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Effect of predicted sea level rise on tourism facilities along Ghana's Accra coast

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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 paper 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 orthophotos and topographic maps, and vulnerability for tourism facilities estimated. Mean sea level measurements indicated an average rise of 3.3 mm/year, while the shoreline eroded by as much as 0.86 m/year. Predictions for Ghana showed 10 cm, 23.4 cm and 36.4 cm 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 · Vulnerability · Coast of Accra · Tourism facilities · Coastal erosion

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Introduction

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 and 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; Appeaning Addo et al. 2008). Most of these tourism facilities are located along the coasts and are thus vulnerable to sea level rises (McLeman and Smit 2004). Risk assessment of enhanced sea level rise (ESLR) 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.

Studies have shown that Ghana's shore experience a significant wave height of about 1.2 m, with relatively long wave periods between 10 s and 15 s and tidal range of 0.6 m and 1.3 m (AESC 1988; Appeaning Addo et al. 2008). Though, the Accra local sea level, rises in conformity with the historic global trend of 2 mm/year., this is expected to increase to approximately 6 mm/year. in the 21 century (Appeaning Addo et al. 2008; IPCC 2007a). The shoreline of Accra has shown a mean erosion rate of 1.13 m/year. 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. 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 200 m 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 90 m recommended by the Ghana Water Resources Commission (WRC 2008) and within 200 m from the shoreline. Hence the importance to undertake a study on the effect of sea level rises on tourism facilities along the coast of Ghana.

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 this study. The SLR for the A2 which is more economically fragmented and the B2 scenario more environmentally inclined of which every economy and country would like to attain were used to model the effect on tourism facilities along the coast of Accra (IPCC-TGICA 2007).

Study area

The study area is within the coastal zone of Greater Accra Region of Ghana. Ghana has a total length of about 550 km 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 (Fig. 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 48 km 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. 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

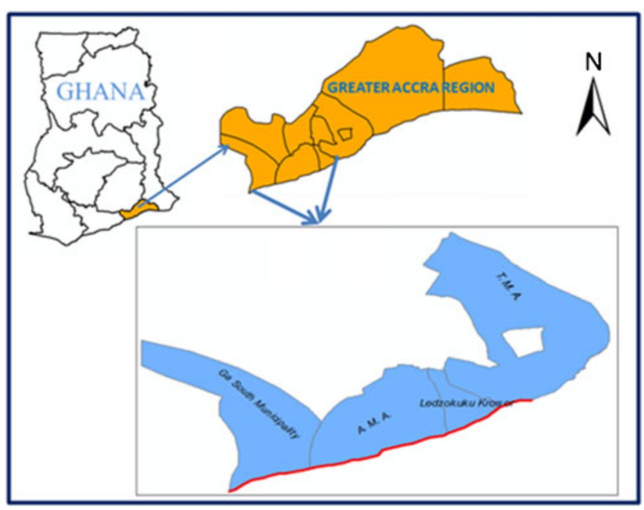

Fig. 1 Study Area: Coast of Accra (in Red) covering four Districts in Greater Accra Region

tourism facilities sited along the coast. Forts, lighthouse, museums, hotels, restaurants and active beaches are all in this area and contribute both socially and economically 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. 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- 14.4 km from Jamestown to Teshie; predominantly coarse sand with moderate slope and exposed rocks in low to moderate slope and (3) Eastern- 14.6 km from Teshie to Sakumo lagoon; coarse sand and rocky between Nungua and Sakumoanya (Sakumono).

Tectonic activities along the coast of Accra

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 in Togo, a neighbouring country, experiencing a trough tidal wave (Blundell and 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 and Banson 1975). Tectonic activities may cause land displacement resulting in adverse effect on tourism facilities along the coast.

Methodology

In general the following methods (Fig. 2) were used to achieve the objectives of the study: analysing the trend of past Mean Sea Level (MSL) data; delineating the shoreline using orthophotos 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.

Data sources

Data collection was done based on the three geomorphic zones (Appeaning Addo et al. 2008). Within each geomorphic zone a five (5) kilometre 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 study.

Year 2005 ortho photographs for the study area were obtained from the Ghana Survey Department for the delineation of shoreline and Google images were used to identify tourism facilities along the coast. Topographic maps and mean tidal data from the Takoradi tide gauge from 1930 to 1994 were obtained from the Ghana Survey Department that enabled analysis of 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 that facilitated determining the types and number of tourism facilities within the study area. 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 orthophoto 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.

Analysing the 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 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 the Takoradi harbour 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. The output of the analysis was used to determine the sea level rise for the past 30 years.

Predicted IPCC scenarios

Estimates of SLR from the IPCC predicted SLR graph (Union of Concerned Scientists 2010) for the years 2020, 2060, 2100 for scenarios A2 and B2 as shown in Table 1 were used for hazard assessment. Ghana SLR scenarios

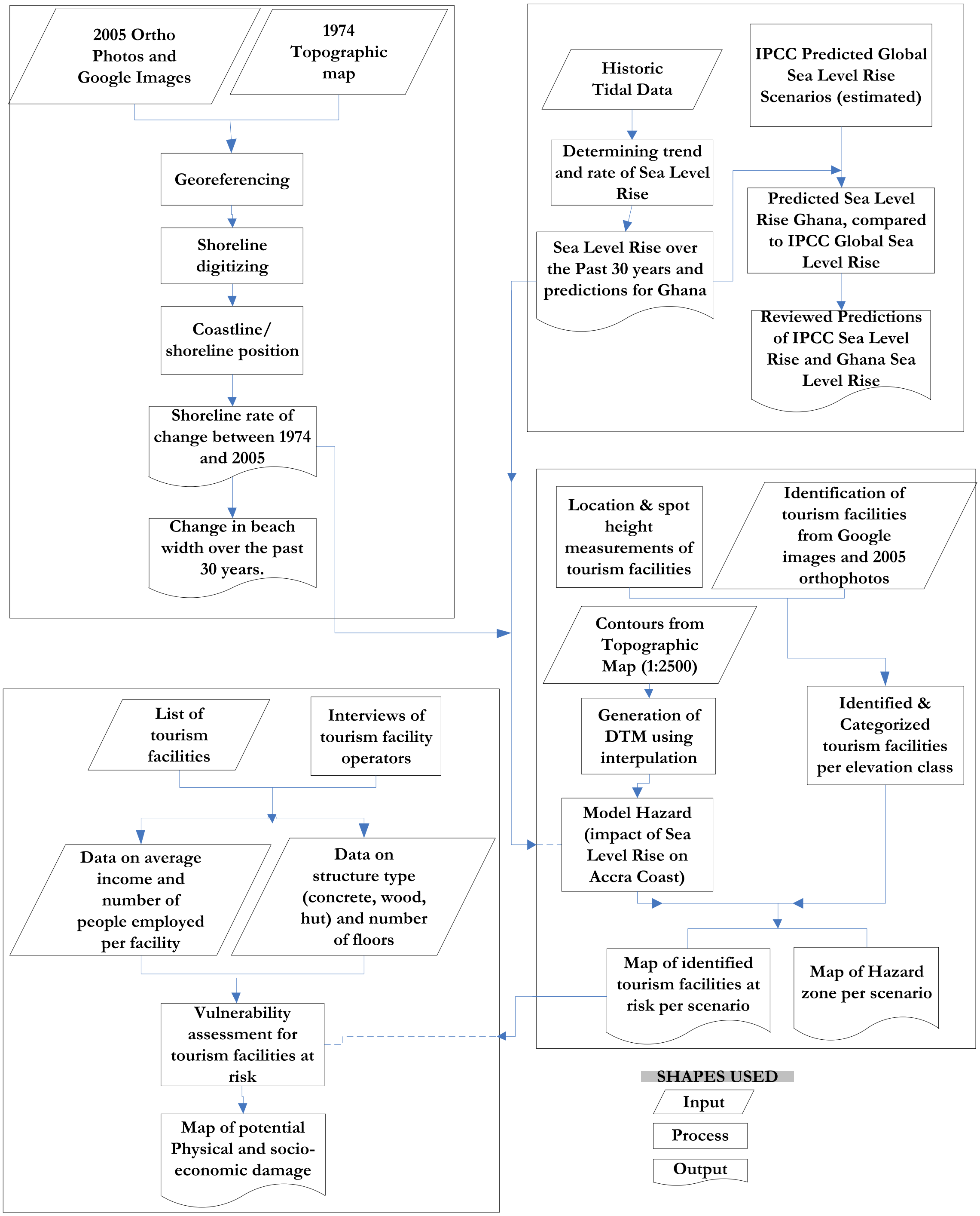

Fig. 2 Methodological flowchart

(GH) were predictions based on the linear trend and extrapolated for the years 2020, 2060 and 2100 after which the SLR was determined as shown in Table 1.

Calculation of shoreline rates of change

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 orthophotogrammetry and topographic maps (Ryu et al. 2002; Fenster et al. 1993; Fletcher et al. 2003). Historic shorelines positions were digitized from digital orthophotos (Fletcher et al. 2003; National Academy of Sciences 1990; Moore 2000) and topographic maps. Selected 2005 orthophotos, Google images and 1:2500 topographic maps were used to determine the shoreline position for the area. The

Table 1 Predicted IPCC Sea Level Rise (SLR) and Ghana Sea Level Rise Scenarios (Base year 1990)

	Enhanced Sea Level Rise (ESLR) (cm)		
Year	A2	B2	GH
2020	5	5	10.0
2060	20	20	23.4
2100	42.5	35	36.7

high water mark was used to define the shoreline position (Pajak and Leatherman 2002)—determined from the image visually and the shoreline digitized accordingly. The shorelines from 1974 topographic map and 2005 orthophotos were used to determine change in coastline (beach width and area) over the past 30 years due to sea levels. Shoreline positions could be influenced by the tide at the time of acquisition of orthophotos and the visualization and determination of the High Water Mark. The orthophotos were georectified before use; however errors due to tidal fluctuations were not accounted. These errors were not calculated since the acquisition of the orthophotos was regardless of tidal cycle.

A variety of methods could be employed for the calculation of shoreline rate of change from historic shorelines. 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, two shoreline position data for this study, the End-Point-Rate (EPR) of change method computation which is flexible and requires only two shorelines for the calculation of the shoreline rate was applied in the study. A baseline was created perpendicular to the 1974 and 2005 shorelines and transects casted (Dolan et al. 1991; Crowell et al. 1997; Thieler et al. 2005, Appeaning Addo et al. 2008; Thieler et al. 2009; Maiti and Bhattacharya 2009) from the baseline across the shorelines at equal intervals of 100m. A relatively small transect interval of 100 m was selected since studies by Doukakis (2004), identified that transect spacing below 100 m does not result in improved estimates of shoreline change rate. The result, shoreline rate of change was used to determine the change in beach width over the past 30 years.

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 orthophotos. 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.

Physical and socio-economic impact

Hazard zone

Inundation maps were created using DEM generated from contours and sea level scenarios. A TIN was generated from contour map (spot heights) with 2 m intervals 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 DEM with the different IPCC and Ghana scenarios of SLR 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 produced for the different scenarios using Eq. 3.1 to model the hazard zone.

$$Y = \frac{X}{X_r} \times S_r \tag{3.1}$$

where:

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

The model 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.

Elements at risk

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 (tourism facilities at risk). The Eq. 3.2 was used to determine the facilities at risk and those with negative values were classified as facilities at risk and mapped using ArcGIS.

$$E@R = Elev - (SL + SLR) \quad (3.2)$$

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)

Potential vulnerability maps

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. 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.

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. Purposive sampling methods and structured questionnaires were used for the collection of interview data which were coded in excel and interpreted. Informal interviews and personal observations were also applied.

Results

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

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 (Fig. 3). 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 (40 years) to analyse sea level trends. Figures 3 and 4 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.

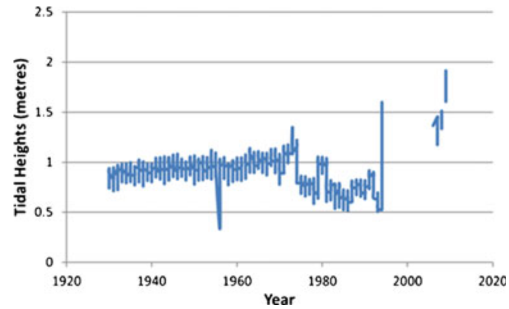

Fig. 3 Monthly mean tidal heights at Takoradi

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 40 years (1930–1969) data used, indicated an average rate of sea level rise per year of 3.34 mm 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 %. The graph Fig. 4 shows an incresing trend from 1931 up to 1955, after which there was a dip up to 1960 and then an increase.

Figure 5 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 1 m and 1.15 m with an average of 1.09 m and sea level rise of 10 cm.

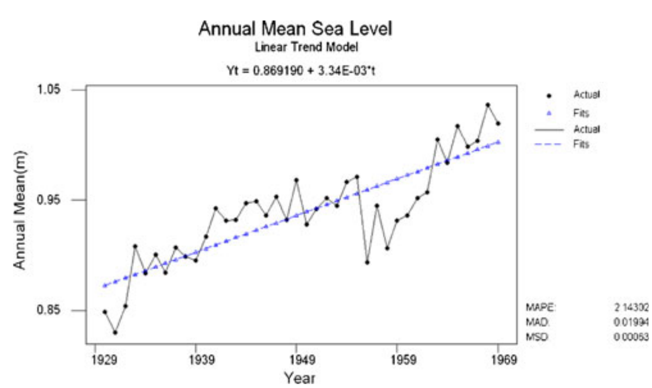

Fig. 4 Linear trend model for annual mean sea level

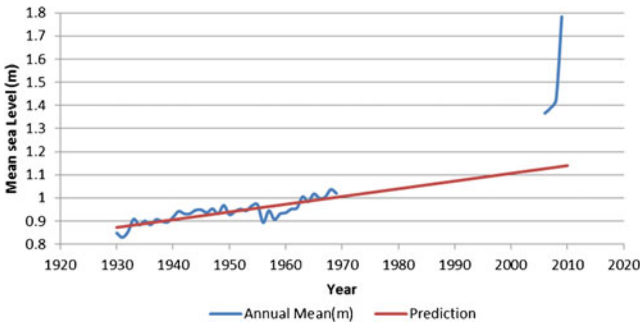

Fig. 5 Annual mean sea level data and predicted mean sea levels

Change in beach width over the Past 30 Years

The shoreline rate of change was calculated with the rate of erosion being 0.86 m/year. and a standard deviation of +/− 0.7. The rather high standard deviation accounts for the variations in the shoreline of approximately 48 km. The varying geomorphic profiles of the coast revealed that the shorelines had different rates of change ranging from −3.6 m to 1.6 m.

Potential hazard zone

The potential hazard zone map was derived and examples shown in Fig. 6—A shows the hazard zone for A2 scenarios; B shows the hazard zones for Ghana scenarios; and 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.

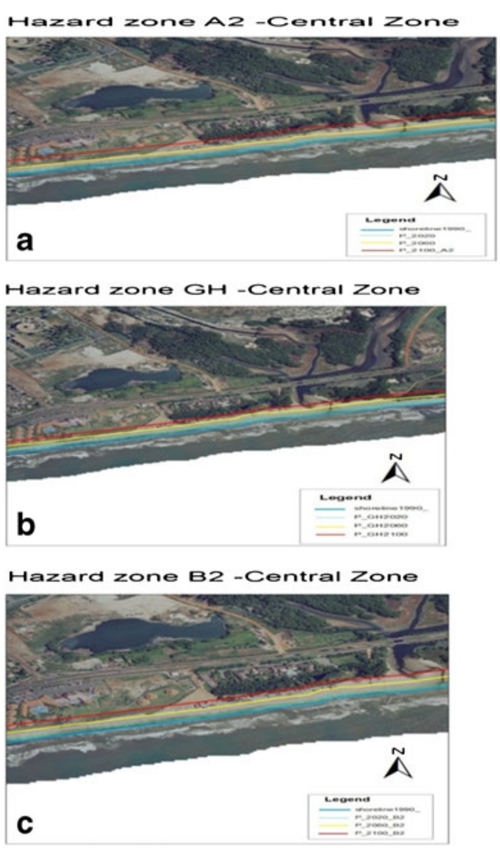

Fig. 6 Hazard zone for the central zone of the study area for the different scenarios

The results show that for the A2 and B2 scenarios the shoreline will retreat about 13 m and 52 m for the years 2020 and 2060 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. Figure 7 shows the length of coastal land to be affected by the hazard for the different scenarios. For scenarios A2 and B2 land loss of about 38 m and more will be lost by 2060 and approximately 58 m by 2100 within the period of 40 year for A2 scenario. The length of land loss measures the same for the years 2020–2060 and 2060–2100 40 years interval each respectively for B2 and Ghana scenarios.

Identification and classification of elements at risk for tourism

Tourism facilities identified were categorized into accommodation, food services and tourist attraction facilities and further grouped per elevation class as shown in the map (Fig. 8). 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.

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 5 m above mean sea level (Fig. 8). Accommodation facilities were located on varying

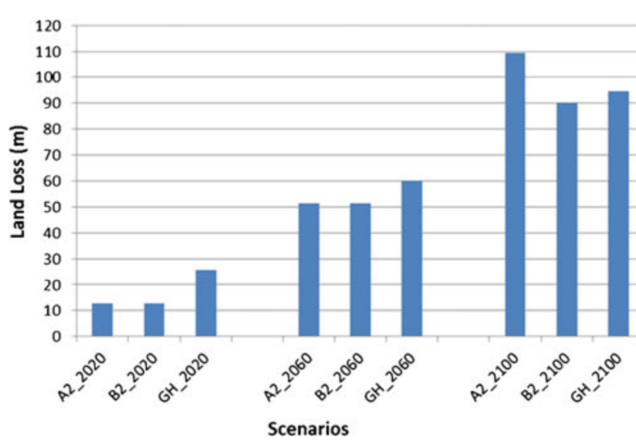

Fig. 7 Land loss for the different scenario

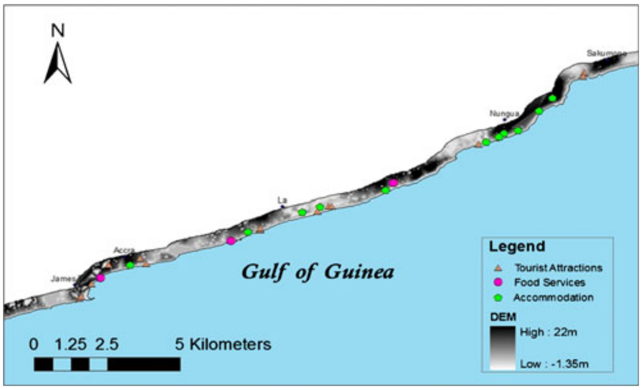

Fig. 8 Identified and categorized tourism facilities

elevation classes with 50 % found to be on the lower elevation. Approximately 63 % of tourist attractions were located within the lower elevation comprising beaches and lagoons. 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.

Assessment of potential physical and socio-economic impact of ESLR

The potential physical impact on tourism facilities vulnerable to the SLR indicated that 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 (Fig. 9).

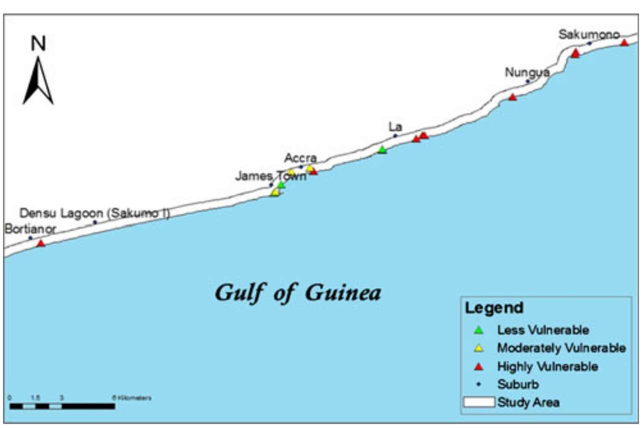

Fig. 9 Potential physical vulnerability map for tourist attractions

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. 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. Approximately 404 guests would be lost per day and may increase to 1,616 guest loss within a month. Socio-economically a total of over 400 employees will be lost to facilities that are highly vulnerable. The food services showed high economic vulnerability to SLR and would lose an amount of GHC 5,443,200.00, rendering 100 people unemployed for the period of the hazard. The socio-economic vulnerability for tourist attractions was mostly low. This was due to the fact that most of these facilities assessed were beaches and had not been economically valued though important facilities. A total of about GHC 231, 532.00 per year and averagely 2000 visitors would be lost per beach per holiday. Economic estimations used only the 13 public holidays. Lagoons and mangroves were not assessed for socio- economic vulnerability because they were not yet well quantified even though they provide a wide range of social and economic value to the communities, visitors and other industries. Socio-economic vulnerability could be high if tourist attractions are properly valued.

Discussion

Sea Level Trend over the past thirty (30) years

The study predicted an average sea level rise rate of 3.34 mm/year. based on the historic MSL data. The predicted rate of 3.34 mm/year is higher than other predictions (IPCC 2007a; Appeaning Addo et al. 2008).

Appeaning Addo et al. (2008), reported a rate of 2.23 mm/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 4 years reveals that the sea level has risen at an average rate of 13 cm. 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 15 cm on the coast of Ghana (Joseph et al. 2006). Tidal measurements in Ghana recorded only from Takoradi is not adequate for effective studies on monitoring the entire shoreline, as the point of measurement is hundreds of kilometres away from the eastern shores of Ghana.

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 be an average of 0.86 m/year. This means that the coast of Accra is eroding at an average rate of 0.86 m per year since 1974 with high variations in the different shorelines accounting for the rather high standard deviation. The rate of erosion is relatively lower than 1.13 m/year and 3 m/year that were reported by Appeaning Addo et al. (2008) and EPA Ghana (Environmental Protection Agency 2010) 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. 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 2010). In any case, erosion of the coast of Accra is crucial to tourism facilities development and management.

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 90 m and 109 m by the year 2100 for the scenarios B2, and A2 respectively 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 90 m. Approximately 13 m of beach width will be lost to a sea level rise of 5 cm from the A2 and B2 scenarios and 10 m 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 12 m to 109 m inland with predicted SLR between 5 cm–42 cm 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 (Boateng 2009), 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.

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. 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. Out of the tourism facilities identified, 64 % were found to be located within the elevation class less than 5 m above MSL and are at high risk to inundation from sea level rises.

Potential physical and socio-economic impact of ESLR

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 because important facilities such as the Ramsar sites and 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.

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. This conforms to the findings that sea level rises could cause salinization in the coastal areas (Gornitz 1991, 2000a, b) which are the concerns of tourism operators. The effect of increased salinity on tourism facilities in the past years is of a major concern to proprietors, since most of the facilities items need to be changed frequently, increasing operational cost and thus maintenance of standards.

Most policy organizations related to tourism and coastal zone management of Ghana do not have clear policies to deal with issues relating to rising sea levels although coastal management is of concern. Policy makers concentrate on their core interest along the coast but ignore the effect of rising sea levels. However, in the advent of climate change many of such Ministries, Departments and Agencies (MDAs) have had several meetings to help find mitigation strategies. Most tourism facilities operators 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; provide some kind of sea defence such as rocks or stones, car tyres, plants and walls to protect the facilities while others watch unconcerned.

Factors that may indirectly influence the impact of the SLR

There are many activities both geological and anthropogenic that may cause the sea to rise and have adverse effect on communities and businesses along the coast (Warrick et al. 1996; IPCC 2001) though SLR in recent years has been attributed to global warming (Rahmstorf et al. 2007). 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 and Banson 1975; Juner 1941). There have been recorded tectonic activities such as earthquakes and tremors along the coast of Accra (Blundell and Banson 1975; Juner 1941).

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 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 and is now being restored with the construction of a sea defence.

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 draws thousands of tourists around the world are found, 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.

Conclusion

The average sea level rise over the past 30 years is 3.3 mm/ year. The beach width of the coast of Accra is eroding at a rate of 0.86 m 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 1 cm though Ghana scenarios give relatively high values. For A2 and B2 scenarios, Accra coast will reduce by 12.9 m and 51.5 m for 2020 and 2060 respectively. By 2100 a distance of 90.1 m and 109.4 m 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.

The GIS method used could be applied for further identification of tourism facilities across the country to improve upon the database on tourism.

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