front indicating the sea had rather retreated at these parts.

3.4.4. Measures against Sea Invasion

Most of the tourism facilities along the coast of Accra according to the study are at risk within an average height of about 3 m and a distance of 200m. Most of the structures of the facilities are built on cliffs or a little away from the shoreline as precautions. However, though the terrain is cliffy, the Accraian formation of the area threatens the invulnerability of the facilities to sea level rise impacts. Some of these facilities had provided measures (43%) against the hazard from the sea (Figure 3.9) including sea defence (rocks), retaining walls, with some using materials such as car tyres to protect their facility from the anger of the sea especially during high tides. However, over 50% of the tourism facilities interviewed had no measures and plans for protection.

Figure 3. 9: Some measures to protect facilities from hazard

4. DISCUSSION

4.1. Sea level Trend over the past thirty (30) years

The study predicted an average sea level rise rate of 3.34 mm/yr. based on the historic MSL data. The predicted rate of 3.34 mm/yr is higher than other predictions (IPCC, 2007a; Appeaning Addo *et al.*, 2008). Appeaning Addo *et al.*, (2008), reported a rate of 2.23mm/year using a normal rate formula. Though the rate of sea level rise from the regression is comparatively higher than that reported by Appeaning Addo, *et al.,* (2008), the model accounts for the 19 years cycle which represents a lunar cycle that could directly influence tidal movement.

Future predictions from the model may differ from actual by 2% which is acceptable and accounting for extreme events that may have occurred. However tidal data over the past four years reveals that the sea level has risen at an average rate of 13cm. A wide difference occurred between the predicted tidal data and the data collected for the years 2006 to 2009. The effect of subsidence at the point where the local mean sea level has been marked will push the mark downward causing the sea water levels to increase. For instance the high water measurements at Takoradi from 2006 to 2009 could be as a result of subsidence in the area. The reported cases of submergence of properties along the coast of western region of Ghana could be a contributing factor to these differences. The sea levels could be affected by the rippling effect of tsunami and earthquakes from other regions. An example is the devastating 26 December 2004 tsunami which occurred in the Indian Ocean resulting in an immediate effect of lowering the sea level of about 15cm on the coast of Ghana (Joseph *et al.*, 2006).

The rate of shoreline change was based on 1974 – 2005 historic data as used by other researchers (Morton *et al.*, 2004; Crowell *et al.,* 1991; Dolan *et al.,* 1992). The rate of change was found to an average of 0.86m/yr. This means that the coast of Accra is eroding at an average rate of 0.86m per year since 1974. The rate of erosion is relatively lower than 1.13m/yr and 3m/yr that were reported by Appeaning Addo *et al.,* (2008) and EPA Ghana (Environmental Protection Agency 2010a) respectively for the coast of Ghana. This may be due to the fact that expected/ predicted erosion at beaches outside the study area may be significantly higher. In any case, erosion of the coast of Accra is crucial to tourism facilities, development and management. The beach width would reduce by averagely 8.6m by 2020 from 2010. This might not be the same for all areas along the coast of Accra. Severe erosion might erupt at La pleasure beach, and Dansoman given the extreme events that might result due to temperature increases and effect of global warming (Lloyd, 2009; Environmental Protection Agency 2010a).

4.2. Mapping potential impact of sea level rise along the coast of Accra

The coast of Accra is at risk to sea level rise. Mapping the potential impact of sea level rise indicated that the Accra shoreline would probably retreat approximately 90m and 109m for the scenarios B2, and A2 respectively by the year 2100 unless Ghana embarks on a more environmentally friendly mitigation practices that will reduce the effect of anthropogenic activities. The coastal zone will shrink as mentioned by Schleupner (2008) with the B2 scenario reducing up to 90m. Approximately 13m of beach width will be lost to a sea level rise of 5cm from the A2 and B2 scenarios and 10m from Ghana scenario by the year 2020 with the base year 1990. Accra coast is at an increasing risk and may experience significant damage due to anticipated extreme events from global warming. Storm surges, erosion and inundation may disturb the coastal ecosystem such as lagoons, mangroves and fisheries (McLean and Mimura 1993; Nicholls and Mimura 1998, Appeaning Addo *et al.*, 2008).

The coast of Accra will encounter land loss of about 12m to 109m inland with predicted SLR between 5cm - 42cm which conforms to the fact that for any rise in sea levels may result in land loss 50 to 200 times the rise. The high rate of erosion at certain parts of Accra coast and the Accraian cliff formation type makes it more alarming and crucial for coastal zone management organizations in the country to investigate. Coastal Zone Management is not well developed in Ghana yet the predictions of impacts on the coastal areas will help policy makers during considerations for adaptation plans in the future. More importantly, there are many more industrial infrastructures and tourism potential along the coast which has high socio-economic values that need to be protected from the effect of the sea.

4.3. Identification and classification of the tourism facilities at risk.

Within the coastal extent of 500 m from the shoreline a total of 39 tourism facilities were identified and geographically located. The GIS method used could be applied for further identification of tourism facilities across the country to improve upon the database on tourism. Out of the tourism facilities identified 64% were found to be located within the elevation class less than 5m above MSL are at high risk to inundation from sea level rises.

4.4. Assessment of potential physical and socio-economic impact of ESLR on the different classes of tourism facilities at risk

Vulnerability was not calculated for beach, and hut and wooden constructions with 2 floors and above because there were no tourism facilities with hut and wood above 1 floor from the interviews and field observations.

Out of the total number of tourist facilities at risk, 31% of these facilities cannot physically withstand the event of sea level rise hazard. Physical analysis of vulnerability of accommodation facilities showed that 50% of the facilities are highly or moderately vulnerable to sea level rise. This is in conformity with the findings from the field that over 50% of the tourism facilities interviewed had no measures and plans for protections and or mitigation/adaptation. This is because tourism operators have limited level of awareness on climate change and consequences of sea level rise to their facilities. The development of awareness programmes for facility operators to cover environmental and climate change concerns will improve adaptation and or mitigation strategies which will to an extent reduce the exposure of tourism facilities to sea level rises and other infrastructure like roads which have high social implications. The destruction of tourism facilities especially will pose some threat to jobs and sources of livelihood considering the number of people employed by these facilities. Furthermore, beaches, lagoons and mangrove are highly vulnerable. This is because the beaches are low terrain and prone to SLR, beaches like La Pleasure Beach are highly vulnerable since it has many informal structures. In total the tourism industry will lose approximately GHC 35,703,192.00 per year from direct income gained from only guest occupancy by the accommodation facilities. This may reduce the current contribution of 43% as per the Greater Accra region quota to GDP by accommodation facilities (Tourism development Project 2009). Most tourist attractions had low socio-economic vulnerability (Appendix 2) because important facilities such as the Ramsar sites, beaches have not been economically valued and or there no documented values available for quantification. However, their environmental and socio-economic contributions/importance cannot be ignored.

A rather simplified method was used to determine the socio–economic vulnerability for the tourism facilities due to limited availability of information and time. There are many other complex ways of determining socio economic vulnerability of tourism (Heins 2009) that could be used to determine susceptibility of tourism facilities along the coast of Accra and Ghana.

4.4.1. Tourism facilities

Sixty percent (60%) of tourism facilities identified along the coast are hotels. These include a five star hotel and many others with beautiful serene atmosphere of the sea front. In addition a number of on-going hotel development projects were sighted during the fieldwork. For the coast of Ghana and its tourism activities, not only are erosion and inundation the only impacts on tourism but also the dumping of heaps of rubbish from the sea unto the coast during high tides. Tourism facilities are not only at risk to sea level rise but also salinization and sanitation problems along the coast. Interestingly the most common concern of tourism operators of the effect of sea level rise is the rubbish produced so close to their facilities and salinization. This conforms to the findings that sea level rises could cause salinization in the coastal areas (Gornitz 1991, 2000a & 2000b). The effect of increased salinity on tourism facilities in the past years is of a major concern to proprietors. Most items in these facilities need to be changed frequently increasing operational cost and thus maintenance of standards.

4.4.2. Mitigation strategies

From the interviews conducted, most of the policy organizations related to tourism and the coastal zone management of Ghana do not have clear policies to deal with issues concerning rising sea levels although coastal management. Policy makers concentrate on their core interest along the coast but ignore the effect of rising sea levels. For instance the Ministry of Tourism and Ghana Tourist Board are more interested in the potential opportunities that are along the coast and nuisance like the dumping of refuse and defecation along the coast, whilst the Ghana Navy is mostly interested in sea levels for docking and in the protection of the coast against intruders and terrorists. However in the advent of climate change many of such Ministries, Departments and Agencies (MDAs) have had several meetings to help find mitigation strategies. The Environmental Protection Agency (EPA) has made some predictions of sea level rise for Ghana to help interested parties develop mitigation strategies.

Most tourism facilities along the coast see the rising sea to be a natural phenomenon and do not have measures to adapt or mitigate the effect. Others have waited for interventions from government agencies to no avail. Some have gone further to provide some kind of sea defence such as rocks or stones, car tyres, plants and walls all to protect the facilities while other facilities watch unconcerned.

4.5. Factors that May Indirectly Influence the Impact of the SLR

Sea level rise in the recent years has been attributed to global warming (Bruun, 1991; Rahmstorf, *et al.,* 2007). However there are many other activities both geological and anthropogenic that may cause the sea to rise and have adverse effect on the communities and businesses along the coast (Warrick, *et al.,* 1996; IPCC, 2001). Erosion, strong winds and weather patterns, storm surges due to sea level rise and subsidence are all contributors to great impact on the coast. Tectonic activities along the coast are likely to cause subsidence in these areas making the water levels to rise and thus the shoreline to move landwards (Blundell & Banson, 1975; Juner, 1941).

Tectonic activities such as earthquakes and tremors have been recorded on the coast of Accra (Blundell & Banson, 1975; Juner, 1941) and may have some effect on the shore and thus the movement of the shoreline inland. Tidal measurements in Ghana recorded only from Takoradi is not adequate for proper studies on monitoring the entire shoreline, as the point of measurement is hundreds of kilometres away from the eastern shores of Ghana.

Geomorphologies vary along the coast and will have impact on the shoreline (Appeaning Addo, *et al.,* 2008). Accra is hundreds of kilometre away from Takoradi and with the evidence of tectonic event along its coast may need closer monitoring for increased the sea levels. The likelihood of subsidence along the coast of Accra must be further investigated. This is evident in the farther easting section of the country's coast in Ada of the Greater Accra region and Keta in the Volta region where some beaches, properties and prominent facilities have been taken away by the waves of the shore. An example is the Danish fort Prinzenstein of Keta which was partially destroyed by the sea since 1980s (Figure 4.1) and is now being restored with the construction of a sea defence.

Figure 4. 1: Fort Prinzenstein of Keta destroyed by the sea from the 1980s
(Picture source: www.torgbuijames-ocloo.org)

There has been no report on storm surges along the coast of Ghana; however severe storms could arise from sea level rise due to the supposed global warming on the coast. Records indicate some evidence of floods at Dansoman in the western zone of the study area which might be due to storms (Lloyd, 2009). Strong winds and weather patterns from seismic activities may affect the tides and may result in more devastating events. High rate erosion due to sea level rise will have a great impact on tourism facilities that virtually share a "wall" with the sea along the Accra coast. Facilities such as Ave Maria, Next Door beach Hotel, Osekan Restaurant and Ussher Fort which when viewed from afar are on cliffs or high lands are yet threatened by the sea and its waves and could be damaged due to erosion since they virtually share a boundary. There is already evidence of erosion against these facilities and the coast. If nothing is done to protect the coast and tourism facilities where most of Ghana's historical heritage which draws thousands of tourists around the world are found then the industry might collapse in the end.

Anthropogenic activities will also cause the sea level to rise. Human activities such as sand and stone weaning along the coast may cause sea levels to rise. Other activities such as dredging of wells inland will increase sea levels. With the rapid development and expansion of Accra and the limitation of the water company to provide adequate water for all in Accra it has become important that most houses especially new private buildings to dig wells to supplement for any water shortage. The continuous increase of well dredging will increase sea levels and thus more damage to coastal residence and business facilities.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The following are the conclusion reached:

The average sea level rise over the past thirty years is 3.3mm/yr. The beach width of the coast of Accra is eroding at a rate of 0.86m per year.

Ghana's predictions compared to A2 and B2 scenarios showed that SLR for B2 and Ghana scenario by 2100 seem to be closer with a difference of approximately 1cm though Ghana scenarios give relatively high values.

For A2 and B2 scenarios, Accra coast will reduce by 12.9m and 51.5m for 2020 and 2060 respectively. By 2100 a distance of 90.1m and 109.4m will be lost by the B2 and A2 scenarios respectively.

Accommodation facilities, food services and tourist attractions which included beaches, lagoons and monuments were the tourism facilities identified along the coast of Accra and could be impacted by SLR and coastal erosion. Facilities at risk include Labadi Pleasure Beach, Bojo Beach Resort, Next Door Hotel, Osekan Restaurant and Usher Fort. These facilities were mapped based on elevation classes.

Beaches and lagoons are highly susceptible to sea level rise. It is estimated that beaches will lose an average of GHC 227,500 annually and 2000 visitors per beach facility per holiday.

Accommodation facilities had high socio-economical vulnerability which may render over 400 people unemployed and lose approximately GHC 35,703,192.00 per year from direct income gained from only guest occupancy by accommodation facilities.

5.2. Recommendation

- Awareness creation is required to sensitize tourism operators on climate change and its related consequences.
- A more complex and detailed determination of socio-economic vulnerability for tourism facilities could be adopted for a more comprehensive result for the tourism industry
- There is the need for the Ghana government to ensure that Integrated Coastal Zone Management is mainstreamed into policies for sustainable development of the coastal zone.
- More efforts must be put in coastal zones vulnerability assessment to safeguard the industries and lives along the coast since IPCC confirms that global warming will be extreme in Africa during the 21st century increasing mean sea surface temperatures.

5.3. Limitations

- Limited data availability
- Limited access to data and documentation
- Climatic conditions were not considered in the SLR predictions.

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APPENDICES

Appendix 1: Socio- Economic Vulnerability for Accommodation

Name of Facility	Type Of Facility	Grade	Occupancy Rate	No of Rooms	Rates GH¢	No. Guests	Income/Day	Ave Monthly Income	Ave Annual Income	Insured	No. employed	Vulnerability	Vulnerability Employment	Socio-Economic
Friends Guest House	Accommodation	budget	0.15	18	30	2.7	81	2268	27216	N	20	1	1	1
Club 1900 Guest House	Accommodation	budget	0.4	5	60	2	120	3360	40320	N	20	1	1	1
Next Door	Accommodation	budget	0.7	11	25	7.7	192.5	5390	64680	N	20	1	1	1
Beach Cumber	Accommodation	budget	0.99	10	30	9.9	297	8316	99792	N	20	1	1	1
Ocean Sky Hotel	Accommodation	budget	0.4	11	80	4.4	352	9856	118272	Y	20	2	1	2
Diplomat Beach Hotel	Accommodation	1 star	0.1	24	200	2.4	480	13440	161280	y	20	2	1	2
Big Milly Backyard	Accommodation	budget	0.6	46	30	27.6	828	23184	278208	y	50	2	2	4
Afia Beach Hotel	Accommodation	1 star	0.9	80	101.25	72	7290	204120	2449440	y	100	3	3	9
Ramada Hotel	Accommodation	3 star	0.42	140	172.5	58.8	10143	284004	3408048	Y	100	3	3	9
Labadi Beach Hotel	Accommodation	5 star	0.9	104	375	93.6	35100	982800	11793600	N	100	3	3	9
La Palm Royal Beach Hotel	Accommodation	4 star	0.8	152	422.5	121.6	51376	1438528	17262336	y	100	3	3	9

Less Vulnerable
Moderately Vulnerable
Highly Vulnerable

Appendix 2: Socio- Economic Vulnerability for Tourist Attractions

Name of Facility	Type of Facility	Grade	Occupancy Rate	Capacity	Rates GH¢	No. of Guests	Income	Ave Monthly Income	Ave Annual Income	Vulnerability	Insured	No. Employed	Vulnerability Employment	Socio-Economic
Accra Beach behind Independence Square	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	1	N	0	1	1
Communal Beach La	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	1	N	0	1	1
La Pleasure Beach	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	1	N	0	1	1
Mighty Beach	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	1	N	0	1	1
Shaba Beach Nungua	Tourist Attraction	beach	0.5	2000	3.5	1000	3500	0	45500	1	N	0	1	1
Ussher Fort	Tourist Attraction	attraction	0.4	20	1.5	8	12	336	4032	1	N	20	1	1
Art Gallery	Tourist Attraction	attraction	0.3	800	60.25	240	14460	404880	4858560	3	N	20	1	3

Less Vulnerable
Moderately Vulnerable
Highly Vulnerable

Appendix 3: Socio- Economic Vulnerability for Food Services facilities

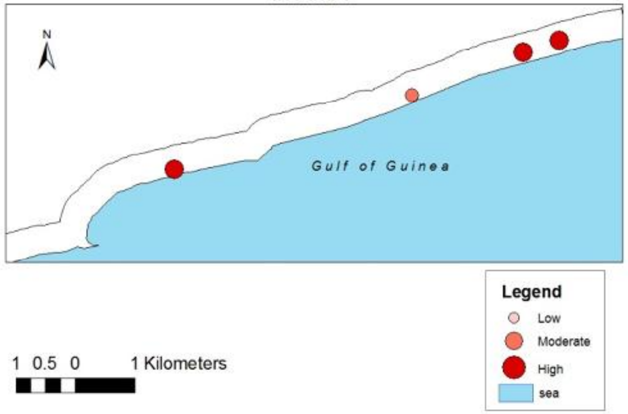
Name of Facility	Type of Facility	grade	Occupancy Rate	Capacity	Rates GH¢	No. of guests	Income	Avg. Monthly Income	Avg. Annual Income	Vulnerability	Insured	No. employed	Employment Vulnerability	Socio-economic
La Tawala	Food Service	grade 2	0.6	2000	3.5	1200	4200	117600	1411200	3	Yes	50	2	6
Bojo Beach Resort	Food Service	grade 1	0.4	6000	5	2400	12000	336000	4032000	3	Yes	50	2	6

Less Vulnerable
Moderately Vulnerable
Highly Vulnerable

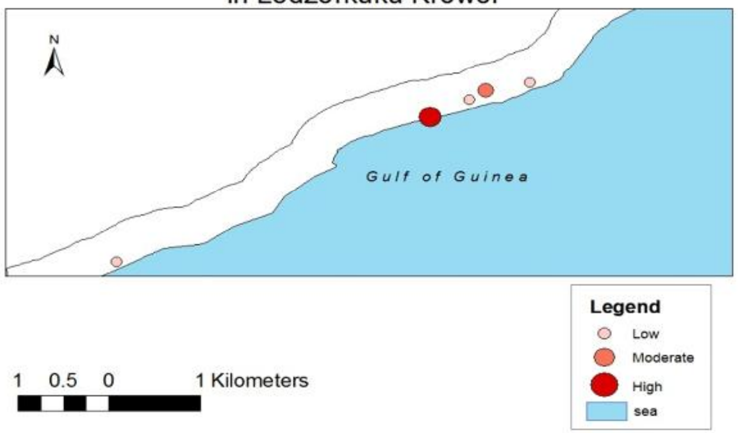
Appendix 4: Economic vulnerability maps

A and B showing the vulnerability for accommodation facilities in AMA and Ledzorkuku Krowor respectively; map C shows the vulnerability of tourist attractions for AMA

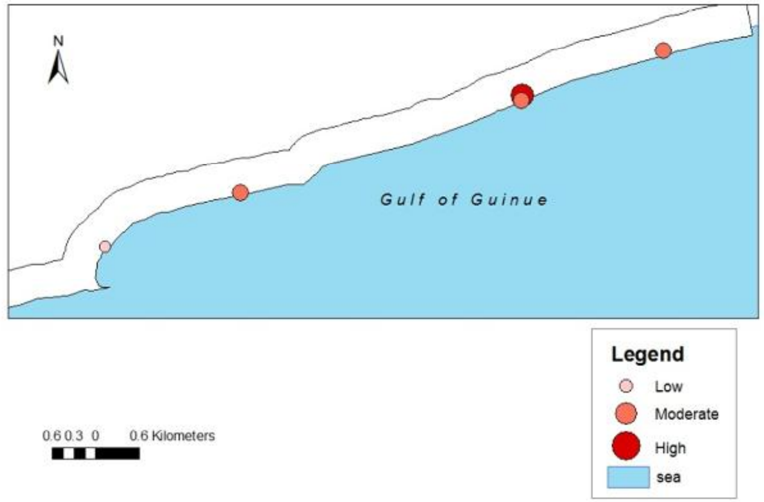
A Economic Vulnerability of Accommodation Facilities in AMA



B Economic Vulnerability of Accommodation Facilities in Ledzorkuku Krowor



C Economic Vulnerability for Tourist Attractions in the AMA



Appendix 5: Socio economic vulnerability maps

A and B showing the vulnerability for accommodation facilities in AMA and Ledzorkuku Krowor respectively; map C shows the vulnerability of tourist attractions for AMA