UNIVERSITY OF CAPE COAST

COASTAL EROSION DYNAMICS AND LANDMASS CHANGE ALONG CAPE COAST - SEKONDI COASTLINE IN GHANA

BY

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JULY 2015

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:...................................... Date: 18/01/16

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Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

The purpose of the study was to investigate the extent to which coastal erosion, accretion and other processes, including human activities, have influenced changes in the coastline between Cape Coast and Sekondi in Ghana. The study sites were Cape Coast, Ekon, Komenda and Sekondi. Fifty pebbles each from the study sites were picked for the study. Sand particles were also sampled from the three study sites. In addition, satellite images, aerial photos as well as topographical maps and Global Positioning System (GPS) Survey were used for shoreline analysis and land cover/use change. Measurements of abrasion platforms, raised beaches, high and low water marks were also manually taken. Forty-five respondents were also purposively selected for in-depth interviews and community interactions. The analyses were done on the basis of Caillieaux indices for pebble analysis, Wentworth Scheme of Grain Analysis for sand, Digital Shoreline Analysis System for shoreline change and digitization of aerial photographs and topographical maps for land cover change. Photographs were also taken and used as part of the analysis. It came out that erosion was more intense between Ekon through Cape Coast and Komenda than Sekondi. Generally, the current shorelines were found to be accreting and retreating. The dominant land cover is built up. The impact of sea erosion was both physical and human. It was therefore recommended that any preventive measures against dynamics of the sea such as erosion should consider both the natural and human dimensions. It is therefore imperative for continuous monitoring of the coast to keep abreast of the changes that will occur as a result of either erosion or accretion.

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DEDICATION

To my lovely wife Suzzy and children, Fiifi, Kobby and Paa Kow

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CHAPTER ONE

INTRODUCTION

Background to the Study

The dynamics of the coast are the complex processes and activities that interact within the coastal environment to bring changes. It is the interaction between water motion and seabed topography, which affects the natural response of coastal systems to change in external conditions and to human interventions (Dronkers, 2005). Thus, the dynamics of the coast are responsible for variations that occur within the coastal environment. It influences the behaviour of waves and swell, and the extent to which the coastal environment is modified. The changes that occur within the coastal environment are mostly the outcomes of the combined actions of erosion and accretion.

Coastal erosion is the wearing away of land and the removal of beach materials by wave action, tidal currents and wave currents. Waves generated by storms, wind or fast moving objects cause erosion which may take the form of long-term losses of sediments and rocks, or merely the temporary redistribution of coastal sediments. Accretion on the other hand is the process by which beach materials are gradually accumulated overtime at the beach. Erosion in one location may result in accretion nearby. These, together with other phenomena whether natural or anthropogenic, may bring changes in the landmass of the coastal environments. Landmass change in this context refers to variations in the shape, size, features and the extent of coastal landmass which is caused by natural and anthropogenic activities thus leading to an increase or loss of coastal landscape. Landmass in this research includes the shoreline, the beach, coastal landforms and features, that is, land cover and the coastal environment in general. According to the (USGS, 2004), diverse and complex natural processes continually change coasts physically, chemically, and biologically at scales that range from microscopic to global. Regional and local characteristics of coasts control the differing interactions and relative importance of these natural processes. According to the same source, human activity adds yet another dimension to coastal change by modifying and disturbing, both directly and indirectly, the coastal environments and the processes of change.

A coastal area that experiences sea level rise can be affected in several ways. From erosion perspective, the most important physical effect is a slow, long-term recession of the shoreline due to direct flooding and partly to profile adjustment to the higher level. It is a fact that generally, a rise in sea level is likely to result in shoreline retreat. The margin of retreat will depend on the level of sea rise, the geology of the coastline, the nature of the marine process and also the duration of the process.

Coastal erosion is known to be one of the most devastating environmental problems confronting a number of countries and has serious implications on national economies. A number of coastal countries on the globe have problems with erosion. According to Masselink & Russel (2013), a large proportion of the UK coast is currently suffering from erosion, that is, 30% in England; 23% in Wales; 20% in North Ireland and 12% in Scotland. In the United States alone, approximately 25% of the coastlines have been categorised as seriously eroding (U.S. Army Corps of Engineers, 1971 cited in Dale, Kochel & Miller, 1995). The Dutch or Netherlands coastline for example, is also continually crumbling due to coastal erosion in such a way that the ability of the dunes, sea dykes and other human-made defenses for keeping out the water is slowly being undermined. In like manner, one can confidently say that a number of coastal countries in Africa such as Nigeria, Tanzania, Cote d' Ivoire, South Africa, Tunisia, and Ghana have suffered the same fate. In other words, shorelines of many coastal regions show the effect of sea erosion, accretion and general changes in the coastal landscape.

The coast is shaped by tectonic and structural features, the nature of the rock forming the coast, depositional and erosive activity. Thus, the vulnerability of the coastal landmass to sea erosion, accretion and submergence depend on several factors. The profile and plan-view-shape of the coast determine its vulnerability to erosion. Land loss can also depend partly on smoothness of the coast and continental shelf because it affects wave energy reaching the shore (Morton, 2004). According to Morton (2004), the shore type most exposed to wave attack and erosion are tall sea cliffs. On the other hand, sea cliffs can also be the most resistant to erosion if they are composed of resistant rocks. Much as it is true that cliffs with resistant rocks resist erosion, it is also believed that the height of a cliff may not necessarily influence erosion but the nature of the rock as said above, the orientation of the coast and even the distance at which the waves have to travel from the shoreline to the cliff will determine the rate of erosion, accretion and hence changes to the coastal landscape.

Coastal erosion in Ghana has been a major feature of the shoreline, especially areas stretching from the eastern side of Cape Three Point to the south eastern border with Togo. With the loss of mangrove strands through human exploitation and also siltation of lagoons comes the loss of its shoreline's protective feature. This has contributed to the enormous erosion problems along the coast of Ghana. Apart from coastal indentation and retreat, erosion and other geomorphic agents and processes have also contributed to the ever changing morphology of the coastline. Thus, coastlines with similar lithology may develop varied landforms due to variations in their responses to sea erosion and other geomorphic processes. This could be one of the reasons why Ghana's coastlines with similar rock structure have different landforms.

The Ghana coast is thus exposed to various degrees of erosion intensities, with the severest areas occurring on the shorelines to the east of the country. In some areas, the rate of shoreline recession due to erosion exceeds 1.5 m per annum (Armah & Amlalo, 1998). The problem of coastal erosion and hence changes in the coastal landmass have different effects on the coastal stretch of Ghana. A visit by this writer to Keta and its environs in 2009 revealed that a large portion of residential and public infrastructure in Keta, Ada, and their adjoining villages, including the road linking it to its northern neighbours (in the case of Keta), has been lost to the sea. In some places if the isthmus were to be breached by the sea, harmful changes in salinity and flow within the lagoon would occur, with quite likely catastrophic consequences for local agriculture, fishing, industry, commerce, and day-to-day conditions for those who live in Keta, Vodza, Kedzi, and the surrounding areas. In the same way, if the massive Volta River swells in the rainy season, flooding can also pose serious threats to the integrity of the fragile fresh-water environment. Other Ghanaian coastal environments such as Prampram, Teshie, through Senya Bereku, Cape Coast to Nkontompo in the Western Region show traces of changes that have occurred to the landscape through sea erosion and other natural and anthropogenic activities.

Anthropogenic activities such as sand mining and construction along the coast can also bring about massive changes in the land mass of the coastal environments. According to Akyeampong, (2001), "the Anlo have explicitly linked artificial deep-water harbours and the construction of the hydroelectric dams on the Volta River to intense erosion of the Anlo coast as well as to a decline in fish stocks in both lagoon and marine fishing". While the construction of dams and harbours can be blamed for such a problem, evidently, variations in climate would also have a devastating effect on the coastal communities. Sea level rise emanating from climate change has been proved to be a contributory factor to increasing level of sea erosion. The Intergovernmental Panel on Climate Change (IPCC) predicted sea level rise between 18-58 cm by 2100 and estimated a rise of 1.8°C - 4C° in temperature (IPCC, 2009). One of the effects of this is that regions with increased precipitation would experience increased runoff and river sediment load transport while the reverse would be observed in regions with decreased precipitation. Therefore, a change in the world's weather pattern will result in the variability of water discharge and sediment supply to the coastal zone. Drought for example, is likely to result in the reduction of sediment supply to the coastal zone through rivers. This is because it has the tendency to reduce the volumes of rivers and hence the supply of sediments. Shoreline change is also influenced by coastal engineering structures and other human activities. Although the coastal environment can retain some degree of natural character, increased human modification reduces the "naturalness" (Dahm, 2000). Coastal erosion is a natural geomorphic process but becomes a hazard when it poses or is perceived to pose a threat to life and property (Ricketts, 1986). Studies by Nail, Addo, & Wellens-Mensah (1993), identified 24 coastal erosion hot-spots in Ghana that need urgent attention. In the worst affected parts of Ghana, near Keta, coastal erosion has persisted for over a century (NADMO, 2007 as cited in Oteng-Ababio, Owusu & Appeaning, 2011). The historic rate of erosion was about four meters per annum (LY, 1980) before the construction of the Keta Sea defense structures. The high rate of erosion is due to the shoreline's orientation and the damming of the Volta River. It is also reported that the erosion currently being experienced at the Prampram beach is the "end effect" of the breakwaters of the Tema Harbour (Oteng-Ababio, Owusu & Appeaning, 2011).

A lot of resources have been sunk into solving this problem including the sea defenses at Keta (2001-2002) and Nkontompo in the Western region. Despite these, most of the problems remain unsolved. The fact is it seems difficult to have solutions to purely natural phenomena like sea erosion and floods, among others. Most of the coastal management practices such as sea defenses are site specific.

They seem not to be sustainable when considered alongside potential future risks of climate change and increased public and legislative appreciation of landscape and environmental values. This means that some of these coastal management practices are not sustainable in view of the risk of sea level rise from climate change and also may affect the aesthetic value of the physical environment. This has led to the development of more holistic and potentially sustainable shoreline and coastal management methods in some nations (Hooke, 1999; DEFRA, 2006; IUCN, 2007). It is therefore imperative to consider both the natural and human dimensions of the problem when proposing holistic management practices.

The total length of the Ghanaian coastline is about 600 km of which 280 km is made up of sandy beaches while the rest which constitutes about 53 percent is rocky (Dei, 1975, in Bird and Schwartz, 1985). The coastline thus represents about 7 percent of the land area. This is home to about 25 percent of the nation's population of about 25 million and where about 70 per cent of industries and businesses are located (Armah and Amlalo, 1998, MLGRD & Environment, 2006). The Ghanaian coastal zone is generally described as low lying and below the 30 meter contour above sea level, thus making it prone to erosion (Oteng-Ababio, Owusu & Appeaning 2011). This coastal zone is faced with environmental problems, especially erosion and flooding which has invariably affected the morphology and the socio-economic livelihoods of the people. Its vulnerability to erosion is further heightened by its coastal orientation and the fact that it is an open coast that enables swell waves to break obliquely to the shoreline, generating longshore currents that carry sediments along the shore

(Armah, 1991). As a result, the advancing sea is responsible for the submergence of structures along the coast (EPA 2005, 2004: EPA & World Bank, 1996). The natural process of coastal erosion is compounded by human activities such as sand mining, removal of coastal vegetation and dredging of rivers (Saha, 2003, Armah & Amlalo, 1998, Dei, 1975).

For years, majority of coastal dwellers in Ghana have had to grapple with problems posed by sea action, especially those who live along the south-eastern coastal stretch from the eastern portions of Cape Three Point through Cape Coast, Accra to the south eastern border with Togo. This area as said earlier, experiences the worst form of coastal erosion in Ghana. Most of the coastal settlements are occasionally inundated due to strong wave energy which sends water inland. As a result, some of the coastal settlements have been flooded by the sea. Others have completely disappeared and one can imagine the problems this situation can create. Examples can be found in and around Ada, Keta, Faana, Kedzi, Nkontompo and other areas along the coast. For example, on the 19th of August, 2012, it was reported that more than 30 houses were destroyed by tidal waves in three communities, namely Dzita, Anynui and Whuti all in the Keta Municipality. Thus, the coastal landscape of Ghana has been experiencing a lot of changes and challenges emanating from sea erosion, accretion and human activities among others.

Statement of the Problem

Coastal landmass change may be land loss or gain depending on whether the coastal land area is mainly under erosion or accretion or which of these processes is stronger at any point in time. Erosion leads to land loss while accretion leads to land gain. The dominance of erosion or accretion within a coastal environment will also depend on the strengths of the waves, orientation of the coast, nature of rocks along the coast and the extent of human activities among others.

The coastal landmass and coastline along Cape Coast-Sekondi may have gone through certain changes mainly caused by erosion and accretion. Due to the continuous activities of erosion and accretion, the coastal landmass may have been fluctuating. According to Oteng-Ababio, Owusu & Appeaning, (2011), these fluctuations are reflected in changes along the shoreline, changes in coastal land cover including features and landforms which make up the coastal landmass. Rocks which used to be located at some distance offshore have been exposed by erosion. Structures along the coast such as forts, castles, coconut trees and human dwellings have been destroyed or are being attacked by sea action mainly through erosion similar to what has been identified in coastal areas around Accra and Keta (Appeaning & Adeyemi, 2013, Boateng, 2009). In some instances, accretion is also very active that portions of the beaches are raised. Thus the advancement and retreat of the coastline have contributed to changes in the coastal landmass. In areas where erosion is very strong, the problem has persisted for a long time and become glaring to the extent that various efforts are being put in place to deal with the devastating effects of the sea (Boateng, 2009). Sea defenses in the form of groins and rocks have been put in place to check sea erosion right from Cape Coast, through Elmina to Sekondi and beyond. At Ekon, Cape Coast and

Ngyiresia, some of the local residents have devised their own means of dealing with the problem. Some have used sand bags; others use concrete walls while in some cases bamboo fences are used. While erosion is taking place, sedimentation is also occurring. Thus the combined actions of erosion, sedimentation and sub-aerial geomorphic processes such as mass wasting and weathering have all contributed to the changes in the landmass of the coastal environments.

The differences in response to the dynamics of the sea by the lithology, the effects of sub-aerial geomorphic processes on physical structures such as landforms and the changes that occur along the coastlines of the study area including the manner in which longshore drift affects sedimentation along the coast make it imperative for investigations to be carried out into the dynamics of sea action in the study area. This research is meant to fill a gap in the study of coastal dynamics because it is aimed at analyzing the changes in the coastal landmass with reference to both shoreline and land cover. Many of the researches in this area, such as Armah, (1991), Boateng, (2009), rarely combine the two. It also seems that most of the studies of such nature have concentrated around the extreme eastern coastline, especially Keta and its environs, hence the need to shift emphasis towards the central and the western coast. Moreover, though the phenomena under study are purely natural, this research was done taking cognisance of both the human and natural perspectives. This will help unravel the extent to which sea erosion and accretion with other processes such as weathering and mass wasting including human activities have contributed to changes that have occurred along the coastline under study. Thus, the extent of change in the landmass including the shoreline and coastal features need to be known and also the causes of these changes are important to this study. Parts of the coastline in the study area have also been identified as having serious problems with coastal erosion (Aheto, Okyere, Mensah, Mensah, Aheto, & Agyarkwa 2010; Oteng-Ababio; Owusu & Appeaning, 2011).

Purpose of the Study

The purpose of this study was to investigate the extent to which the dynamics of the sea, have contributed to changes in the coastal landmass between Cape Coast and Sekondi.

Objectives of the Study

The specific objectives of the study are to:

1. Make a comparative analysis of the extent to which erosion and accretion influence sedimentation of grains along the coastline of the study area.
2. Assess the extent to which particle size and shape reflect the dynamics of sea action.
3. Investigate the changes that have occurred in the coastal landmass in relation to shoreline and land cover change of the study area.
4. Analyse the influence of sea action on geomorphic features along the coast of the study area.
5. Analyse the problems posed by the dynamics of sea erosion and the mitigating mechanisms put in place.

Research Questions

Thus, the questions which this study seeks to find answers to are:

1. In what ways do erosion and accretion influence sedimentation of grains along the coast between Cape Coast and Sekondi?
2. How do particle size and shape reflect the dynamics of sea action?
3. What changes have occurred in the coastal landmass in relation to the shoreline and land cover?
4. What is the influence of sea action on geomorphic features in the study area?
5. What are the problems posed by coastal erosion and what mitigating mechanisms are being put in place?

Significance of the Study

Coastal erosion and landmass modification are very important concepts in coastal geomorphology and as a result attention is being focused on them. The emergence of climate change as a driving force to sea erosion has even drawn much attention to the problem. Coastal erosion and accretion bring changes in the position of the shoreline which affect several activities and phenomena along the coast. The changes can be drastic and costly and thus it is very important for coastal dwellers to know whether the shoreline and for that matter the land mass is advancing, retreating or stable.

This research thus gives education on the issues relating to sea erosion including the nature, causes, effects, future trends and how the problem can be minimized. There is no physical capability of humans to prevent long term SLR. Humans can only cope with the phenomenon and the key to coping with sea level rise is education on the effects and accurate assessments of hazards for given points in time. In this way, humans can act decisively and appropriately to minimize loss of life, and economic and ecological impacts (Aubrey & Emery, 1993).

Thus, this research will be of immense help to environmentalists, coastal zone engineers and managers, coastal communities and policy makers since it will enhance their appreciation of the dynamics of coastline modification along this stretch of the Ghanaian coast and elsewhere. This is because, the study indicates the extent of changes in the shoreline and land cover of the coastline under study which can help policy makers to incorporate these changes into their plans. It is thus an important document for policy makers since it will be an important reference material for the management of the coast. It thus has the merit of adding to the existing body of knowledge in the discipline.

Delimitation of the Study

This study was designed to investigate the dynamics of sea action and how it impinges on changes in the landmass between the coastline of Cape Coast and Sekondi. The study sites are Cape Coast, Ekon, Komenda and Sekondi. The issues that formed the basis of investigation were erosion, accretion, sedimentation, shoreline change, land cover change and mitigating mechanisms against the problems posed by sea action.

Limitations of the Study

One major problem of this study was difficult terrain which impeded traversing with Global Positioning System (GPS) in the field survey. Due to bad terrain along parts of the coastline under study, GPS survey could not be conducted entirely along the coast. This necessitated the use of satellite images for the same purpose. Moreover, 2013 aerial photograph for Komenda was not very clear for land cover change detection and as a result, land cover change analysis could not be done for Komenda.

Definition of Terms

Sea erosion is used synonymously with coastal erosion to mean the removal of materials from the floor of the sea and at the coast by waves.

Accretion is a process by which layers of beach materials are gradually accumulated overtime at the beach.

Turtle Cove refers to the study site around Sekondi hence it is used synonymously with Sekondi.

Gold Hill refers to the study site around Komenda, hence it is used synonymously with Komenda.

Ekon and Cape Coast is used interchangeably to mean the study site around Cape Coast.

Pebbles are smaller particles of rocks relatively larger than gravels but smaller than boulders.

Sedimentation refers to the process of eroding, transporting and deposition of materials (sediments) along shorelines.

Shoreline is the boundary or the line which marks the intersection of the water surface with the land. In the context of this research, it is defined as the line of contact between the land and the sea.

Shoreline change is the variations or movements that occur along the coast causing it to advance towards the land or to retreat further into the water or sea.

Near shore refers to areas close to the lower water level or the shoreline.

Upper beaches/reaches or levels refers to the parts of the beach further away from the lower water level.

High Water Mark refers to the point at the beach that represents the maximum rise of sea waves.

Low Water Mark represents the lowest level reached by the sea waves at the beach.

Raised beach is an elevated area or former beach marked by marine deposits which stands above sea level at some distance inland.

Sub-Aerial Processes are land based processes which operate at and alter the shape of the coast but do not involve direct contact with the sea. Examples are weathering and mass movements.

Landmass is used to mean the shoreline, the beach, coastal landforms and features and the coastal environment in general.

Landmass change refers to the variations that occur in the land of the coastal environment. It includes changes in the shoreline and land cover, landforms and features that make up the coastal zone.

Land cover is the physical material found at the surface of the earth.

Land cover change generally refers to the modifications brought upon the earth's terrestrial surface mainly by humans.

Organisation of the Study

The study was organised into six chapters. Chapter One dealt with the background of the study, including the problem statement, objectives and the significance of the study among, others. Chapter Two covered the review of related literature. It was discussed under relevant sub headings. Chapter Three also covered the background characteristics of the study area. Issues discussed include the physical and human characteristics of the study area. Chapter Four discussed the methodology, that is, the explanation of how the study was conducted. Chapter Five was devoted to discussion of results while the final chapter, which is Chapter Six, comprised the findings, conclusions and recommendations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This section of the study was devoted to reviewing of related literature. It was discussed under relevant sub-headings including the meaning and processes of sea erosion, factors that influence sea erosion, causes, effects and management of sea erosion. Other aspect of the review considered sedimentation, shoreline recession, and other related issues. In addition to the above, the philosophical underpinning of this research, theoretical perspectives and conceptual the framework of this research were all discussed in this chapter.

Processes and Causes of Coastal Erosion

Erosion may take the form of long term losses of sediments and rocks or mainly the temporary redistribution of coastal sediments. Erosion in one location may result in accretion nearby. Erosion and accretion work hand in hand, that is why though erosion occurs continuously, the beach is never deprived of deposited materials. The sea thus has the tendency of replenishing itself.

Some coastal areas may be accreting in the short term but the general trend is in the direction of shoreline retreat (Beathey & Brower, 2002). According to Beathey & Brower (2002), beach erosion is either episodic or sporadic. Beach erosion is episodic when it occurs over a short period, sometimes in hours such as those that are caused by hurricanes or sometimes during a season such as El Nino event. It is sporadic when all areas are not eroded at the same rate during a storm. Some areas have severe erosion during an event while other areas may have much less erosion. Some areas are constantly and rapidly eroding such as the Mississippi delta region in the US. The above statement by Beathey & Brower (2002), is a truism since even areas with the same coastal orientation may suffer differently from sea erosion since other factors such as geology, the direction of the alongshore drift and even the extent of anthropogenic activities all impinge on the extent and rate of erosion.

Wave erosion occurs in several ways. Waugh, (1995), identifies five main processes of wave erosion namely, wave pounding, hydraulic pressure, abrasion, attrition and corrosion. Wave pounding, according to Waugh, (1995), is when the energy of waves is used to break part of the sea walls at the coast. The waves may generate shock-waves of up to 30 tonnes per sq m. For example, some of the sea walls in parts of eastern England need replacing within 25 years of being built due to wave pounding. In like manner, most of the sea walls along the coast of Ghana, especially at, Nkontompo, Komenda and Ada among others, need to be fortified against wave pounding due to the fact that the sea is fast advancing towards the land. Hydraulic pressure occurs when a parcel of air is trapped and compressed either in a joint in a cliff or between a breaking wave and a cliff. Over a period of time, the cliff weakens and breaks off or in areas where sea defenses have been constructed, hydraulic pressure can also damage these sea defenses. Another process of wave erosion is abrasion.

Abrasion is the wearing away of the cliffs by the materials carried by the waves. These materials may include sand, shingles and boulders hurled against them by the waves. It is the most effective method of sea erosion and is most less erosion. Some areas are constantly and rapidly eroding such as the Mississippi delta region in the US. The above statement by Beathey & Brower (2002), is a truism since even areas with the same coastal orientation may suffer differently from sea erosion since other factors such as geology, the direction of the alongshore drift and even the extent of anthropogenic activities all impinge on the extent and rate of erosion.

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Abrasion is the wearing away of the cliffs by the materials carried by the waves. These materials may include sand, shingles and boulders hurled against them by the waves. It is the most effective method of sea erosion and is most rapid on coasts exposed to storm waves. Along the coast of Ghana, this is responsible for most of the erosion landforms, especially between Cape Coast and Takoradi where these landforms are well developed (Dei, 1975). With corrosion, soluble minerals and rocks such as limestone, chalk and rock salts are dissolved by carbonic acid in sea water. At some point, these processes become ineffective in periods when the sea retreats. This is because when both the sea and the cliff along the beach retreat, the gap between the limit of the waves and the rocks becomes wider. As a result, it may be very difficult for wave action to attack the rocks at the coast; hence they rather suffer from sub-aerial geomorphic processes such as weathering and mass movements (Longley-Cook, 2013). Thus, apart from wave erosion processes, it should be noted that the rocks found along most coasts also come under constant attack from weathering, mass wasting and other geomorphic processes, and are continually being modified.

Sub-aerial or cliff face processes are geomorphic processes which alter the shape of the coast but do not involve direct contact with the sea. They take place above ground level with effect on objects on the ground. They are most apparent on marine and fluvial features which do not necessarily suffer from constant wave attack. Examples of such processes are weathering and mass wasting. Along most coastlines, cliff face processes have a serious effect on the features. While marine erosion acts on the base, sub-aerial processes also act on the upper levels.

The magnitude and rate of wave erosion depend on several factors. Waugh (1995) identifies factors such as the breaking point of the wave, the steepness of the slope, the nature of the rocks and the nature and orientation of the coastline among others. Waves which hit the cliff as they break have less energy. Waves which break as they hit the foot of a cliff release most energy and cause maximum erosion. If the waves hit the cliff before it breaks, then much less energy is transmitted whereas a wave breaking further offshore will have had its energy dissipated as it travelled across the beach. Waugh (1995), further identified wave type and steepness as factors that influence the rate of erosion. He argues that very steep destructive waves have more energy and erosive power than gentle constructive waves. This is because destructive waves are steep with high energy and are capable of removing materials from the sea floor and at the beach. Constructive waves, on the other hand, are very gentle with less energy; hence they rather build the beach. Moreover, the depth of the sea and nature of the coastline all affect sea erosion. A steep beach helps to create higher and steeper waves than one with a gentle gradient.

The nature of the rocks also influences the rate of sea erosion. The strength of the coastal rocks influences the rate of erosion in that coastal areas with very resistant rocks such as granite are guaranteed of coastal protection. Erosion rates, thus tend to be higher in areas where soft substrates such as sandstone and mudstone are the dominant geological type rather than hard substrates such as basalt or granite. Thus following from this premise if one considers the geology of the study area, one may not be far from right in postulating that erosion is likely to be stronger around Komenda and Sekondi where the dominant lithology is sandstone while erosion is likely to be less around Cape Coast which is mainly made up of igneous and metamorphosed schist. On the other hand, erosion could be very devastating along the entire coastline; resistance to the effects of erosion could be much higher in Cape Coast than Sekondi and Komenda due to the nature of the rocks along the coast.

The discussion of the rate and the extent of erosion is not complete if one limits the argument to natural factors without considering the anthropogenic dimension. Humans contribute to the increase in coastal erosion through engineering techniques. For example, humans may move sand dunes in an attempt to protect a specific structure, only to have the dune washed away. Sea walls can protect structures but often lead to complete loss of beaches along the bays. It is therefore sometimes very important to allow nature to take its course which could lead to less loss overtime. Thus, sand mining and quarrying could also promote sea erosion as they contribute to the removal of sediments and protective rocks from the beach.

A critical look at Ghana's coastline makes one believe that gradient seems to increase from the west towards the eastern portion which has resulted in intense sea erosion in the eastern coast than the western side. Loss of sand at the beach can also cause severe coastal erosion. This could be due to the breaching and over-wash of a barrier island and wind transport. Sand loss may not be permanent since the sea is capable of replenishing the beach from time to time. Sand loss could also be due to extreme wave and storm surge conditions. The high waves cause the bars to move seawards and the high storm surges also cause an offshore movement of sand due to non-equilibrium in the profile during high surge (Mangor, 2008). On the other hand, sand loss could also be attributed to human activities such as sand mining and erection of structures at the beach. Even removal of vegetation at the beach could precipitate sea erosion as the land becomes bare with no obstruction to the waves. Generally, the causes of erosion can be of local (decrease in sediment supply) or global (worldwide change in sea level) importance (Feagin, Sherman & Grant, 2005).

Thus, naturally, one can talk of increasing sea levels as a result of climate change. According to IPCC (2007), notwithstanding the differences in erosion potential along the world's coastlines, there has been a dramatic increase in coastal erosion over the last two decades and this is expected to continue as sea level rises and storm frequency and severity increase. Climate change is thus one of the most important natural causes of increasing coastal erosion. With increasing sea level rise, storm patterns are becoming stronger and are less likely to be predictable. The combined processes of climate change and fall in land are likely to increase coastal erosion in some areas over the next 100 years and more (http://www.environment-agency.gov.uk/homeandleisure 24/08/12). Thus two main natural causes of coastal erosion are changes in sea level emanating from climate change due to freezing and melting of ice and changes in the land relative to the sea, that is, isostacy and eustacy respectively. Melting ice augments the amount of water in the sea leading to a rise in sea level. Changes in the level of the land in relation to the sea can also cause sea erosion. A fall in the land bordering the sea can cause landward advancement of the sea while a rise in the land causes the sea to retreat.

Related to the above, Dale, Kochel & Miller, (1995), also posited that apart from human induced activities, the two major causes of shoreline or coastline erosion are raising sea level and coastal storms. According to them, rising sea level provides the impetus for change whereas storms provide the energy or the mechanics to accomplish the geomorphic work. It is widely documented that sea level was more than 100 m lower than present some 18,000 years ago (Dale et al., 1995). They went ahead to argue that since 4000-5000 years ago, sea level has been slowly, but steadily rising. Sea level has risen some 25 cm since the early part of this century. The magnitude of these changes translates into significant lateral dimensions along low-relief shorelines and also accelerates undercutting of cliffs in high relief areas. According to Dale et al., (1995), the rise in sea level has been significant to facilitate steady landward migration of Barrier Island and mainland coastal environment worldwide. Examples are the common appearance along the barrier and mainland shorelines of the Mid-Atlantic coast of dead trees that have succumbed to the invasion of saline groundwater in their root systems and also abandoned farmlands and agricultural activities where fresh water or sub-aerial environments have been overrun by silt marshes resulting from the rise in sea level (Dale et al., 1995; 470).

The impact of sea level rise will vary locally with relief, lithology, landforms, rates of shoreline erosion, beach slope, vertical tectonics, wave climate and tidal range. Thus shorelines may have the same climatic conditions but the impact of climate on sea level will vary due to the fact that the coastal orientation may differ. Relief and general lithology of the coast determine the rate of shoreline change whether an advancement of the sea or a retreat. This is reflected in the nature of the lithology since resistant rocks will impede the rate of erosion.

The dynamics of coasts are directly affected by storms that impinge on the shoreline. Coastal storms provide the energy for accomplishing significant erosion over short period of time. Storms are more destructive when they coincide with high tides but the effect also depends on the duration of such storms at the coast and the area affected. Coastal storms could be cyclical and follow partial periodic trends. Davis & Dolan (1993), clearly show that there has been a significant cyclicity in the pattern of Atlantic coastal storms during this century, with a particularly stormy period occurring between the mid 1940s and mid 1960s.

Coastal Erosion and Coastal Features/Landforms in Ghana

Many settlements along the Ghanaian coastline have been submerged due to increasing sea levels in the past few decades. Areas that are mostly prone to sea erosion are concentrated at the eastern coastline of the country. Examples of such areas include Keta, Amedzofe, Dzelukofe, Blekusu, Ada Foa all in the Volta Region. Other areas include La, Osu and Kpeshie beaches in Accra. Some other areas are Nkontompo, between Sekondi and new Takoradi, Cape Coast and its environs and Axim shoreline (EPA, 1996). On the average, the annual rate of erosion is between 1-2 metres (Appeaning Addo, Walkden & Mills, 2008). Attempts on coastal reclamation projects, both large and small scales are ongoing in some erosion prone areas in Ghana (EPA/World Bank, 1996). The erosion prone Keta/Ada areas are currently the only places where massive protection programmes are going on with few isolated places undertaking localised mitigation measures by building stone revetments and groins (EPA & World Bank, 1996). Examples of man-made structures like breakwaters could be found at Princesstown, Ajua, Nkontompo, Essipong, James Town beach, Tema and Prampram (EPA, 2004). Coastal erosion influences the shoreline and the beach in several ways by modifying them from time to time. One of the glaring effects is the development and modification of landforms. Landforms are discrete products of geomorphological processes. Thus coastal landforms are discrete products of coastal processes. The aggregation of coastal landforms makes up the coastal landscape. The landforms and features along the coast are brought about by combined processes of erosion, transportation, deposition and other related processes. Coastal erosion landforms are well developed along rocky coastlines more than sandy coastlines. This is because most of the erosion landforms/features are associated with coastal cliffs and headlands. This is affirmed by de Blij & Muller (1993 :502) when they put it as follows "where wave erosion (rather than deposition) is the dominant coastal process, a very different set of landforms develop. Exposed bedrock, high relief, steep slopes, and deep water are key features of this topography". As a result, as erosion affects these relief features, they are continually moulded and modified into various erosion landforms. Thus, through wave pounding, hydraulic action, abrasion, attrition and solution, landforms such as coastal cliffs, notches and caves are created. Others include blowholes, geo, stack, arch, wave cut platforms and bays, among others.

Cliffs can also be found on the shores of rivers, lakes, estuaries, lagoons and other water bodies. Other sea erosion landforms found within the study area are notches, abrasion platforms, caves and blowholes. A notch may develop along a line of weakness at the cliff face or at the base of a cliff which has been subjected to prolonged wave action. This may result when wave energy is at its maximum and a high steep wave breaks at the foot of a cliff. The undercutting of the cliff will result in the formation of a wave-cut notch (Waugh, 1995; Davidson-Arnott, 2010). When undercutting is prolonged it causes increased stress and tension in the cliff until eventually it collapses. A repetition of this will cause the cliff to retreat, leaving a gently sloping platform at its base known as a wave-cut platform. This feature cuts across all rocks regardless of their type and structure (Waugh, 1995; Davidson-Arnott, 2010). The widening of the platform allows waves to travel over a wider area of beach. This dissipates the energy of the wave, reduces erosion and hence reduces the extension of the platform. Thus, the width of the platform is normally less than half a kilometre (Waugh, 1995; Davidson-Arnott, 2010). Extensive abrasion platforms are well developed along the coast of Sekondi, especially around the Turtle Cove. However, they are found in some specific areas along the coast of Ghana. They are about 0 -2 metres above sea level. Those above a metre are believed to have been cut by higher sea stands in the past although recent sea action may have contributed (Small, 1978).

Further erosion of the notch will enlarge it to form a cave. The roof of the cave is sometimes eroded, reaching the surface some distance inland as a vertical pit. This is known as blowhole or gloup. Two caves found on either side of a headland or promontory may erode back-to-back and break through to form a natural arch. Sometimes the sea cuts inland along a joint to form a narrow, steep-sided inlet called a geo (Davidson-Arnott, 2010).

The next stage is the collapse of the arc leaving a seaward section standing as a stack such as the one at Nkontompo near Takoradi (the Nkontompo Stack). Some of these stacks are covered by the sea to form stamps which pose danger to canoes, boats and other vessels that sail close to the coast.

Headlands and bays are also common. In areas where the coast is underlain by alternating soft and hard rocks, the softer rocks are eroded to form bays or inlets, leaving the hard rock standing out to form promontories or headlands. Initially, the less resistant rock experiences most erosion and develops into bays, leaving the more resistant outcrop as headland (Waugh, 1995). Later the headland receives the highest wave energy and so becomes more vulnerable to erosion than the sheltered bays. The bay then receives low energy waves and allows sediments to accumulate and help protect that part of the coastline. These features have greater influence on littoral drift. Though the emphasis of this study is on erosion, it should be noted that erosion and accretion/deposition are related as they occur concurrently along the coast, hence, it will be proper to discuss deposition features such as beaches, sand spits, bars and mudflats among others.

The accumulation of materials or sediment on the shore forms beaches. The shore is the area between the low water mark and the base of the cliff. It could also be referred to as the gently sloping land along a body of water which is washed by waves or tides (Bates & Jackson, 1984). The beach can be rocky, sandy or both. The sediments or material making up the beach may consist of boulders, pebbles, cobbles, coarse sand, fine sand and silt. A beach could also be a geological landform along the shoreline of a body of water. The particles of which the beach is composed can sometimes have biological origins, such as shell fragments or coralline algae fragments (Davidson-Arnott, 2010).

Although the shore is most commonly associated with the word "beach", beaches are not only found by the sea or ocean. Beaches also occur inland at the margins of the land along lakes and rivers where sediments are reworked or deposited (Davidson-Arnott, 2010). There are several conspicuous parts to a beach, all of which relate to the processes that form and shape it. The part mostly above water (depending upon tide), and more or less actively influenced by the waves at some point in the tide, is termed the beach berm. The berm is the deposit of material comprising the active shoreline (Davidson-Arnott, 2010). The berm has a crest forming the upper part and a face which is the slope leading down towards the water from the crest. At the very bottom of the face, there may be a trough, and further seaward one or more longshore bars; slightly raised, underwater embankments formed where the waves first start to break. The sand deposit may extend well inland from the berm crest, where there may be evidence of one or more older crests (the storm beach) resulting from very large storm waves and beyond the influence of the normal waves.

These geomorphic features make up the beach profile. The beach profile changes seasonally due to the change in wave energy experienced during high and low tides. The beach profile is higher during the dry season when there is low tide and where there is little or no rainfall and run-offs to cause slumping and erosion of cliff face (Baldwin, Mckee & Mendelssohn, 1996). This leads to gentle wave action during low tide period. The lower energy waves deposit sediment on the beach berm and dune, adding to the beach profile. Conversely, the beach profile is lower in the rainy seasons due to the increased wave energy associated with storms. Higher energy waves erode sediment from the beach berm and deposit it offshore in deep ocean trenches (Davidson-Arnott, 2010). The removal of sediment from the beach decreases the beach profile. However these sediments are deposited offshore at the farther end of the littoral zone. The drift line (the highest point of material deposited by waves) is one potential demarcation. This would be the point at which significant wind movement of sand could occur, since the normal waves do not wet the sand beyond this area (Small, 1978). However, the drift line is likely to move inland under the influence of storm waves.

Beaches are deposition landforms or features, and are the result of wave action by which waves or currents move sand or other loose materials of which the beach is made as these particles are held in suspension. Alternatively, sediments may be moved by saltation. Beach materials may also come from erosion of rocks offshore, as well as from headland erosion and slumping producing deposits of talus or scree. Some beaches have very fine and whitish sand and this comes from the erosion of quartz along rocky coasts or offshore on the seafloor. A coral reef offshore may also be a significant source of beach sediments (Small, 1978). Therefore, beach sediments are dependent on the bed rock offshore or onshore. The shape of a beach depends on whether or not the waves are constructive or destructive, and whether the materials are of fine or coarse sediments (Crowley, 2006). Constructive waves move material up the beach to accumulate while destructive waves move the material down the beach causing erosion. On sandy beaches, the backwash of the waves removes material forming a gently sloping beach. On shingle beaches the swash is dissipated because the large particle size allows percolation, so the backwash is not very powerful, and the beach remains steep (Crowley, 2006). A look at Ghana's beaches gives an indication that erosion features and landforms are well developed and are thus common than depositional features.

Many beaches are very popular as they serve several purposes including tourist and recreational activities. Though beaches in Ghana including those in the study area, for instance, attract a lot of holiday makers for recreation, they are also subject to several negative human activities which reduce their aesthetic value. Sand mining, defecation, refuse dumping and subsequent loss of beach sediments through sea erosion can have a severe effect on tourism revenues. Due to intense use by the expanding human population, most beaches are lost due to human impact on the beaches which leads to increased erosion activities. Others are degraded, often serving as dumping grounds for waste and litter, necessitating the use of beach cleaners and other cleanup projects. More significantly, many beaches are a discharge zone for untreated sewage in most underdeveloped countries, even in developed countries beach closure is an occasional circumstance due to sanitary sewer overflow.

Mudflats (also known as tidal flats) are coastal wetlands that form when mud is deposited by tides or rivers. They are found in sheltered areas such as lagoons and estuaries. They may be viewed geologically as exposed layers of bay mud resulting from deposition of estuarine silts, clays and other sediments. Most of the sediment within a mudflat is also within the intertidal zone, and thus the flat is submerged and exposed approximately twice daily (Oude, Boekelman & Bosters, 1993). Mudflats are typically important regions for wildlife, supporting a large population, although levels of biodiversity are not particularly high. They are often of particular importance to migratory birds. The maintenance of mudflats is important in preventing coastal erosion. However, mudflats worldwide are under threat from predicted sea level rise, coastal land reclamation for development, dredging due to shipping purposes, and chemical pollution. Some of the coastal features, such as estuaries and coastal lagoons, may not necessarily be formed by erosion or deposition but a combination of processes including the presence of a river.

An estuary is a semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea (Baldwin et al, 1996). Estuaries are thus subject to both marine influences, such as tides, waves, and the influx of saline water; and river influences, such as flows of fresh water and sediment. As a result, they may contain many biological niches within a small area, and so are associated with high biodiversity. Estuaries are typically the tidal mouths of rivers and they are often characterized by sedimentation or silt carried in from terrestrial runoff and, frequently, from offshore. They are made up of brackish water. Due to their suitability to human settlement, estuaries typically have a heavy human presence and most cities in the world are located on estuaries. This is affirmed by Briney, (n.d. :3) who puts it as follows "major cities all over the world are located on estuaries. Places like New York City and Buenos Aires have grown and become major cities on estuaries".

In Ghana for instance, some rural as well as urban areas such as Ada, Weija, Winneba, Narkwa, Shama and Axim among others are located on major estuaries. Estuaries are marine environments with varying pH, salinity and water levels, depending on the river that feeds the estuary and the ocean from which it derives its salinity. This is because oceans and seas have different salinity levels depending on the environment they are situated in. Landlocked seas, sea located in desert areas and seas that have few rivers draining into them are highly saline and these tend to have effect on the salinity of estuaries around them (Tsyban, Everett & Titus, 1990). Estuaries provide habitats for a large number of organisms and support very high productivity. Estuaries provide habitats for many fish nurseries, depending upon their locations in the world, such as salmon and sea trout. Also, migratory bird populations, such as the black-tailed godwit, sea herons and cranes make essential use of estuaries. Two of the main challenges of estuarine life are the variability in salinity and sedimentation. Many species of fish and amphibians have various methods to control or conform to the shifts in salt concentrations. Many animals also burrow to avoid predation and to live in the more stable sediment environment. However, large numbers of bacteria are found within the sediment which has a very high oxygen demand. This reduces the levels of oxygen within the sediment often resulting in partially anoxic conditions, which can be further exacerbated by limited water flux (Day, Cormner, Constanza & Mendelssohn 1993). Sea weeds are key primary producers in estuaries. They move with the water bodies and can be flushed in and out with the tides. Their productivity is largely dependent upon the turbidity of the water. A coastal lagoon is a body of comparatively shallow salt or brackish water separated from the deeper sea by a shallow or exposed sandbank or sand bar, coral reef, or similar feature. Thus, the enclosed body of water behind a barrier reef or barrier islands or enclosed by an atoll reef is called a lagoon. There are pockets of lagoons found at the estuaries of rivers in the study area including Fosu and Essei Lagoons in Cape Coast and Sekondi respectively. Thus, much as sea erosion has contributed to the development and modification of the coast and its features, it could not have been complete without the combined action of erosion and deposition.

Nature of Coastlines, Alignment and Geological Structure

A coastal zone is the interface between the land and water. It consists of the general interaction between the land and the ocean or lake. It ranges from the inland limit of coastal influence through the present shoreline to the lowest submerged elevation to which the shoreline fluctuates (Peterson, Sack & Gabler, 2011). The shoreline is the exact and constantly changing contact between the ocean and dry land. Shorelines are continually changing due to the dynamic interaction between the oceans and the land. Deposition and erosion continually occur along the coast by wind and waves. These make the coastal zone very vulnerable to natural hazards yet majority of the of the world's population inhabit such zones.

There are variations in the length of the world's coastline depending on the methods used. It is estimated to be about half a million kilometres. However, when all the intricacies of indented bays and promontories and offshore islands are included, the total length will be about a million kilometres (Bird & Schwartz, 1985). It is made up of different types of coast and geological forms. There are other parts of the world's coastline also made up of rocky with intervening sandy coastlines. About 20 % of the world's coast is sandy and 70 % of the sandy coastlines have been retreating (Bird, 1985). A morphogenetic classification of coasts may be based on a combination of the forms of the shore zone and the landforms next to it. Based on these, several types of coast may be identified. For example, strand-flat coast as found along the coast of Norway is a gently sloping bedrock plain partly sub-and partly supra-maritime, only locally covered with deposition of some thickness. It is limited both inland and seaward by steeper slope. Another type of coast which is also partly found in Norway is Fjord coast. It is an arm of the sea stretching inland between distinct fjord-sides which either plunge steeply into the sea or reach it through a gently sloping valley bench. Cliff abrasion coast is characterized by a rugged cliff descending from the undulating paleic surface to the sea.

Thus coastlines can generally be classified as rocky or sandy based on geological characteristics. Volcanic coasts, for instance, are example of rocky coast characterized by volcanic activities such as most of the coastlines of the

Pacific Ocean islands. These include the coastlines of Fiji, Hawaii and Maui, New Caledonia, Papua New Guinea, Tahiti, Solomon Island and Vanuatu. Other volcanic coastlines include those found in Iceland and Ecuador, among others. The northern coastal region of Ecuador, according to Faucher & Savoyat (1973) in Bird & Schwartz, (1985) is characterized by ranges with horst-like bases of pyroclastic rocks, basic lavas and dolerites underlying Cretaceous and Tertiary sediments. This part of the coastline is truncated by rocky promontories, cliffs with pockets of sandy beaches. In like manner, much of the eastern coastline of Canada within the provinces of Quebec, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland (including Labrador) is rocky, barren and subarctic in character (Bird and Schwartz, 1985: 235).

Sandy beaches consist of sand and shingles and sometimes with stones and ridges. Sandy beaches in parts of the Norwegian coast consist of sandy offshore, foreshore and backshore but also some low stony bench ridges. Long sandy beaches are also found on Vigra, an Island on the More Coast and also, the Island of Andoya, in Norway (Klemsdal, 1982, in Bird and Schwartz, 1985). Sandy shores can also be found in some parts of the coastline along the Netherlands. It is part of the low sandy shore bordering the southwest part of the North Sea between the French-Belgian border and north of Denmark (Jelgersma, 1970). The coast of France, on the other hand, can be said to be rocky as well as tidal, marshes, estuaries, spits and dunes.

In Africa, sandy and rocky beaches occur in all the coastal countries. From Mauritania across Senegambia through Guinea and Guinea Bissau sandy beaches occur. According to Bird & Schwartz (1985), these areas can be geomorphologically reviewed as mangrove swamps and mud flats, coastal dunes, sandy beaches with muddy shoals sometimes exposed at low tide. The Sierra Leone coast is swampier with patches of sandy and rocky beaches. The eastern coast is rocky with ridges while the western coast is marshy and swampy with mangroves. In like manner, the Liberian coast is a rocky one with a mélange of rocky outcrops and as a result, there is almost total lack of natural port sites (Gnielinski, 1972, in Bird & Schwartz, 1985). This notwithstanding, the coastal zone is 16-58 km wide and in several places is covered with unconsolidated sand, clay and gravel deposits of the Quaternary age (Schulze, 1973, in Bird & Schwartz, 1985). Other coastal regions on the African continent including Ghana have both rocky and sandy beaches.

The coastline of Ghana as said earlier, is about 600 km of which 280 km (46.7%) is entirely sandy (Dei, 1972, in Bird and Schwartz, 1985:591). The sandy beach is mostly made up of fine sand. The sandy beaches are interspersed with rocky beaches which is 53% of the coastline. Between 1969 and 1973, Dei, (1975) traversed the entire rocky shoreline of Ghana on different occasions and gives the following description:

From Axim to Princesstown, consists of Birimian outcrops of granite. This also extends to Dixcove all in the extreme west of the country. Takoradi and Sekondi are made up of Sekondi Sandstone. The immediate east of the Sekondi Harbour is sandy but becomes rocky around the Turtle Cove area. Komenda is made up of Sekondi Sandstone especially around the Gold Hill beach. Both the *eastern and the western parts of Gold Hill are sandy. Feldspathic Elmina Sandstone is found at Elmina. From the Elmina Castle eastwards towards the Cape Coast castle, a sandy beach is predominant. Between the Cape Coast Castle and Ekon (Queen Ann's Point), outcrops are mainly granite, pegmatite and metamorphosed schist* (Dei, 1975).

Other rocky shorelines identified were located at Moree, Saltpond, Apam, Winneba, Senya Bereku, parts of Accra, Tema, Kpone and Prampram, among others Dei, 1975). The Accra-Tema beach, according to McCallen, (1962) is said to be iron-cemented beach with sand preserved on a rock bench. The eastern coast is dominated by the Volta Delta. The delta sediments according to Dei (1975), are marine, fluvio-marine and fluvial, and occur up to a depth of 170 m below sea level. Mudstone and cretaceous shales have been located at over 200 m depth (Ghana Public Works Dept., 1960, in Bird & Schwartz, 1985). The researcher observed upon a visit to the Volta estuary that the delta is no more in existence due to intense erosion. Thus, it can be said that in recent times, the Volta Estuary is devoid of a delta due to intense erosion as was identified by Dei, (1975) when he puts it "particle shape analysis indicates an increase in wave energy from west to east which may be responsible for the erosion in the Volta Delta zone".

Armah (2005) also classified the coastal zone of Ghana into three geomorphologic zones. These are west coast which is about 95 km and made up of fine sand, gentle beaches with coastal lagoons. The other is the central coast, about 321 km. It is embayed with rocky headlands, rocky shores, littoral sand barriers with coastal lagoons while the last category is the east coast. This is about

149 km with sandy beaches and the estuary of the Volta River. The ensuing section of this chapter reviews literature on coastal erosion, grain size and sedimentation.

Coastal Erosion, Grain Size and Sedimentation

The intensity of sea erosion and sedimentation can be determined through the size, shape, roundness and flatness of grains and pebbles (particles). Grain size refers to the particles less than gravel that are found within sediment. With erosion and sedimentation, the simple rule is that generally, a greater proportion of finer grains may be pushed higher up the beach by waves while coarse grains are deposited closer to the water (Masselink, Hughes & Knight, 2011; Komar, 1998, 1977). What this means is that in the analysis of grains to determine the rate of erosion, the tendency is that larger particles are deposited closer to the shore but as distance increases from the shore inland, the particles get smaller and smaller or finer. It is based on Wentworth, (1922) grain size classification. This is used for measuring and classifying grain size for sand and other beach particulates. It uses geometric interval of ½ to determine the limit of each size fraction. According to the Udden Wentworth Scheme of grain size classification, from the shore, boulders will be deposited first followed by gravel, sand and mud. There are intermediate particles from very coarse to fine particles. This helps to classify sediments into various sizes and categories or types based on the rate of coastal erosion and wave energy. Thus, the scale helps to know which parts of the sediments are boulders, gravel, sand and mud with their sub types and sizes in mm.

Grain shape refers to the form of the outer edges or surfaces of pebbles. Roundness is related to wear during transport and may be considered partly as a measure of the susceptibility of rock particles to erosion provided there are no serious or severe breakages. Pebbles of different mineral content respond differently to the processes of erosion. As a result, pebbles of similar characteristics and roughly the same sizes are selected. The smoothness, even and level surfaces (flatness) as well as sharp angular shapes (asymmetry) and other shape parameters of pebbles are also related to wear and susceptibility to erosion. Roundness refers to the three-dimensional shape of the grain that considers the roundness of grain corners and protrusions. The degree of roundness, according to Masselink, Hughes & Knight (2011, pp: 113-114), usually indicates the susceptibility of the grain to channel weathering and or the degree of mechanical abrasions it has experienced. Angular grains often indicate resistant minerals or a depositional site that is close to source. Well rounded grains indicate either easily weathered minerals, energetic environments where there is active mechanical abrasion or a depositional site that is far from the source. The indices of roundness and flatness have been used by Cailleux and Tricart (1959), Tricart (1965), Cestre and Cailleux (1969-70), Dei (1975) and modified by other authorities. These have proven to be very appropriate for morphometric analysis. Thus, grain size and shape parameters are the most important determinants of sedimentation along the coast. Grain roundness also influences the sediments friction angle and packing.

The term "coastal sediment processes" refers to the forces that erode, transport and deposit sediments along shorelines. Sediments according to Sverdrup, Duxbury & Duxbury, (2003) are particles from living organisms, the land, the atmosphere and sea itself that are accumulated on the sea floor. The coastal environment consists of constantly changing conditions, caused by the forces of wind, waves, currents and tides. Beach sediments are made up of various materials including sand, gravel, boulders, plastics and the like. Sand is the dominant material of beach sedimentation. Beach sand can appear fairly uniform, but it is actually a complex mixture of substances with various sizes and densities and it comes from both biotic (living) and abiotic (non-living) sources. Living sources include coral, algae, mollusks and bryozaons. Non-living sources include rocks such as igneous, sedimentary and metamorphic. According to Langland and Cronin (2003), sediments are solid materials such as soil and rock fragments transported and deposited by wind, water or ice; chemically precipitated from solution; or secreted by organisms. Sediments may also be particulate organic and inorganic materials.

In temperate regions, many sources are deposits of glacial till (mixtures of clay, sand, gravel, and cobbles left behind). Seaside cliffs or bluffs composed of glacial till are eroded by the combination of waves and high tides. Inland glacial deposits can be eroded by water and deposited in the ocean by rivers and streams. In tropical areas, deposits of the shells and skeletons of marine organisms contribute to the formation of white sand beaches. Deposits of volcanic ash and lava create black sand beaches in some areas. In areas near inland deserts, offshore winds can transport sand into the ocean, where it is later washed up on the shore. Streams and rivers also erode large amounts of sediment into the lithoral zone and the shore. For example, erosion from upland surfaces and erosion of stream corridors are the two most important sources of sediment coming from the watershed in the Chesapeake Bay (Langland & Cronin, 2003). "The primary sources of fine-(clay and silt) and coarse (sand and gravel)-grained sediments into the main bay are input from the main rivers in the watershed, erosion from smaller tributaries and streams, erosion from shorelines and coastal marshes ocean input at the mouth of the bay and internal biogenic products of skeletal and organic material" (Langland & Cronin, 2003). Thus sediment erosion is a natural process influenced by geology, soil characteristics, terrestrial habitat cover (land cover), topography and climate. From the above, it can be deduced that though there are various sources of sediments, it is also imperative to state that location is the most important factor that will determine the major source of sediment to a particular coastline.

Corso & Joyce (1995:39) thus classify marine sediments based on the origin. They identify about four types based on the origin of the materials that make up the sediments. The types are lithogenous sediments, biogenous sediments, authigenous sediments and cosmogenous sediments.

Lithogenous sediments according to Corso & Joyce (1995) are derived from the mechanical and chemical erosion of existing rock, which can be igneous, metamorphic or sedimentary. They are mostly found in deep sea and are principally derived from the erosion of continental rocks but also are derived from the erosion of submarine rocks. They vary from boulder-sized to clay-sized particles. Their distribution is influenced by their grain size. Larger particles tend to be transported through water movements, that is rivers and ocean currents and tend to be deposited near continents. Finer materials are transported via wind and accumulate in the deep ocean. They are also influenced by the chemical composition of the rock. Some are easily eroded by chemical processes (for example, feldspar) while others are resistant to chemical processes and are broken down only by mechanical processes (for example, quartz).

Biogenous sediments according to Corso & Joyce (1995) are the remains of plants and animals which consist of microscopic shells, which marine geologists call tests. These are the primary type of sediments which form major reservoirs of important elements like carbon. According to these same authors, biogenous sediments vary in size and mainly consist of calcium carbonate ($CaCO_3$) or silicon dioxide (SiO_2). The chemical composition of biogenous sediments is thus siliceous and calcareous in nature. Biogenous sedimentation is mostly influenced by ecological factors due to its chemical composition. For example, high inputs of nutrients and physical processes that mix nutrients throughout the water column will results in high rates of biogenous sedimentation. Their distribution is thus influenced by the ecology of the location. For example, coral reefs which are examples of biogenous sedimentation are mostly deposited on continental shelves in equatorial latitudes. Reefs are cemented accumulations of calcareous skeletal debris that form wave-resistant, topography.

The other types of sediments identified by Corso & Joyce (1995) are authigenous and cosmogenous sediments. Authigenous sediments according to them are chemical precipitates (solids that result from the chemical reactions of substances dissolved in seawater); they also are called hydrogenous sediments. They mostly tend to form in specific areas of the ocean basins and are not carried far away from their origin (for example, around hydrothermal vents and on abyssal plains). Some examples of authigenous sediments are ferromanganese deposits, phosphorite deposits and metal sulfide deposits, among others. Authigenous sediments are the main source of salt which is a major export commodity of many tropical countries.

Cosmogenous sediments are particles that have fallen into the water from outer space. They are rare and make up less than 1% of the total volume of marine sediments but provide evidence of meteorite impacts. These consist of small spherules of iron and silicate minerals. Rates of lithogenous and biogenous sedimentation are much greater than cosmogenous sedimentation, even though tons of cosmogenous materials accumulate on earth's surface each year; thus, spherules are mixed with and diluted by these other sediments (Corso & Joyce, 1995:42).

Based on the classification above, it can be deduced that though every beach is made of sediments, these sediments if carefully examined will show a lot of differences and in some instances similarities based on the origin, chemical composition and the ecological environment that the sediment is located. Though origin of the sediments, as espoused by Corso & Joyce (1995) has the greatest influence on the type of sediments and hence the extent of sedimentation, that alone may not be enough for general classification and types of sediments. It must be noted that even the influence of climate and effects of sea erosion and transportation can determine the type, composition and distribution of sedimentation along the beach. Thus, this writer believes that any of the sediment types identified above irrespective of their origin may have different characteristics from the origin due to differences in climate and the rate at which they are acted upon by sea erosion and transportation.

Thus according to Sverdrup, Duxbury & Duxbury (2003), geological oceanographers classify sediments by particle size, location, origin and chemistry. This is distinguished from Corso & Joyce (1995) who classify sediments only based on origin. Though a careful scrutiny of their classification model incorporates all these, they are not explicitly stated. It is thus imperative to identify the size and its sub-types, location, origin and chemical composition of sediments so as to bring the different dimensions.

Sediments are therefore classified by size from the largest particles such as gravel through sand to the smallest particles such as mud and clay (Wentworth, 1922; Sverdrup, Duxbury & Duxbury, 2003). The size of particles in this classification is with reference to diameter in millimetres. This formed the basis of particle size analysis for this research. Particle size influences the deposition of sediment by the horizontal distance it is transported before settling out of the water and the rate at which it sinks. In general, it takes more energy to transport large particle than it does for small particles (Sverdrup, Duxbury & Duxbury, 2003). In the coastal environment, when poorly sorted sediment is transported by wave or current action, the larger particles will settle out and be deposited first, while the smaller particles may be carried farther from the coast and deposited elsewhere.

The location, source and chemical composition of sediments are very important in their classification. With location, sediments are either neritic, found near continental margins and islands and have a wide range of particle sizes or pelagic, found on deep-sea floor. Pelagic sediments are also made up of fine-grained particles. The source and chemical composition may be related because the source to a large extent determines the material from which the sediment is formed and hence the chemistry of the particles. For example, sedimentary particles may come from one of four different sources such as preexisting rocks, marine organisms, the seawater itself or from space. Thus those from a particular rock are expected to have similar chemical composition. On the other hand, the chemical composition of sediments from the same source may differ due to processes like weathering, especially chemical weathering which is capable of altering the chemical composition of rocks. Thus sediments derived from igneous origin can have different chemical composition under different climatic environment due to the effects of weathering and other physical and even anthropogenic factors. Much as Sverdrup, Duxbury & Duxbury (2003) also categorize sediment types into four main classes as identified by Corso & Joyce (1995). They also went further, and based on source, identified areas of significant deposit with examples. For example, they posit that, lithogenous sediments are from eroded rocks, predominantly neritic, pelagic in areas of low productivity and examples are coarse beach and shelf deposits, turbidites and red clay. Hydrogenous sediments on the other hand, are mostly found in mid-ocean ridge, and areas starved of other sediments types with examples as metal sulfides, manganese nodules, phosphates and some carbonates (Sverdrup, Duxbury & Duxbury, 2003:119).

Understanding sand composition and the distribution of grain sizes can help in understanding the coastal processes shaping the coastline in a particular area. Higher-energy waves produce beach surfaces with a relatively homogeneous, or similar grain size distribution, whereas lower-energy waves produce surfaces with a more heterogeneous or mixed, size distribution (Spaldling, Duncan & Norcross-Nu'U 2009). At a particular beach, a greater proportion of finer sand grains may be pushed higher up the beach by waves while coarse grains are deposited closer to the water (Komar, 1977). A simple rule of thumb is that beaches exposed to high wave energy (longer wavelengths) tend to have coarser sediments than those exposed to lower wave energy. Beaches, however, are complex and highly variable environments, and there are conditions under which this rule does not hold true. Some of the conditions are the steepness of the beach may affect the intensity of the wave energy and thus influence grain size distribution and sediments transport (Anfuso & Gracia, 2005).

Other factors influencing grain size include the near shore and offshore bathymetry (depth), bottom type, sand source, currents, wind exposure and coastline shape. Sediments availability is a critical factor in determining beach characteristics and beach sediments often represent past conditions that are out of sync with current wave conditions. It could be realized that much beach material especially sand on the beaches today, was deposited by waves thousands of years ago.

Sediment Budget could be used to assess shoreline change and it involves the evaluation of the sediment mass balance, or sediment budget, for a given portion of the coast (Komar, 1977). Using this method, the gains (accumulation) and losses (erosion) of sediment to a portion of the shore, often referred to as a control volume, are quantified and evaluated based on estimates of beach volume change (Gornitz, 1991; Thieler & Hammar-Klose, 1999). Changes in the volume of sand for a particular setting can be identified and evaluated with respect to adjacent portions of the shore and to changes in shoreline position over time.

One challenge related to this method is obtaining precise measurements that minimize error since small vertical changes over these relatively low gradient shoreline areas can result in large volumes of material (Thieler & Hammar-Klose, 1999). To apply this approach, accurate measurements of coastal landforms, such as beach profiles, dunes, or cliff positions, are needed. Collection of such data, especially those on the underwater portions of the beach profile, is difficult. In addition, high density measurements are needed to evaluate changes from one section of the beach to the next. While the results can be useful to understand where sediment volume changes occur, the lack of quality data and the expense of collecting the data limit the application of this method in many areas (Thieler & Hammar-Klose, 1999). Sedimentation has a lot of effects on the coastal zone. It affects estuaries, bays, coastal vegetation and fauna as well as human activities along the coast. Sediments can reduce water clarity and increase light attenuation such that light penetration commonly is below the thresholds needed to support healthy submerged aquatic vegetation. Excess sedimentation can also have effects on ecosystems. For example, sediment can carry toxic contaminants and pathogens that may negatively affect fisheries and other living resources. *Excessive sedimentation can also degrade the vitality of oyster beds and other* bottom dwelling organisms in water.

Sea Level Changes and Coastal Erosion

Mean sea level is the average of the position of the sea surface over a long period of time. It is the average elevation of the sea which is observed over a long period of time. Thus mean sea level is not a static point with the same elevation everywhere but currents and variations in the gravitational attractions between the water and the crust cause the level to vary in different parts of the ocean. According to Spencer (2003), there are both short-term and long-term changes in sea level. The long-term is variations for centuries and more while shot-term can within minutes. Physical climatic systems cause short-term variations through waves, currents, tides, changes in atmospheric pressure and changes in ice, that is water balance. Long-term changes are caused by plate tectonic systems through changes in size and shape of ocean basins, addition of water from earth's interior and isostatic adjustments of lithosphere.

Sea level is rising worldwide and it is caused by both natural and human factors. Most research indicates that sea level is rising by approximately 6 millimeters a year (Warrick & Oerlemans, 1990). Although annual rate of 6 millimeters seems to be a relatively small amount of change, a small increase in sea level can have devastating effects. Other factors such as glacial isostatic adjustment are causing coastal lands to sink, increasing the rate of SLR for those areas. Since more than 75 % of the human population live within about 60 kilometers of the coast it is important that the effects of any change in sea level rise are studied (Hinrichsen, 1995; Goldberg 1994, cited in Viles & Spencer, 1995; Michener, Blood, Bildstein, Brinson & Gardner, 1997).

Global sea level can change due to expansion or shrinking of ocean water due to changes in climate and periods of worldwide glacial advance and retreat (Davis, 1997). Human impact has no control over changing the volume of the ocean basins. However, the greenhouse effect can cause the ocean to gather thermal inertia that will heat the continents and slowly melt the polar ice caps, increasing sea level worldwide (Michener et al., 1997). The effects of sea level rise will be spatially non-uniform since glacial isostatic adjustment will cause some areas to uplift and others to subside (Gornitz, 1991). Furthermore, the characteristics of a given coastline are controlled by many different variables, including interactions between lithology, geomorphology, wave, climate, currents and storm frequencies. The IPCC reports that a centimetres rise in sea level erodes beaches about a meter horizontally. This becomes a large issue for developed beaches that are less than 5 metres from the ocean (IPCC, 2000). In addition, rising sea level would create larger storm surges that would quicken the rate of beach erosion; an intense storm can erode enough shore to change its entire profile in one year (Dubois, 1990). Dubois' research has shown that observed values of beach erosion were two to three times greater than the erosion predicted for that year. Dubois suggests that Bruun's theory and rising sea level may be the primary force responsible for observed erosion rates. Bruun's rule states that "a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth" (Bruun, 1962). Bruun's rule can be applied to correlate SLR with eroding beaches which is effective on sandy beaches.

With present rates of sea level rise, 70 % of the world's sandy beaches are eroding and retreating (Bird, 1993; 1985). If the rate of sea level rise continues to increase, the loss of beach to coastal erosion will increase. Rising sea level would allow saltwater to penetrate farther inland and upstream (IPCC, 2000; Aubrey et al., 1993). Higher salinity impairs both surface and groundwater supplies. This effect would impair water supplies, ecosystems, and coastal farmland. Saltwater intrusion would also harm some aquatic plants and animals as well as threaten human water supply (Day et al., 1993). In humid equatorial climates, gradual sea level rise would cause a brackish-water zone to migrate inland (Gornitz, 1991). Salinity has also been found to decrease seed germination in a variety of wetland species and higher salinity may decrease breeding of seed bank species (Baldwin et al., 1996). In addition to damage to ecosystems, SLR promotes saltwater intrusion into coastal aquifers (Day, et al., 1993).

Although the IPCC lists five impacts as the main consequences of SLR there are many others. SLR has a profound effect on the rate of sedimentation for different parts of the coastal gradient. Peak rates of sedimentation occur at higher elevations and less sedimentation occurs on the lower elevations. Varying of sedimentation rates will result in changing vegetation zones and succession on marshes (Olff, Leeuw, De Bakker, Platerink, Wijnens & De Munck, 1997). In addition, storm surges would force large quantities of shore-face sediments through inlets and create tidal deltas on which barriers would later transgress (Dubois, 1990).

Variations in sea level may be either a rise or fall. Each of these comes with its own consequences. From the recent evidence on climate change, sea level rise seems to be on the ascendancy. According to the US Geological Survey (2004), by the year 2100 the rate of global sea-level rise (SLR) may increase to over 10 mm/year (high scenario), which would represent a sevenfold increase over present rates. Local increases could be still greater, depending on local subsidence factors. Coastal zones are particularly vulnerable to climate variability and change. A lot of concerns have been expressed due to the consequences sea level changes especially rising sea level from climate variability can have on coastal environments. Continued and or accelerated sea level rise due to climate change will lead to increased coastal erosion in the future. This will eventually have implications relating to land loss, changes in marine storms and flooding, sedimentation and response to sea level rise.

Sea level rise is a global phenomenon. It is mainly due to increase in temperatures. According to the United States Environmental Protection Agency (EPA-US, 2011), higher temperatures are expected to further raise sea level by expanding ocean water, melting mountain glaciers and small ice caps, and causing portions of Greenland and the Antarctic ice sheets to melt. The Intergovernmental Panel on Climate Change (IPCC) estimates that the global average sea level will rise between 0.6 and 2 feet (0.18 to 0.59 meters) in the next century (IPCC, 2007). While current model projections indicate substantial variability in future sea level rise at regional and local scales, the IPCC has concluded that the impacts are "virtually certain to be overwhelmingly negative" (IPCC,2007).

The potential impacts of accelerated SLR include the permanently inundated portions of the coastal zone to an elevation equivalent to the vertical rise in sea level. The increase in sea level will also increase the likelihood of episodic flooding events and will cause tidal prisms to be altered (thus changing tidal ranges). Finally, increasing salinization of coastal aquifers and upstream penetration of saltwater resulting from the SLR could contaminate drinking water supplies and adversely affect agriculture. "Rising sea levels inundate wetlands and other low-lying lands, erode beaches, intensify flooding, and increase the salinity of rivers, bays, and groundwater tables" (EPA-US, 2011). The effects of the global SLR on the shoreline, however, will vary spatially because of the presence of local vertical crustal movements, differential resistance to erosion, varying wave climates, and variations in longshore currents and sediment supplies (USGS, 2004).

Studies by Romine & Fletcher, (2013) on the shoreline of Hawaii isolated sea-level rise as a principal cause of coastal erosion. They indicated that globally, average sea level rose to about 2 mm per year over the past century. The rate of rise is now approximately 3 mm per year and may accelerate over the coming decades. They identified SLR as an important factor in historical shoreline change and will be increasingly important with projected SLR acceleration in this century. Much as the above assertion confirms the fact that sea level rise leads to shoreline recession, other influences on shoreline change such as waves, sediments supply and littoral processes with anthropogenic changes need to be examined carefully. This is because location of shorelines can make a difference since different coastline will respond differently to SLR hence it may not be a major factor to bring about massive change in certain coastal environments.

Landmass Change

Landmass refers to a large continuous area of land, either surrounded by sea or contiguous with another landmass. Collins Dictionary defines landmass as "a large continuous area of land as opposed to sea or island". It is therefore used to mean a large area or part of land that is near or adjacent to another land. Thus, a landmass can be a continent, a country or part of it. From the above, landmass can therefore be defined as the total surface area of land, a geographical region or country. Landmass in the context of this research is therefore used to mean a large area or part of it which is adjacent or close to another land or water. Thus, the coastal landmass which is under study is that part of the land including the coastline or the shoreline, the beach, coastal landforms and features and the land cover of the coastal environment in general. It is demarcated from the coastline to 30 meter-contour inland.

Landmass change according to de Blij & Muller (1993), is the variations or changes that occur in the unique physical properties of the land. It can be a continental landmass or a well demarcated expanse of land. In the context of this research, landmass change refers to the variations that occur in the land of the coastal environment. It includes changes in the shoreline and land cover, landforms and features that make up the coastal zone. It thus includes changes that have occurred in the coastline to 30 meter contour inland. Review of related literature on landmass change is thus restricted to shoreline change and land cover change.

Shoreline Change and Beach Loss

Shoreline which in this text is used synonymously with coastline is the boundary between the land and the sea. It is the line of contact between the land and the water body (Alesheikh, Ghorbanali & Nouri, 2007). Coastline is one of the most important linear features on earth's surface which has a dynamic nature (Alesheikh et al., 2007). The natural character of coastlines is to constantly change and move landward, that is advance or seaward, that is retreat.

Shoreline change is thus the variations or movements that occur along the coast causing it to advance towards the land or to retreat further into the sea. Shorelines or coastlines keep changing their shape and position continuously due to dynamic environmental conditions. The change is mainly associated with waves, tides, winds, periodic storms, sea level change, and the geomorphic processes of erosion and accretion and human activities. According to Gibeaut, Hepner, Waldinger, Andrews, Gutierrez, Tremblay & Smyth, (2001), "the changes are caused by changes in the forces that move the sand, namely wind, waves, and currents and by the supply of sand while short-term and long-term relative sea-level changes also control shoreline movements". Waves, for instance, change the coastline morphology and form the distinctive landforms. The coastline of Ghana like many in the rest of the world has changed over the years in response to changes in the natural environment (Boateng, 2009). Such changes have occurred over a wide range of temporal and spatial scales that reflect influences such as movement of the earth crust, and variations in sea level and climate. The physical shoreline change is also influenced by coastal engineering structures and other human activities.

Changes in sea level either through tectonic activities, climate change and any other factor such as those identified by Waugh, (1995) and adapted as conceptual framework for this study will cause changes along the coast. Tectonic activities, for instance, may cause an advancement of the shoreline when there is an upliftment of the sea floor while there will be a retreat of the shoreline when there is upliftment in the land bordering the sea. Thus, isostatic movements will cause changes along the coast or the shoreline. Human activities also have a lot of influence on the movements or changes along the shoreline. Human activities such as sand mining, stone quarrying and removal of vegetative cover as well as sea defences contribute to shoreline change. With reference to the area under study, though commercial sand mining is banned, the activities are still going on. For example, between Cape Coast and Ekon, building blocks are produced right at the beach. Stone quarrying on commercial basis is done at the beach between Cape Coast and Ekon. These have significant effects on the shoreline.

Shoreline change may occur periodically and may also be a continuous process. Thus to understand and determine the rate of shoreline change along a particular coast, the setting of the shoreline and the supply of sand become important determining factors. Setting, according to Gibeaut, et al (2001), refers to whether a beach is sheltered from waves, adjacent to a tidal or storm channel or next to a jetty or seawall. Gibeaut, et al; (2001) therefore, identify three types of shoreline change, namely, short-term change, long-term change and episodic change.

Short-term shoreline change according to Gibeaut, et al; (2001) is the movements occurring over several seasons to 5 or 10 years. It is shoreline change that occurs over about 10 years or less and that may be in the opposite direction of the long-term trend. It is difficult to understand and predict because it is variable in nature. One portion of the coast may be experiencing retreat while just a few kilometres away stable or advancing conditions may prevail.

Long-term shoreline change, on the other hand, occurs over tens to thousands of years. It is the changing of sea level relative to the land and the increase and decrease in sand supply to the coast that cause the shoreline to retreat or advance over a period of about 50 years or more. Shoreline change as has been said earlier may not always be a continuous and steady process but may be periodic or episodic. Episodic change is that which occurs in response to a single storm (Gibeaut, et al 2001). Tropical storms, hurricanes, tsunamis and periodic storm surge can move the shoreline landward in a day for several meters. For example, "during Hurricane Carla in 1961, foredunes on Mustang Island were eroded back 50 to100 m" (Hayes, 1961, in Gibeaut, et al; (2001). There is often dramatic recovery for months and years following a storm, but it is usually incomplete, and the shoreline remains significantly landward of its pre-storm position. According to Gibeaut, et al; (2001), "even though shoreline change rates are given as annual rates, they must be considered "average" annual rates. This is because a particular shoreline with a long-term retreat rate of 2 m/yr would be expected to be 120 m landward in 60 years yet a single storm, however, could cause much of this movement".

It should also be worth noting that the rate of shoreline change may differ from coast to coast due to differences in natural and anthropogenic characteristics of the various coastlines. For example. in the US, shorelines are receding at an average rate of 0.8 m/yr yet there are differences among the various coastal regions. For example, erosion rates vary from 0.0 m/yr along the Pacific Coast to 0.8m/yr along the Atlantic and 1.8 m/yr along the Gulf Coast (May et al., 1983). Dale et al., (1995) agreed with May et al., (1983) when they stated that *significantly, rates may vary drastically on a local basis where they depend on geology, wave and climate. This means that the nature of rocks found along the coast, the energy of the waves and influence from climate are responsible for different rates of sea erosion and shoreline recession. These notwithstanding, the influence of anthropogenic factors cannot be underestimated. This is an important factor in areas where there are uncontrolled human activities such as sand* *mining and quarrying.* The importance of climate and anthropogenic factors in shoreline erosion is also affirmed by Kuhn & Shepard (1983), when they concluded that coastal erosion is episodic, site specific, strongly related to meteorological conditions and influenced by human factors.

A changing global climate combined with intense human activity imposes additional stresses on coastal environments. Although the climate is warming at a global scale, the impacts and the timing of the impacts are highly variable across coastal regions. Some effects, such as rising sea level, are already evident in increased erosion of beaches, more frequent flooding from both rivers and tidal surge, and wetlands converting to open water. Sea surface temperatures have risen over much of the globe, and hurricane activity has increased over the past several decades, particularly in the Atlantic basin, although it is uncertain whether these storm changes exceed the levels expected from natural causes. In addition, increased uptake of atmospheric carbon dioxide by the oceans has increased ocean acidity that threatens coral reefs and shellfish. The primary driving forces are: sea-level rise, changes in temperature, precipitation, major storm events including waves, winds and currents, and changing ocean circulation patterns. These driving forces interact in complex ways with the landforms and infrastructure that make the coasts particularly vulnerable to many of the impacts of climate change.

A major challenge facing the planet Earth and its resource in the next century is the changing climate; its impacts on our life sustaining resources and our ability to adapt to the change (IPCC, 2007). The outcome of many scientific researches indicated that climate change has varying impacts raging from physical, environmental, economic to social dimensions. On coastal regions, the biggest danger, many experts warn, is that climate change is causing sea levels to rise increasingly rapidly. This poses global problems because majority of the world's population lives in coastal areas. Sixty percent of the world's 39 metropolis with a population of over 5 million are located within 100 km of the coast, including 12 of the world's 16 cities with populations greater than 10 million (IPCC, 2007). Some of the possible impacts of sea-level rise on the coastal zone include:

1. Increased inundation (flooding) of coastal land, which may cause loss of life and property
2. More frequent storm-surge flooding, which may cause destruction of life, property and beaches and severe shoreline erosion e.g Hurricane Katrina;
3. Accelerated coastal erosion, which may also cause destruction of coastal properties and possibly loss of life;
4. Seawater intrusion into fresh and groundwater sources thus reducing the supply of fresh water in coastal towns;
5. Altered tidal range in estuaries and tidal river systems which may destroy estuarine ecosystems; and change in sedimentation pattern (IPCC, 2007).

According to the IPCC Third Assessment Report (TAR) (IPCC, 2001), coasts are experiencing the adverse consequences of hazards related to climate and sea level. Coasts are highly vulnerable to extreme events, such as storms, which impose substantial costs on coastal societies. Annually, about 120 million people are exposed to tropical cyclone hazards, which killed 250,000 people from 1980 to 2000. Through the 20th century, global rise in sea level contributed to increased coastal inundation, erosion and ecosystem losses, but with considerable local and regional variation due to other factors. Late 20th century effects of rising temperature include loss of sea ice, thawing of permafrost and associated coastal retreat, and more frequent coral bleaching and mortality (IPCC, 2001).

Also, coasts will be exposed to increasing risks, including coastal erosion, over coming decades due to climate change and sea-level rise. Anticipated climate-related changes include: an accelerated rise in sea level of up to 0.6 m or more by 2100; a further rise in sea surface temperatures by up to 3°C; an intensification of tropical and extra-tropical cyclones; larger extreme waves and storm surges; altered precipitation/run-off; and ocean acidification. These phenomena will vary considerably at regional and local scales, but the impacts are virtually certain to be overwhelmingly negative (IPCC, 2001).

In Ghana, different scenarios for the estimation of current and forecasted sea level rise in the Gulf of Guinea are being developed. Trends on Ghana obtained using nationally observed climate data for the period of 1960 to 2000, coupled with regional climate models together with IPCC scenarios indicate that:

1. Estimated temperature will continue to rise by on average about 0.6°C, 2°C and 3.9°C by the year 2020, 2050 and 2080 respectively.
2. Rainfall is predicted to decrease on average by 2.8%, 10.9% and 18.6% by 2020, 2050 and 2080 respectively in all agro-ecological zones except the rainforest zone, where rainfall may increase.

3. A projected sea level rise (SLR) of 1m by 2100 could see the loss of over 1000km^2 of land, with 132000 people likely to be affected. The east coast is particularly vulnerable to flooding and shoreline recession (UNEP/UNDP, 2012)

While it is approved that the SLR is considered a serious risk, changes in extreme sea levels are perhaps more important than mean sea level rise as they pose significantly higher risks to coastal regions. Extremes are related to non-exceptional atmospheric and environmental conditions related to climatic change (extreme weather, wind stress, cyclones, etc.). Other parameters, having less impact to be included in the assessment of SLR, are the tide effect, and normal weather conditions (IPCC, 2001). Extreme weather conditions will also pose risks to businesses and other economic sectors, especially in coastal areas due to sea level rise.

Employment, recreation, tourism, water-based commerce, energy and mineral production are driving forces of population migration to coastal areas (Heinz, 2000). Coastal population growth in many of the world's deltas, barrier islands and estuaries has led to widespread conversion of natural coastal landscapes to agriculture, aquaculture, silviculture, as well as industrial and residential uses (Valiela, 2006). It has been estimated that 23% of the world's population lives both within 100 km distance of the coast and less than 100 m above sea level, and population densities in coastal regions are about three times higher than the global average (Small & Nicholls, 2003). The attractiveness of the coast has resulted in disproportionately rapid expansion of economic activity, settlements, urban centers and tourist resorts. Migration of people to coastal regions is common in both developed and developing nations. Rapid urbanization has many consequences; for example, enlargement of natural coastal inlets and dredging of waterways for navigation, port facilities, and pipelines exacerbate saltwater intrusion into surface and groundwater, all of which affects the coastline.

The direct impacts of human activities on the coastal zone have been more significant over the past century than impacts that can be directly attributed to observed climate change (Scavia et al., 2002; Lotze et al., 2006). The major direct impacts include drainage of coastal wetlands, deforestation and reclamation, and discharge of sewage, fertilizers and contaminants into coastal waters. Extractive activities include sand mining and hydrocarbon production, harvests of fisheries and other living resources, introduction of invasive species and construction of seawalls and other structures. Engineering structures, such as damming, channelisation and diversions of coastal waterways, harden the coast, change circulation patterns and alter freshwater, sediment and nutrient delivery. Natural systems are often directly or indirectly altered, even by soft engineering solutions, such as beach nourishment and foredune construction (Nordstrom, 2000; Hamm & Stive, 2002).

Effects of Shoreline Change

Coastal erosion has serious consequences on coastlines. One of the effects is the recession of shoreline and loss of beaches. It is not easy to quantify the impact of coastal erosion, shoreline change and beach loss as they affect the coastal zone in various ways. There are both positive and negative impacts. Coastal erosion is very important in various ways. It provides the beach with sediments which mostly come from the rocks and their related landforms. Without sea erosion, many of the world's biologically productive bays, estuaries, salt marshes and tidal flats would not exist. Erosion of glacial landforms, for instance, provides the primary source of sand and cobble for the beaches in temperate coastlines. It is also responsible for most of the beautiful sceneries in coastal communities that attract tourism including landforms. Some of these landforms are very common along the coastline under study.

From Ekon, through Cape Coast, Elmina, Komenda, Shama to Sekondi-Takoradi, wave action has contributed immensely to the numerous erosion landforms especially between Komenda and Sekondi. Around the coast of Komenda, the cliff face has been carved by waves into erosion features and landforms such as caves, blowholes, stacks and arches among others. Some of these features are continuously under the influence of waves while others due to the distance between them and the sea are mostly affected by sub-aerial geomorphic processes than wave action.

Sub-aerial geomorphic processes such as weathering and mass wasting become very effective along the coast where the gradient is very steep and the cliff is high above wave action. This is typical of areas where the gradient is very steep and the cliff is further and higher above water or wave action. An example of this, is the western side of the Komenda beach. Strong winds and high tides cause periodic storm surge which contribute immensely to the movements or change in shorelines. These have rapid effects, most especially, on sandy beaches.

Notwithstanding how beneficial coastal erosion may be, it is also not out of place to say that it is considered a major economic problem in most coastal communities. A lot of coastal communities are counting their losses to coastal erosion and beach loss. It ranges from destruction of property, physical structures, inundation of hitherto dry lands, loss of lives, contamination of fresh water and destruction of the aesthetic values of the coastal zone. For example, in Massachusetts, hundreds of millions of dollars of shorefront real estate is at risk due to both chronic, long-term erosion of coastal bluffs and episodic, short-term induced erosion of dunes and barrier beaches (O'Connell, 2002). The same report also states that in 1994, the US Army Corps of Engineers reported that *seventy four structures could potentially be lost in the next 50 years along Humarock Beach in Scituate as a result of erosion. Today, for example, many homes along the 100-foot-high coastal banks of southern Plymouth and the east shore of Nantucket are presently at high risk of loss due to long-and short-term erosion and slumping* (O'Connell, 2002). A beach erodes because the supply of sand to the beach cannot keep up with the loss of sand to the sea. Most sand is transported from inland through rivers and streams. Sand can also be transported from beach to beach along a shoreline but this is mostly just a redistribution of sand that is already on the beach.

The problem of beach loss can be exaggerated if sea level rises relative to the land (either due to true sea level change or geological sinking of the coastline). On an uninhabited shoreline, new beach can be created further inland but when the encroaching sea comes against people's property, the tendency is for people to try and stop the encroaching sea. In Ghana for instance, a lot of strategies have been put into fighting sea erosion along the beaches of Keta, Ada, Tema, Prampram, Accra, Cape Coast, Elmina, Shama, Sekondi, Takoradi and Nkontompo (and even other coastal communities outside Ghana). These are sea defences of various kinds such as seawalls, revetments and jetties among others but they seem to have negative effect on beaches. This is because once sea water reaches them; it "bounces" off them with more energy than a wave washing back off a normal sand beach. More sand is carried offshore promoting beach loss. Additionally, jetties placed perpendicular to the beach, distributing along-beach currents can cause sand loss downstream of the jetty. This writer believes that much as some of these sea defenses could be effective to manage the situation, most of them only remain as interim stop-gaps unless constant monitoring and reinforcement are done.

Land Cover Change

Land cover refers to the physical material found at the surface of the earth. It includes both natural and human made materials such as trees, buildings, grass, water, asphalt and any other object that covers the surface of the earth. The Food and Agriculture Organization (FAO) defines land cover as "observed (bio) physical cover on the earth's surface" (FAO, 2000). The FAO document on land cover classification systems, (2000) partly answers the question as to whether everything that is found on the surface of the land can be classified as a cover (land cover). "When considering land cover in a very pure and strict sense, it should be confined to describe vegetation and man-made features. Consequently, areas where the surface consists of bare rock or bare soil are describing land itself rather than land cover. Also, it is disputable whether water surfaces are real land cover. However, in practise, the scientific community usually describes those aspects under the term land cover" (FAO, 2000:1).

From the above, it can be deduced that what actually constitutes land cover could be somehow subjective. It could be sometimes defined by the observer's subjective thinking. This notwithstanding, it should be noted that the term land cover is all embracing. It is used to include whatever is found on the surface of the land including both natural and human-made materials. Thus, this writer agrees with the definition of Ellis (2013), when he puts it as follows "land cover refers to the physical and biological cover over the surface land, including water, vegetation, bare soils and or artificial structures". Land cover should however not be used synonymously or confused with land use since land use concerns the utilization rather than what is found on the land. Land use is thus characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it.

Thus, as the land is utilized, the cover is also modified, hence, land cover change. Land cover change according to Ellis (2013), is a generic term for the human modification of Earth's terrestrial surface. Though, humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. The changes encompass the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water, soils and air (Ellis, 2013). According to Yang (2001), human activities are increasingly altering the surface of the earth, yet, there are few landscapes remaining on earth surface which have not been significantly altered or are not being altered by humans in some manner. This means that, though, human activities are fast changing the cover of the earth; there are a few areas which may not have been affected. Ellis (2013), argued further that it is therefore, important to monitor and mediate the negative consequences of land cover change while sustaining the production of essential resources. This has therefore become a major priority of researchers and policy makers around the world (Ellis, 2013). Thus, from the above, it can be said that land cover changes have always been part of human societies since wherever humans are; they make their activities impact the environment. From the argument made by Ellis (2013), he is alluding to the fact that though land cover change had always been part of humanity, the extent and degree of changes far outweigh those of thousands of years back.

According to Ringrose, Vanderpat & Maheson, (1997), land use land cover change in Africa is currently accelerating and causing widespread environmental problems and thus, need to be mapped. In Ghana, sand mining, forest degradation and other human activities are fast changing the cover and use of land. For example, around the Oweri River in the Ashanti region, studies by

Frimpong, (2007) reveals a serious logging and clearing of the bushes in the catchment areas of the river to pave way for sand mining. Thus, with time, the cover on the land may be altered mainly through human activities. Thus this writer also believes that if the rates of changes and consequences are not checked, it could be more devastating in the future than the current situation.

Causes and Effects/Consequences of Land Cover Change

The physical surface of the earth is in constant change. Abundant water resources give rise to new growth, cities expand, what was once forest is converted to farmland. Man causes some of these transformations; others are merely the result of the changing of the seasons NASA, (1999). Land cover changes are basically caused by the direct and indirect actions of humans and nature. Thus, land cover change is caused by both anthropogenic and natural phenomena. Human actions are very essential through exploitation of resources. Ellis (2013) summarises the causes and consequences as follows; "*changes in land use and land cover date to prehistory and are the direct and indirect consequences of human actions to secure essential resources. This may first have occurred with the burning of areas to enhance the availability of wild game and accelerated dramatically with the birth of agriculture, resulting in the extensive clearing and management of Earth's terrestrial surface that continues today. More recently, industrialization has encouraged the concentration of human populations within urban areas and the depopulation of rural areas, accompanied by the intensification of agriculture in the productive lands and the abandonment* *of marginal lands. All these causes and their consequences are observable simultaneously around the world today*" (Ellis, 2013:6).

What one deduces from the submission above is that changes in land cover have been old phenomena due to the quest of humans to earn a livelihood. This had occurred through agricultural activities when societies were more primitive. Agriculture and other activities are still affecting the Earth's surface and with industrialization in modern society, there is a shift of population and human activities from the rural to the urban areas. With these, more productive lands are still being utilized while marginal lands are being abandoned. Thus, the causes and consequences occur around the world at the same time. This writer also believes that though land cover change is facilitated by the needs of the people, the rate and extent will depend on several factors such as the technology and the overall level of socio-economic development of the people, among others. Consequences of land cover change are thus manifested in biodiversity, changes or variations in climate, pollution and other environmental consequences.

Biodiversity is usually affected and often reduced by land use and land cover change. The changes come through several human activities such as lumbering, farming, mining, construction and other activities that disturb the ecosystem. For example, land can be transformed from primary forest to a farmland. This leads to loss of forest species. Generally, biodiversity loss and disturbance of the ecosystem occur whenever undisturbed lands are transformed to more intensive uses such as livestock grazing, intensive agriculture, industrial activities and human habitation. These activities can cause disturbances to plant and animal species, destruction of habitats and even general extinction. Research demonstrates that, species invasions by non-native plants and animals, and diseases may occur more readily in areas exposed by Land Use and Land Cover Change (LULCC), especially in proximity to human settlements (Ellis, 2013:6).

Land Use and Land Cover Change contribute a lot to variations or changes in climate at all levels. LULCC is partly, responsible for the release of Greenhouse Gases (GHG) into the atmosphere. This statement is supported by Pielke (2005), when he posits that "although the presence of greenhouse gases in the atmosphere is the best known impact of human activity on climate change, variations in land use and surface cover may be of equal importance in this perspective" (Pielke, 2005 :1). Ellis (2013) also argued that LULCC can increase the release of carbon dioxide to the atmosphere by disturbance of terrestrial soils and vegetation, and the major driver of this change is deforestation especially when followed by agriculture, which causes the further release of soil carbon in response to disturbance by tillage. He also argues that land cover changes that alter the reflection of sunlight from land surfaces (albedo) are another major driver of global climate change. Changes in climate may be in response to changes in cover by dense vegetation and built structures. *These changes alter surface heat balance not only by changing surface albedo, but also by altering evaporative heat transfer caused by evapotranspiration from vegetation and by changes in surface roughness, which alter heat transfer between the relatively stagnant layer of air at Earth's surface and the atmosphere. An example is the* *warmer temperatures observed within urban areas versus rural areas, known as the urban heat island effect* (Ellis, 2013:7).

It can thus be argued from the above submission that the impact of LULCC on climate stems from human activities that impact negatively on climate through the release of GHG into the atmosphere. These activities usually reflect the amount of carbon dioxide and oxygen that are in the atmosphere. These are reflected in activities such as farming, land clearing, human settlements and industrial activities among others. The impact of these activities differs from one location to the other since the extent of the activities is different.

Land use and land cover change are also important drivers of all forms of pollution. Land degradation, soil, air and water pollution are sometimes promoted by the kind of land use and the changes that are produced. Vegetation removal for instance, leaves soils vulnerable to massive increases in soil erosion by wind and water. Agricultural practices such as slash and burn releases pollutants into the atmosphere. Agricultural chemicals such as fertilizer, herbicides and pesticides pollute the soil and water bodies. In some cases they remain as contaminants in the soil. Mining can also produce impact such as pollution by toxic metals exposed in the process. The burning of vegetation biomass to clear agricultural fields (crop residue, weeds) remains a potent contributor to regional air pollution whenever it occur, and has now been banned in many areas (Ellis, 2013). Other environmental impacts of LULCC according to Ellis (2013) include the destruction of stratospheric ozone by nitrous oxide release from agricultural land and altered regional and local hydrology. He further posits that “perhaps the most important issue for most of Earth’s human population is the long-term threat to future production of food and other essentials by the transformation of productive land to non-productive uses, such as the conversion of agricultural land to residential use and the degradation of rangeland by overgrazing” (Ellis, 2013:8).

The methodology adopted for analyzing land cover change involves the acquisition, extraction, validation and processing of data. Aerial photographs are mainly demanded for periodic update from national base maps. Using aerial photographs as a source for generating land use/cover information, especially in the coastal areas, is therefore, justified by the availability of these photographs, accessibility to several time period, and their high resolution and geometric fidelity. Al-Tahir and Ali (2004) posit that the high resolution of aerial photograph increases the ability to identify features in the scene, which in turn improve the process of epoch-to-epoch image registration and minimize the error of registration. Based on this method, land cover categories, such as vegetation, built-up, water, wetland, bare land and farms, among others are generated. The ensuing paragraphs are devoted to discussions on the effects and control of coastal erosion.

Effects of Coastal Erosion

Coastal erosion will have significant effects on coastal habitats, which can lead to social and economic impacts on coastal communities. The impacts are also either negative or positive. Coastal communities will experience more frequent and destructive flooding, that is, coastal erosion is likely to inundate the coastal communities in a way that hitherto inhabited land will be taken by the sea. This is what has happened in most coastal communities. According to Othman (1994), nearly 30% of Malaysian coastline is undergoing coastal erosion. It is possible that if care is not taken, much of the land will be taken by the sea. Similar situations have occurred in some coastal communities in Ghana and elsewhere. Thus sea erosion can lead to loss of lives, destruction of settlements, destruction of farmlands and may also affect the vegetative patterns and landform associations along some shorelines. For example, Roman & Nordstrom (1988) statistically evaluated a number of geomorphic process variables and vegetation patterns along Assateague Island (40-km-long Barrier Island on the coast of Maryland and Virginia) and found significant correlation with long-term erosion rates. They found that there was a critical erosion rate threshold value 4.5 m/yr at which major changes in the vegetation and morphologic associations occurred, and that this rate was related to succession and recovery processes following disturbance by recent erosion. When vegetation is erased by erosion, succession occurs overtime. Thus the time frame or time history of erosion can be determined by mapping vegetation communities (Roman & Nordstrom 1988, in Dale et al., 1995:466). From the above submission, it can be said that sea erosion can destroy and also change the nature of plant species within certain coastal environment since different plant community can spring up after the original or the native vegetative cover is removed by sea erosion. This notwithstanding, it should be noted that the type of vegetation that succeed in any coastal environment will depend on factors such as the rate and duration of erosion and accretion and the climatic conditions among other factors that prevail in that particular area. It thus has negative impact on both socio-economic and physical environment.

Much as coastal erosion may be "branded" as a negative coastal process, it is also of great benefit to both humans and the natural environment. Coastal erosion is responsible for the development of coastal landforms such as cliffs, caves, blowhole and arch among others which are beautiful sceneries in the coastal environrnent as mentioned earlier in this chapter. These are important tourist attractions which could be or are enhanced for national development. It should also be noted that without sea erosion, there will be nothing like deposition. Thus erosion is an engine to deposition since it is the main source of sand along the beach.

Shoreline Protection and Management (Control of Sea Erosion)

Managing coastal erosion is a complex issue. This is because coastal erosion, sedimentation and beach loss can have complex effects on the composition and morphodynamics of the coastal zone. Due to the fact that the coastal zone is affected both negatively and positively by these activities, it is important to minimise the negative effect. Deciding on the best management approach is not simple and there are many factors that can be taken into account such as those identified by Waugh (1995) as follows: the causes and effects of the management approach, the people to be affected, the nature of the project, its technical and environmental viability, cost and benefit, among others.

These factors need to be analysed carefully regarding the decision to manage coastal erosion and its related issues. For example, the cost of installing hard structures for coastal protection is very high while strong negative public reaction to rock emplacements along the coast often aggravates the problem (Clark, 1995). It thus has the tendency of becoming an issue of serious debate among stakeholders. To manage coastal erosion, it is important to understand both the spatial and temporal time scales as well as human activities along the coast. This is because the coast is influenced by both physical and human factors which have spatio-temporal dimensions. It therefore follows that much as coastal erosion in itself creates a lot of problems to coastal dwellers, finding appropriate management practices to control it is also problematic.

There is a need to protect and control shoreline and sea erosion. This is because the coastal zone is home to millions of people. Property owners and coastal dwellers have made a lot of investment in these areas. The coastal zone is also the home of diverse flora and fauna. It is thus vital that residents and all stakeholders work to save the coastal zone. In protecting the shoreline and coastal zone, coastal dwellers need to understand that shorelines have been naturally changing over time as a result of the geologic processes that have controlled erosion and sedimentation for millions of years (Sea Grant, n. d.). According to this same source, these processes are governed by climate, geology, ocean currents, water-body depths and wind. An effort to try to prevent or reduce coastal erosion comes at a cost to the nation and property owners as well as coastal ecosystem. Another problem is that the stabilization structure likely will not provide life-long success unless people can understand the big picture of the geology and topography of the coast and the many variables that shape the coastline (Sea Grant, n.d.).

If property is located where erosion is occurring, it must be protected from erosion. The current trend in most coastal regions is to build seawalls and other structures to protect coastal properties and the coastline as a whole. For example, in Mobile Bay alone in the Alabama and Mississippi coast in the US, more than 30% of the property owners have built some sort of hard structures for shoreline protection (Douglass & Pickel, 1999). Douglass & Pickel, (1999) went further to state that the current prediction is that within the next 5-10 years, 50% of the bay will have some type of hard structural protection. Not only do hard structures reduce habitat through loss of the land and water interface, they reflect waves to areas that are not protected and scour the land underneath the seawall making the water body deeper and the edge steeper (Douglass & Pickel, 1999). Property owners need to be aware there are other structural alternatives that can address erosion that might be more economical, aesthetically pleasing and environmentally sound.

Seawalls can be the best alternative in a medium to high-erosional settings, but in lower erosional environments, other soft or non-structural stabilization alternatives could be the most economical choice. Hybrid structures may be a good choice in medium wave environments. These structures combine vegetative planting and hard structural control such as rock sill or breakwaters. Non-structural alternatives such as a living shoreline created from vegetative plantings or combination of seagrass and a rock sill, also can be a very viable means of erosion control. Thus, in protecting shorelines and controlling sea erosion, soft as well as hard structures can be used. These are termed shoreline stabilization structures which include vegetative cover, soft, non structural stabilization, shoreline revetment, offshore breakwaters, hybrid structures and groynes or groins among others. These are briefly discussed in the ensuing paragraphs.

Vegetative cover is the planting of native wetland plants, seagrasses and submerged aquatic plants. Vegetation holds soil in place with its roots, absorbs wave energy and filters water by collecting or storing sediment and absorbing pollutants. There are also soft, non-structural stabilization strategies at controlling sea erosion. These include beach nourishment, fringe marsh creation, coir logs, organic matting, erosion control blankets, geotubes, bioengineering and turbudity curtains. Non-structural alternatives create a natural buffer to protect shorelines from erosion by trapping sediments, which allows vegetation to grow.

Shoreline revetment is also a strategy to control sea erosion. It is the use of rocks, coarse limestone, oyster shell, articulating concrete mats, gabions and other materials to protect the shoreline. This type of shore protection tends to lower the wave energy because it is constructed to meet a low-grade slope while using irregular-shaped stone or shell. There is also the use of offshore breakwaters.

Breakwaters can be stone, concrete rubble, oyster shells, and attenuation devices or headland breakwaters placed offshore. Oyster shells or coarse limestone followed by an application of juvenile oyster spat is an example of living breakwater. Breakwaters buffer waves before they reach the shore, and sediments tend to settle in this zone to create a low-energy area with potential for marsh creation. Hybrid structures, on the other hand, include marsh fringe with groins, marsh fringe with sills or rocks positioned parallel to shore, marsh fringe with breakwaters and beach nourishment with breakwaters are hybrid structures for shoreline protection. Hybrid structures are used to restore, protect and create shoreline habitat while maintaining natural sedimentation and water change.

Groins are also used to control sea erosion and protect shorelines. Groins are long, narrow walls or mounds of rock built perpendicular to the shoreline. They minimize transport of sand down a beachfront. Groins and jetties may accelerate or induce erosion problems on the adjacent shorelines. Areas downshore may be deprived of sediment, which may lead to scouring and erosion. There are also bulkheads made of walls built parallel to the shoreline. They are typically constructed of concrete, treated wood, steel, aluminum or PVC. Bulkheads or seawalls tend to alter or create a loss of natural habitat. These alterations affect water circulation patterns, increase suspended solids, create erosion and decrease the quantity of organic matter and biological organisms needed for the maintenance of wetlands. Erosion of adjacent areas may also occur because of reflection of wave energy.

Shoreline Protection, the Ghana Experience

In Ghana, sea defenses using concrete groins and other methods some of which have been discussed in this text can be found on the shores of Keta and its adjoining coastline as well as Teshie, Cape Coast to Elmina and Sekondi – Takoradi. These projects are mainly undertaken by the state.

The Keta and Ada Coastal Defense Projects are the most prominent of all sea defenses in Ghana due to the fact that the most severe and internationally known areas noted for the problem of sea erosion in Ghana are located in the Volta estuary basin, at Keta and Ada (Ministry of Water Resources, Works and Housing, 2010).

The Keta project involved an 85 million USD beach stabilization, reclamation, and flood control project required to restore and stabilize a severely eroded portion of the Ghana coastline (Baird Inc, 2011). According to the Great Lakes Dredge and Dock Company, (2007), in Baird Inc (2011), "the Keta project was performed to create a much-widened stretch of reclaimed land and to put in place a protective revetment and groyne system that would prevent future inundation of inhabited areas by storm waters from the Gulf of Guinea in one direction or by flood waters in the Keta Lagoon from thė other. The works also entailed the construction of a 9-km road" (Baird Inc, 2011). .

The Ada Coastal Protection Works involving the construction of 15 groynes and other onshore works have been completed, while work is progressing steadily on the second phase. The second phase comprises mainly beach nourishment and protective barriers. The project is expected to reclaim 14.7 km stretch of coastal bed lost along the Atlantic Ocean in the Ada East District in the Greater Accra Region (Asare-Baodu, 2014).

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After the completion of the Keta Sea Defense Project and the near-implementation of the Ada Sea Defense Project for which financial support has already been obtained, the listed sea defense projects are among the government's/Ministry of Water Resources, Works and Housing's highest prioritized coastal erosion projects:

1. New Takoradi Sea Defense Project – Western Region
2. Amanful Kumah Coastal Protection Works – Western Region
3. Axim Coastal Protedtion Works – Western Region
4. Cape Coast Coastal Protection Works – Central Region
5. Dixcove Coastal Protection Works – Western Region
6. Komenda Coastal Protection Works – Central Region
7. Nkontompo Coastal Protection Works (Phase 2) – Western Region

(NBCC, n.d. http://www.nationalbcc.org/resources/contracting/1299-sea-defense)

Apart from the national sea defense projects being undertaken by the government, there are also localised mitigating strategies which serve as stop gaps by the local residents along the coast. They range from sand bags, rock and concrete embankment to wooden and bamboo fences. Sea defences in Ghana as already stated were necessitated by the devastating effects of the sea on coastal communities. For example, the Ada coastline was said to be disappearing at a rate of between 6-8 meters a year, which created a serious threat to the lives and livelihoods of the inhabitants. Many people living along the coastline were forced to evacuate their homes to safe places as the marauding sea waves approached (Asare-Boadu, 2014). According to Mr. Alban Bagbin (2010), the Minister for Water Resources, Works and Housing, "about two thousand lives are feared to be in danger if nothing is done within three months to complete the Keta Sea Defense Wall Project. If the sea continues to rise to between 2 and 6 meters government's/Ministry of Water Resources, Works and Housing's highest prioritized coastal erosion projects:

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Though sea defences are meant to solve the problems discussed above, they are also associated with certain problems. One of the problems likely to be created is that the natural input of sediment into the coastal system will be stopped. Sometimes too the energy of the waves is likely to be redirected to unprotected adjacent coastline. Thus while that part of the coastline with sea defences may be protected, the nearby coast without any form of protection may continuously suffer from sea erosion. Though sea defences and other erosion mitigating strategies can create problems, to a large extent, they have proven to be effective in at least extending the duration of coastal destruction from erosion. They are also constructed to reclaim land that had been inundated by the sea and also to arrest environmental deterioration as well as mitigating the negative social and economic consequences of the beach erosion.

Sea defences are also meant to strengthen the economic and productive base of the areas through enhanced tourist, industrial, fishery and commercial activities. For example, the site engineer of the Phase 2 of Ada Sea Defense

Project was reported to have said that "the defense wall serves other purposes. For instance, a reclaimed stable coastline and a beach for tourists is projected to be a source of tourist attraction. When completed, the project will also facilitate fishing and other commercial activities in the area. The Project will also lead to the stabilization of the coastline and the beaches to minimise the risk of flooding in the area" (Darfah-Frimpong, 2013). One other benefit that may be direct or indirect is the generation of job opportunities during the implementation of such projects. For example, it was reported that the Ada Sea Defence Project was offering employment to skilled youth in the area. According to the project engineer, 260 of the employees were Ghanaians while 40 were expatriates (Asare-Boadu, 2014). It can therefore be concluded that since the year 2000, there has been a serious commitment on the part of both the government and local communities to arrest the devastating effects of sea erosion. It can be seen right from the east coast of Aflao through Keta, Ada, Teshie, the central coastline to the west with prominent among them being the Keta and Ada projects. These range from concrete walls and groins on the part of the state to sand bags by the local residents. Much as the intention was to halt the devastating effect of the sea, sea defenses directly or indirectly are associated with other social and economic benefits. The philosophical underpinning of this research is discussed below.

Research Philosophy

A research paradigm is a loose collection of logically related assumptions, conceptions or propositions that orient thinking and research (Bogdan & Biklen, 2003, in Nazer, 2006). It has a deep philosophical significance; therefore, it should be congruent with a philosophy of knowledge, that is, epistemology. There are two major philosophical paradigms in the broader context of the social sciences research. These are positivist and interpretivist paradigms.

Positivist believe that there is a real world "out there" and consider that knowledge can only be passed on what can be observed and experienced through scientific means similar to those that were developed in the physical sciences (Gall, Gall & Borg, 2005). Positivist thinking generally attempts to test theory in an effort to increase the predictive understanding of phenomena under study (Myers, 1997). It is based on deductive methods where they begin with theories and define variables for study and predict their relationships through framing hypotheses that are then tested (Williamson, 2006). Practitioners of positivism use experimental designs with emphasis on cause and effect in which validity and reliability are the key construct (Powell, 1997).

The interpretivist paradigm on the other hand involves studies with the assumption that access to reality is only through social constructions such as language, consciousness, shared meanings, experiences and understanding of social world that sees human action as being the force that creates what is perceived to be society (Streubert & Carpenter, 1995). It is based on inductive style of reasoning and emphasises qualitative data (Williamson, 2006). The social world is seen as a social construction which is closely related to constructivism as opposed to positivism. Constructivism is one of the general interpretivist paradigms in qualitative research (Williamson, 2006). It is concerned with the ways in which people construct the meaning and understanding of their social world (Denzin & Lincoln, 2005). It maintains that individuals construct their own new understandings through what they already know and believe and the ideas, events and activities with which they come in contact (Cannell & Reiff, 1994; Richardson, 1997). With the above assertions in mind, the question is what is the philosophical foundation of this research?

The purpose of this study was to investigate the extent to which sea erosion and other factors have contributed to changes along the coast of the study area. A study of this nature largely fits into the positivist approach of research design because it is largely based on what has been observed and experienced through scientific means similar to that of the physical sciences. The phenomenon under study is largely natural and as such lends itself for observation, testing, experimentation and prediction. Emphasis is laid on cause and effect; that is, the study is looking at causes and effects associated with the dynamics of sea action. On the other hand, this study, to some extent, also fits into the interpretivist approach of research due to the fact that it involves what the researcher perceives as human action also contributing to the changes along the coast. That is, issues relating to the phenomena under study must not be considered only from the point of view of the natural science but the social construct is also important. Thus, the philosophical underpinning of this research is a combination of both the positivist and interpretivist approaches. This is because the research procedure involves testing, experimentations, as well as description of data that is both quantification and description of data.

Theoretical Perspectives

A considerable amount of research has been carried out over the last 20 years to explain concepts and develop models and theories that form the basis for predicting erosion and landmass change. These models are based on representations of physical processes and typically include forcing by waves and/or currents, a response in terms of sediment transport and a morphology-updating module. However, there are still major gaps in our understanding of long-term morphological behaviour of the coastal environment (Southgate and Brampton, 2001; de Vriend, 2003; Hanson et al., 2003) which mean that modeling results are subject to a considerable degree of uncertainty. Their use requires a high level of specialized knowledge of science, engineering and management. Southgate and Brampton (2001) provide a guide to model usage, which considers the engineering and management options and the strategies that can be adopted, while working within the limitations of a shortfall in our scientific knowledge and data. In this study, some theoretical explanations underpinning issues relating to the origins of coastal features and changes that occur in the coastal environment are discussed in this text. Coastal erosion has diverse influence on coastal structures and the beach as a whole. As erosion intensifies so do beach processes such as sedimentation and coastal vulnerability are also intensified. The most important issue to discuss is the causes of coastal erosion and how it influences the coastal environment. A lot of theoretical explanations have been espoused in relation to these. Some of the theories are discussed in the ensuing paragraphs.

The Theory of Submarine Origin

According to classical theory, shore platforms are developed by deep submarine abrasion while sea level is stationary (Davis, 1909, Johnson, 1919 and Thournbury, 1954). These authors observed that the attack of waves causes sea cliff to retreat landward, leaving a wave-cut platform thinly veered with detrital material. Various authors have come out with the estimation of the limiting depths of submarine abrasion. Some of these authors talk about the fact that abrasion is effective in deep waters, that is, some submarine abrasions are found at deeper depth hence the "deep water view" of Johnson (1919). This idea was replaced by the "shallow water view" (Dietz and Menard 1951, and by Dietz, 1952) which explains that abrasion is very effective in shallow waters. Abrasive materials include sand, pebbles and shingles which can act on coastal features, especially rock outcrops whether they are found deeper or at a shallow depth in the sea. It is therefore not realistic to put a limit to a specific depth at which various rocks may be abraded. This is because, many complex factors come to play before abrasion can be very effective. These factors include climatic conditions, energy of the waves and nature of the abraded material. Such factors may differ from one coastal environment to the other hence it is not proper to use one factor such as the limiting depth to explain complex beach process or processes such as abrasion.

The Theory of Water-Level or Water-Layer Weathering

This theory was named and adequately examined by Wentworth (1938, 1939) based on earlier submissions by Bartrum and Turner (1928) and later by

Bartrum (1935). According to this theory, splash pools many metres above high-water mark are capable of developing horizontal water-layered surfaces. The nature of the process of water-layer benching appears to be a form of physical weathering caused by frequent wetting and drying of the rock. It is said to complete and make more perfect, the flattening of a bench already partially formed by wave quarrying or other means. The process is not related to variations in sea level and the bench is liable to destruction once the rampart holding in the water at its seaward edge is breached. Hills (1949) agrees that water layer weathering can only occur in rocks susceptible to weathering by alternating wetting and drying hence, preference to the use of the term water layer weathering instead of water level weathering by other authors which could easily be confused with sea level. Dei (1975) identifies examples of water leveling weathering on rocks around the Cape Coast Castle and beaches of Teshie-Nungua where the platform surfaces were rough rather than smooth as observed by Johnson (1938) that weathering may roughen rather than smoothen the platforms.

The Theory of Wave Erosion

Authors such as Wentworth, (1938) and Hills, (1949) relegate the role of wave action in the development of platforms and other lithological structures and benches in favour of other processes such as the water-level weathering. On the other hand Edwards, (1951) Guilcher, (1958) and Russel, (1963) recognize the importance of wave action in platform cutting and the development of other coastal features.

Bartrum (1924, 1926) recognizes "storm-wave platforms which could be described as narrow benches found some few metres above high water level, as a result of storm-wave action. Jutson (1940) identifies three types of platforms based on Bartrum's observation. The first is high level platforms about 1 m above the level of normal platforms. The second is 'normal platform" which is exposed between mean low tide and mean high tide and the third 'ultimate platform' which occurs well below low water level. High-level platforms may not represent true platforms since they could be developed by combined action of waves and other processes. Edwards (1941) accepts Bartrum's idea of storm-wave platforms but rejects Jutson's terms as unsuitable. Hills (1949) opposes the views of Bartrum, Jutson and Edwards, observing that wave attack starts from well below low water level to several metres high water level. This he believes will result in a profile consisting of a submarine shelf below low water level, sloping up continuously to a wave ramp at the shore up which the waves of translation sweep. According to this idea, in areas of soft rock, erosion below low-tide level will be relatively easy, so that the submarine section of the profile will extend very close to the cliffs and the wave ramp will then be absent.

According to Hills (1949), in Dei, (1975), under conditions of varying wave height, it is impossible for a plane platform to develop since the seaward edge of the platform will surely be more eroded than the landward side. For a horizontal platform to develop, Hills believes strongly that there must be maximum erosion at a defined level. From these submissions, it is clearly established that wave action is a major factor for the development of platforms, benches and other litological structures along major beaches. This is supported by Edwards (1951), in Dei, (1975) who concluded that "storm wave attack is the one positive or constructive process in platform building and describes all other processes such as those enumerated by Hill (1949) as negative or destructive processes.

Theories of Sea Level Change

Relative changes in the level of land and sea can affect the coastal environment in several ways. They affect the rate of sea erosion, the development of landforms as well as the origin and changes that occur in the coastal environment. The concepts of isostasy and eustasy can be used to explain changes that occur in the coastal land mass.

Isostasy refers to a state of equilibrium or balance existing in the crust such that equal mass underlies equal surface area. It is an ideal condition of gravitational equilibrium between the heights of continents and ocean floors in accordance with the densities of their underlying rocks. This idea was proposed by an American Geologist, Dutton in 1889. The continents are supposed to float in the Sima by displacing certain amount of Sima equivalent to their volume so as to maintain equilibrium. It is similar to the concept of hydrostatic pressure (i.e. fluid balance) between the lithosphere and the asthenosphere. Isostasy thus, suggests that a column of lithosphere (and the overlying hydrosphere) anywhere on earth weighs about the same as a column of equal diameter from anywhere else regardless of vertical thickness. As a result, if additional load is placed on an area of earth's surface the lithosphere there will subside in a process called Isostatic

Depression until it attains a new equilibrium level. Conversely, if the surface accumulation is later removed, the region will tend to rise in a process called Isostatic Rebound. It works by the Principle of Buoyancy that is "an object will float in a fluid as long as its weight (specific weight) per unit volume is less than that of the fluid". Thus, the volume of water displaced by a floating object is the amount that has the same total weight as the object. Isostasy thus works in a similar situation like the float of an object such as a log or a canoe in water. Isostatic balance helps to explain many aspects of the earth including why most of the continental crust lies above sea level; why wide areas of the sea floor are at a uniform depth; why the crust subsided in areas that were covered by thick accumulation of ice during the last glacial age and now continues to rebound after glaciations; why many mountain ranges continue to rise even though erosion removes materials from them.

Relating this to coastal erosion and features of the coastal environment, one can say that a rise and fall in the level of the sea is related to movements (rise and fall) in the landmass bordering the sea. This is because any change in the level of the sea is likely to affect the land in that when there is a rise in sea level, or a fall in the landmass bordering the sea, part of the land is likely to be claimed by the sea. In this situation, the land is relatively lower and due to the rise in sea level, more water is pushed by waves thus intensifying erosion. On the other hand, a fall in sea level or a rise in the land draws water further inshore thus more land is exposed. These incidents occur due to the fact that it is impossible to attain a perfect equilibrium. Thus beach processes such as erosion and accretion as well as features produced behave in accordance to the changes that occur in the level of the sea in relation to the land bordering the sea. It should also be noted that sometimes sea level can change without a corresponding change in the land. This is caused by eustatism which can also have a significant influence on the coastal processes and features they produce.

Eustasy refers to a world-wide change in sea level without any movement in the land itself. It is the world-wide fall or rise in sea level resulting from the withdrawal of large quantities of water to form ice-sheets and ice-caps or return to the sea of melted water from ice-sheets. Such a major change occurred in the Quaternary Period (Quaternary glaciation) especially in the existing ice-fields such as Greenland, Northern Europe, Siberia, Antarctica and ice-caps. In that period, accumulation of enormous masses of ice averaging 2000-3000m thick covered about 20% of the land surface. Eustatism leads to general lowering of sea level during each glaciation. Rise in sea level occurs due to return of melted water to the same oceans. When sea level rises without a change or movements in the landmass, it means that some of the features which were hitherto exposed may now be covered. On the other hand, when there is a fall in sea level without movements in the land, coastal features that were hitherto covered with water would now be exposed.

Thus it is very difficult to understand and explain the origins and state of the coastal environment based on only one factor such as erosion or accretion, hence, it is important to discuss it holistically taking the issues discussed above into perspective, hence the conceptual framework for the study is presented below.

Conceptual Framework

Figures 1 and 2 were the conceptual framework used for the study. Figure 2 was modified from Figure 1 Waugh (1995) to suit this study. It was selected for the study because it gives a holistic explanation of all the factors that combine to bring changes in coastal environment. Waugh (1995) identified four main factors that influence changes in coastal environment which could be used to explain and understand the nature of beach processes and features. These are terrestrial, human, marine and atmospheric as depicted in Figure 1.

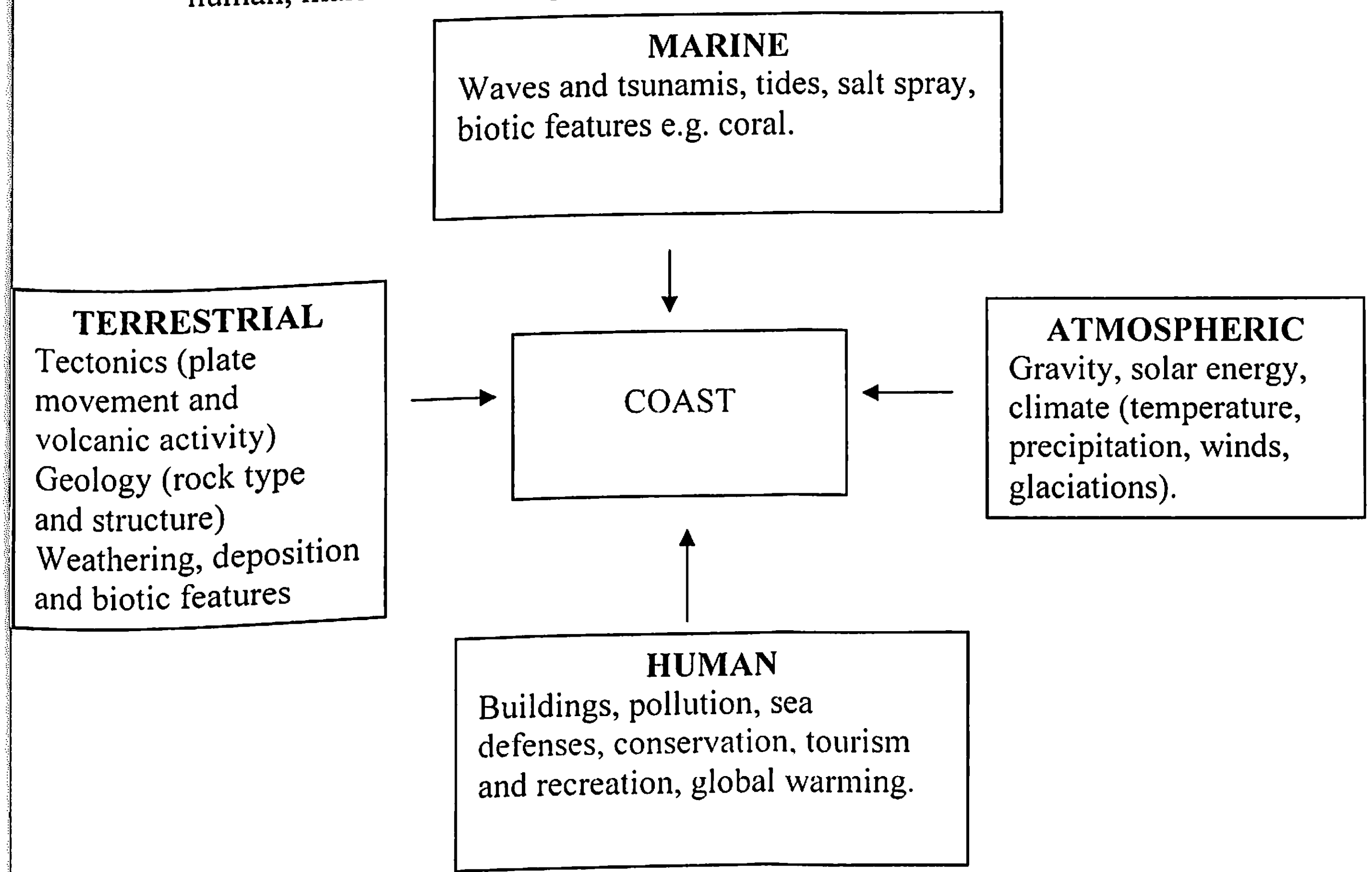

Figure 1: Factors Affecting Coast. Source: Waugh, (1995).

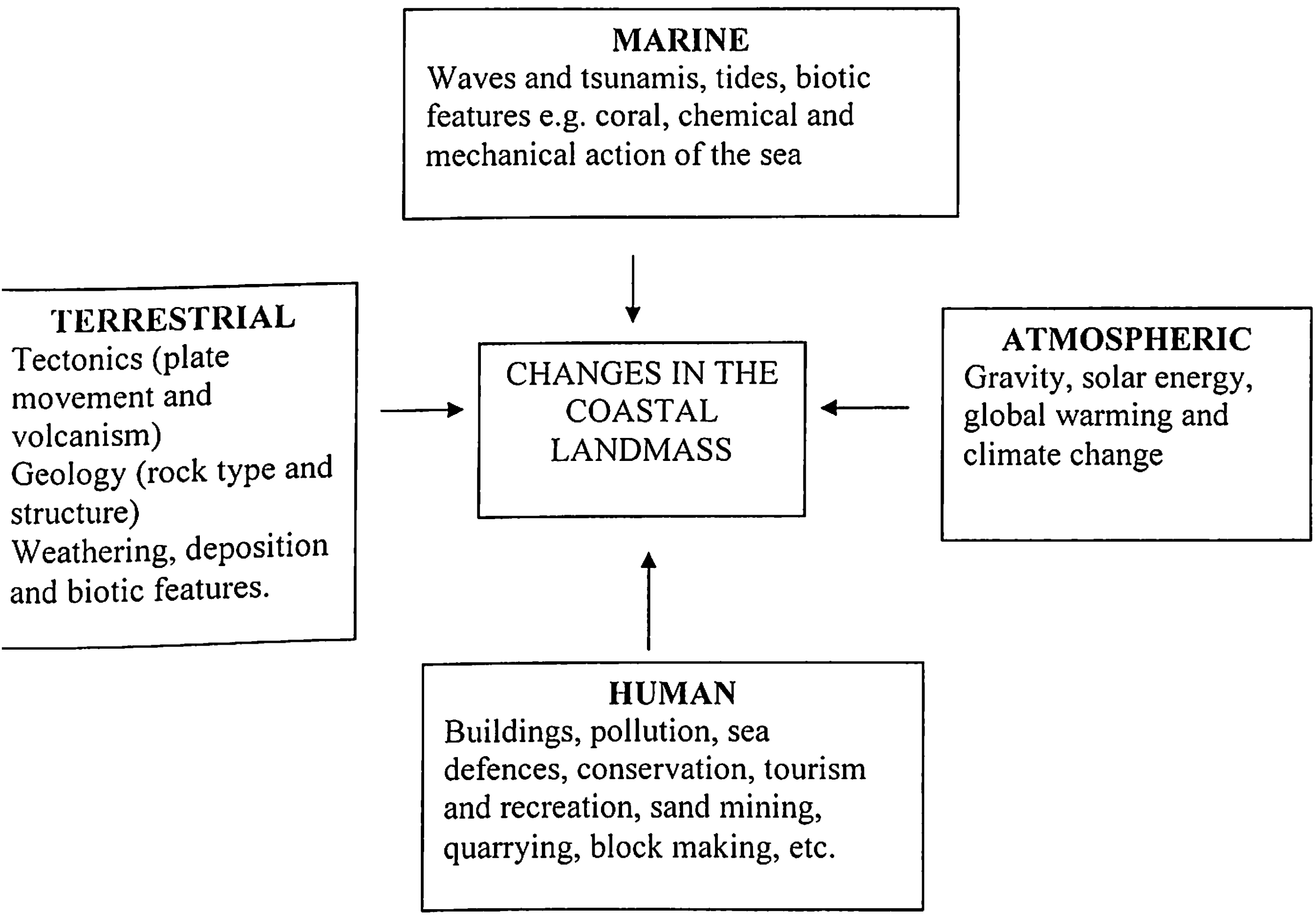

Figure 2: Factors Influencing Changes within Coastal Environment

Source: Adapted from Waugh, (1995).

Both natural and human factors operate to produce and regulate coastal processes and features and thus can be used to explain the origin, characteristics, changes and other issues relating to the coastal environment as a whole. Terrestrial processes are in the form of the movements in the land through tectonism and volcanism, that is, internal or endogenic processes of the earth. These work with external or exogenic processes such as weathering, deposition and other sub-aerial geomorphic processes to create changes in the coastal landmass. What Waugh (1995) referred to as marine processes, which induce changes in the coastal landmass include waves, tides, chemical and mechanical actions of the sea. In addition, some biotic features such as coral were identified. Atmospheric processes on the other hand, are those caused by gravity, solar radiation, global warming and climate change. Variations in climatic activities have a lot of influence on sea level changes thus it impinges directly on the changes that occur within the coastal environment. Human activities, such as sea defenses, erection of dwelling structures, conservation, recreational activities as well as sand mining also contribute to changes in coastal environment. Some elements such as sand mining, block making, quarrying, chemical and mechanical actions of the sea were modifications introduced by this writer. It can be concluded that the changes in the coastal landmass are mainly brought by the combined processes of natural and anthropogenic factors.

It should be noted that due to differences in the nature of coastal environment, the extent to which each of the factors identified in Figure 2 contributes to changes in the coastal landmass will also differ. This is because some of the factors may not be applicable to some specific coastal environment. This notwithstanding, it takes care of both human and natural factors that impinge on coastal environment.

CHAPTER THREE

BACKGROUND CHARACTERISTICS OF THE STUDY AREA

This chapter discusses the background characteristics of the study area. Issues discussed include the location, physical characteristics and some economic issues that are relevant to the study. Classification of the coastline into rocky and sandy is also discussed in this chapter.

Location

The study area covers the coastline between Cape Coast and Sekondi in the Central and Western regions of Ghana respectively, that is, from Ekon-Cape Coast through Komenda to Ngyiresia near Sekondi Fishing Harbour.

The study area, which covers a distance of about 90 km, has been purposely selected because it is part of Ghana's coastline where sea erosion is reported to be very severe (Dei, 1975; Aheto, Okyere, Mensah, Mensah, Aheto, & Agyarkwa 2010; Oteng-Ababio, Owusu & Appeaning, 2011).

This area also has peculiar landforms which have been produced by a combination of sea action and sub-aerial geomorphic agents and processes. The area lies within Longitudes 1°200'W and 1°400'W and latitudes 5°00'N and 5°100'N. Figure 3 is a map covering the study area.

Climate

The area lies within the dry equatorial climate of Ghana with an average annual rainfall of less than 1000 mm though rainfall increases towards the Western Region. The major rainy season is from April to June while the minor

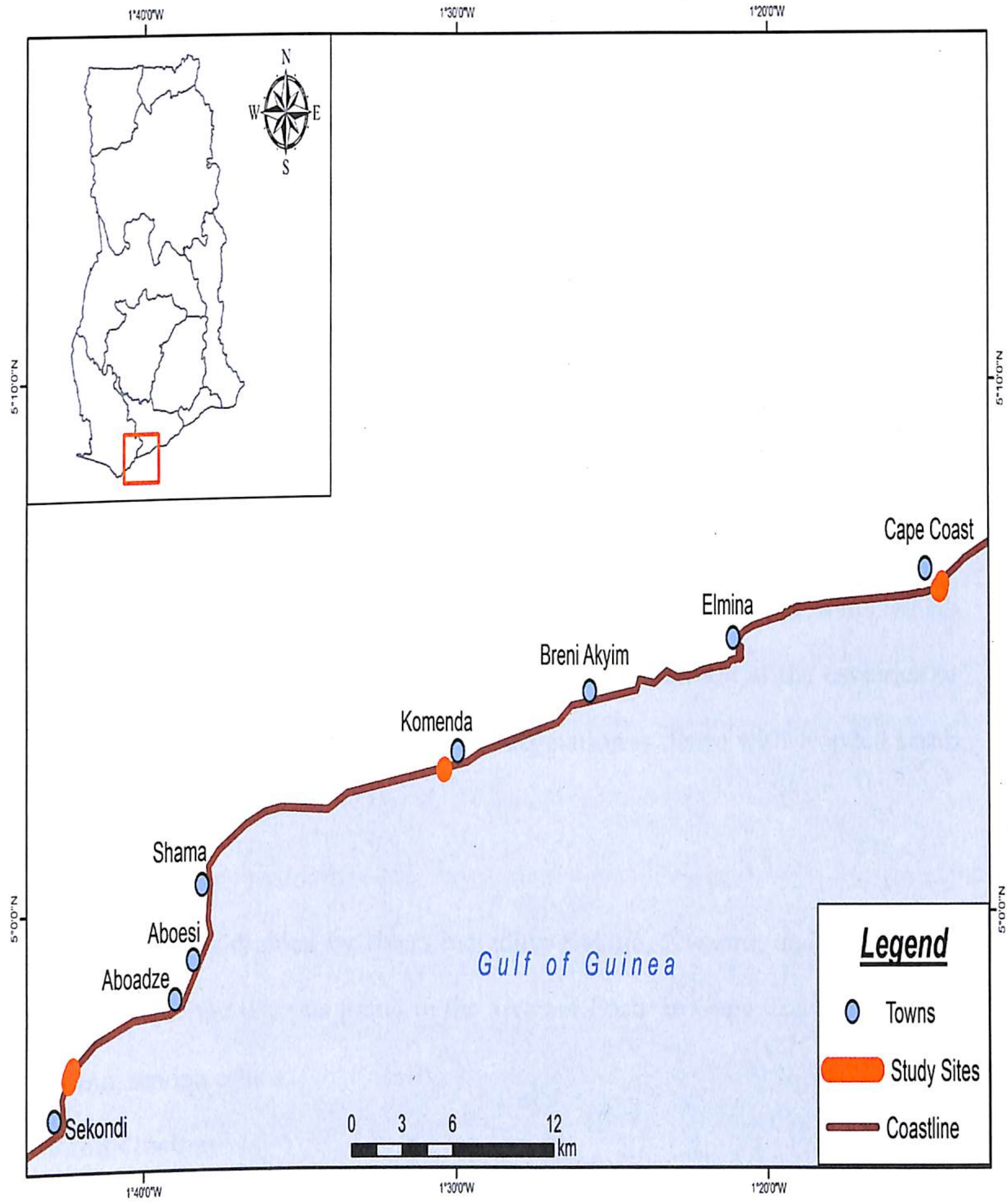

Figure 3: Coastal Stretch from Cape Coast to Sekondi

Source: Cartography and GIS Laboratory of the University of Cape Coast, (2013).

season is from September to October. The period from November to March is relatively dry. The dry season is not well marked due to the dominance of the Tropical Maritime air masses. As a result, relative humidity does not fall drastically and thus ranges between 75% in the wet season and 60% in the dry season (Dadson, 2008:84). Temperatures are high in the hottest month, that is March, about 30°C and about 26°C in August, the coldest month.

Vegetation

On the coastal margin, the vegetation is mainly strand and mangrove, oil palm and coconut trees are also found. The mangroves are closely packed and evergreen throughout the year. They have broad leaves and stilt roots which develop from the stem into the water. They are very common at the estuaries of rivers such as Kakum and Pra. Inland, the vegetation is dense with wooded scrub and evergreen trees.

Drainage

The area is drained by rivers including Kakum, Kwapro, and Pra, among others. Some of the lagoons found in the area are Fosu in Cape Coast and Benya in Elmina, among others.

Soils and Geology

Along the coast, the soils are mainly sandy in nature while inland it is mainly made up of forest ochrosls. The geology of the area is similar though there are variations in some few areas. The rocky outcrops are similar between Komenda and Sekondi but their responses to sea erosion are different. Those around Cape Coast are also quite different from those found in Komenda and

Sekondi. This thus, makes the selection of the study area very appropriate since it offers opportunity to investigate how areas with similar lithology respond to the dynamics of sea erosion as compared to an area with different lithology. Most of the surface rocks are underlain by very ancient rocks belonging to the Precambrian metamorphosed schist and sandstones. Between Cape Coast and Takoradi, such sandstones are known locally as Sekondian or Sekondi Sandstone (Dei, 1975).

Outcrops of granites, pegmatites and schist are common in areas around Cape Coast-Ekon. Around Komenda, the Sekondi Sandstones are massive and highly exposed to the vagaries of the weather and sea attack. From observation one may think that these rocks used to be very susceptible to sea erosion. This is because they have been seriously attacked by combination of hydraulic action, abrasion, weathering and mass wasting and as a result have been modified into various erosion features and landforms such as caves, blowholes, headlands, cliffs and stumps. There is total collapse of the cliff face while the headlands have been totally destroyed especially at Gold Hill beach in Komenda. Presently, a visit to the place shows more resistant sandstone due to indurations as was observed by Dei (1975).

At the Turtle Cove in Sekondi, the rocks have been massively attacked by active sea erosion including collapsed arch leaving behind stumps of abrasion platforms. The abrasion platforms are extensive due to the fact that the underlying rocks seem to be more resistant to sea erosion than the surface rocks. The severity of erosion here could be attributed to the construction of sea defenses against erosion on the immediate west.

Besides the effects of erosion on the rocky coastline, the patches of sandy coast that occur within the study area is also affected by longshore drift. Dynamics of sea erosion has the tendency of bringing sediment and at the same time eroding them back into the sea. The sorting effects of erosion on sediments through longshore drift is thus worth analyzing. Sediments are eroded and accumulated at the coast based on several factors that impinge on the behaviour of the waves.

Economy

The major human and economic activities in the area are fishing, farming, trading, manufacturing and other services such as banking, transport and communication among others. Along the coast, the major occupation of the indigenes is fishing. Vegetable and fruit farming is done inland but not far from the coastal region. In the interior, crop farming is done. Some of the urban areas in the study area include Cape Coast, Elmina, Komenda, Shama and Sekondi. In these areas, apart from fishing, secondary and tertiary activities are very buoyant. As said earlier, the study covers parts of the coastal regions of the Central and Western Regions. The ensuing paragraphs, thus give brief description of the general characteristics of the Central and Western Regions.

The Central Region

The Central Region occupies an area of 9,826km^2 or 4.1 percent of Ghana's land area, making it the third smallest in area after the Greater Accra and

Upper East Regions. It shares common boundaries with Western Region on the west, Ashanti and Eastern Regions on the north, and Greater Accra Region on the east. On the south is the Atlantic Ocean or the Gulf of Guinea coastline which stretches for about 168km (MLGRD, 2006). Cape Coast is the regional capital.

The relief of the region can broadly be divided into the coast and hinterland. The coast is made up of undulating plains with isolated hills and occasional cliffs characterized by sandy beaches and marsh in certain areas. In the hinterland, the land rises between 200 and 300 meters above sea level.

The region lies within the dry equatorial zone mainly restricted to the southern-coastal areas and moist–semi equatorial zone in the hinterland. Annual rainfall ranges from about 1000mm along the coast to about 2000mm in the interior. May-June and September-October are the wettest months while drier periods occur between December and March and a brief period in August. Mean monthly temperatures range from 24°C in the coldest month, August to about 30°C in the hottest months, March-April.

Vegetation along the coast is mainly coastal savanna and mangroves. The coastal savanna vegetation is made of grassland and few trees while strand and mangroves are mostly found at the estuaries of rivers. In the interior, the vegetation is semi-deciduous forest. Much of the original dense forest vegetation has been cleared for the cultivation of cocoa and food crops.

The Central Region is endowed with rich natural resources such as gold, oil and natural gas, clay, fish, forest, water resources and rich soils among others. The predominant occupation in all districts except Cape Coast is agriculture which employs about 52 percent and followed by manufacturing employing about 10.5 percent (MLGRD, 2006).

The Western Region

The Western Region occupies an area of 23,921 km^2, which is about 10 percent of Ghana's total land surface. It is located in the south-western part of Ghana, bordered by Cote d' Ivoire on the west, Central Region on the east, Ashanti and Brong Ahafo Regions on the north, and the south, by the Atlantic Ocean or Gulf of Guinea. The coastline stretches for 192 km.

The Western Region is mostly found in the Forest Dissected Plateau with relief of about 300 meters above sea level and consists mainly of hilly Tarkwaian rocks (Dadson, 2012:10). The region lies in the wet and semi-equatorial equatorial climatic zone. It is characterized by moderate temperatures, ranging from 22°C at nightfall to 34°C during the day. The region has a double maxima rainfall patterns averaging 1,600mm. The south western corner is the wettest part of the country which records mean annual rainfall of about 2000 mm or more. The two rainfall peaks fall between May-July and September/October. In addition to the two major rainy seasons, the region also experiences intermittent minor rains all the year round. Thus, in the south western most corner, the climate is very moist due to the fact that there is no month without rainfall. This high rainfall regime creates much moisture culminating in high relative humidity, ranging from 70 to 90 percent in most part of the region.

The region has about 75 percent of its vegetation within the high or tropical rain forest zone of Ghana. The south-western areas of the region are noted for the rainforest interspersed with patches of mangrove forest along the coast and coastal wetlands, while a large expanse of tropical rain forest and semi-deciduous forest is also found in the northern part of the region. The Western Region has about 24 forest reserves, which account for about 40 percent of the forest reserves in the country (MLGRD, 2006).

The region hosts most of the country's natural resources such as gold, manganese, bauxite, oil and gas, timber and cocoa. It also has water resources, and fertile soils among others. The major occupation in the region is agriculture with manufacturing activities mainly concentrated around Sekondi and Takoradi.

Classification of the Coast

The coastline under study, like any other coastline was classified based on geology and features. Two main types of coastlines were identified that is sandy beach/coast and rocky beach or coast (Figure 4). Around Cape Coast and Ekon, rocky beach was identified in the eastern coast of Ekon with a bit of sandy beach following from the eastern portion, extending westwards to the beach around the Regional Office which is more rocky. After the rocky beach around the Regional Office, sandy beach continues westwards until around the Cape Coast Castle beyond which sandy beach becomes more prominent.

Thus, from the Cape Coast Castle, sandy beach stretches westwards across the estuary of Kakum or 'Sweet' River to the Elmina Castle area where a rocky beach is found.

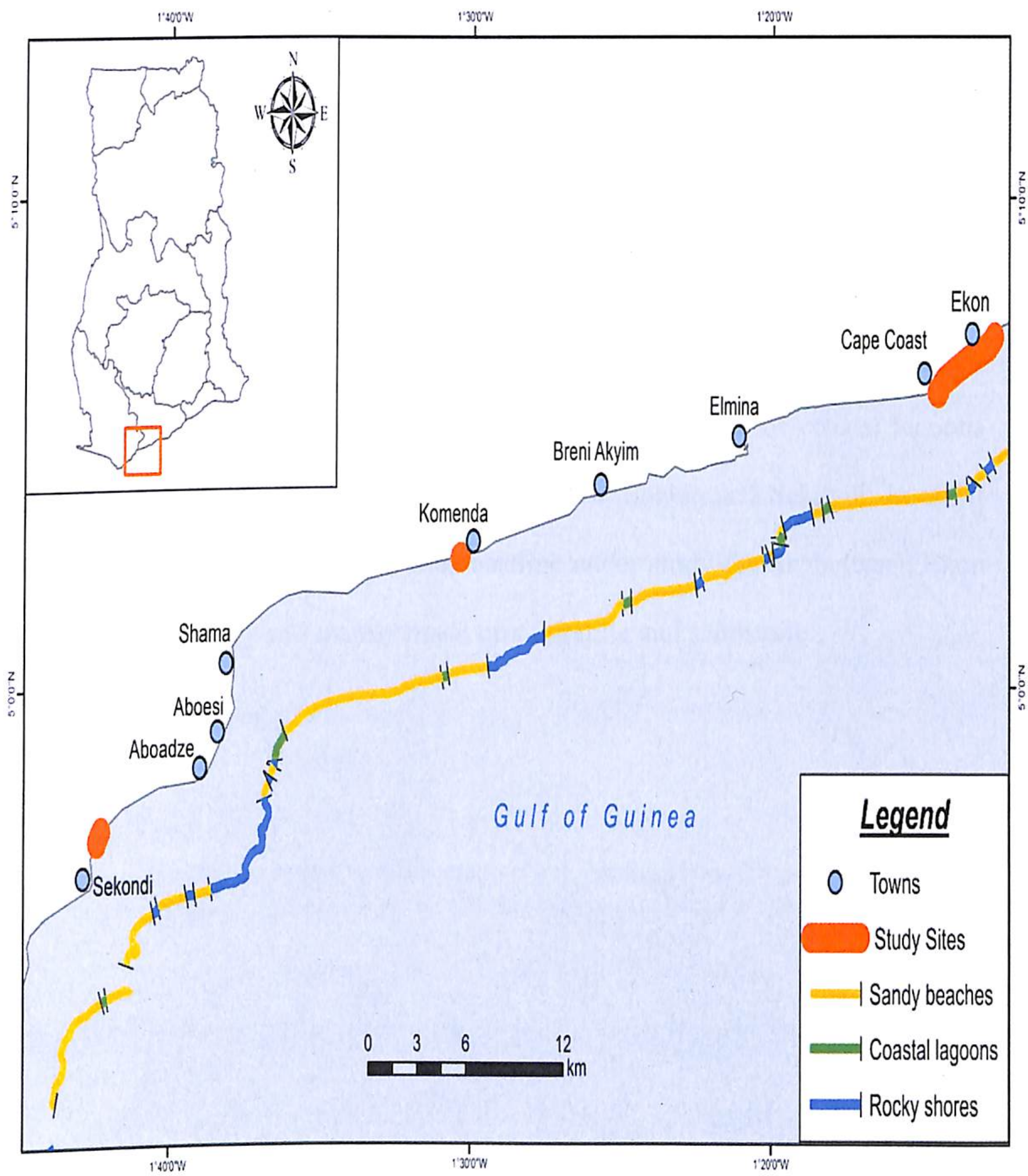

Figure 4: Rocky and Sandy Coast along Cape Coast-Sekondi Coastline

Source: GIS laboratory of UCC, (2014).

A sandy beach occurs from the western side of the Elmina Castle across the coast of Breni Akyim to the eastern portion of Gold Hill beach at Komenda. A rocky beach or shoreline with Sekondi sandstone occurs around the Gold Hill beach at Komenda that is the beach around the Komenda College of Education. From the western side of Gold Hill beach, a sandy beach occurs through Kafo Dzidzi and the Pra River estuary at Shama to the eastern coast of Aboasi. From this point through Aboadzi to the eastern side of Ngyiresia around the Turtle cove near Sekondi, a rocky beach with Sekondi Sandstone is found. From Ngyiresia to the Sekondi Fishing Harbour occurs a sandy beach. Asides the rocky and sandy characteristics of the coastline under study, there are patches of coastal lagoons located around Cape coast, Elmina, Breni Akyim, Shama and Sekondi. In all, it can be said that about 40-45% of the coastline under study that is, between Ekon and Sekondi, is rocky and mainly made up of granite and sandstone.

CHAPTER FOUR

RESEARCH METHODOLOGY

This chapter deals with the methodology, that is, how the study was conducted. It discusses the research design, sampling procedure, methods of gathering the data and presentation and analysis of data.

Research Design

This is a comparative study which was aimed at investigating how sea erosion influences landmass change along Cape Coast-Sekondi coastline. It combines both qualitative and quantitative research techniques in analyzing the issues. Both qualitative and quantitative techniques are used because the study makes use of both laboratory data on natural phenomena and also considers the human aspects relating to the subject under study. The quantitative analyses are mainly laboratory results while results from the interviews and case histories were analyzed qualitatively. According to Gooch, (2012), qualitative methods can be used in variety of context and in different stages of a research project as the main tool or in combination with other methods. It is thus appropriate to compliment the results from laboratory analysis with responses from interactions with the local communities.

Both primary and secondary data were used for the study. The primary data were mainly obtained from the field including samples of sand and pebbles as well as interviews and observation. Secondary data were obtained from documented sources such as reports, journals, articles, books and online information both published and unpublished.

Sampling and Data Collection

The subject matter of the study is purely natural and as a result onsite information was needed. Personal interviewing and case histories were applied to supplement onsite information. As a result, personal interviewing and case histories were used to solicit information on human activities that take place along the coast that might contribute to changes that have occurred in their environment, impact of sea erosion and efforts being made to cope with the challenges sea action. Purposive sampling was therefore, used to select 15 respondents from each of the selected sites. Those who have stayed in the area for at least, 10 years were purposively selected since they will be in the position to give information within the last ten years and beyond.

Samples of sand, pebbles and photographic images were mainly relied on for data. Three sites along the coast from Cape Coast/Ekon to Sekondi were chosen. The sites are Cape Coast/Ekon, Komenda (Gold Hill Beach) and Turtle Cove near Sekondi. At Cape Coast/Ekon, samples of sediments were collected at two levels from the shore. The first samples were taken at the shoreline or close to the shoreline (water) at an interval of 8 m in between each sample. The next samples were taken 5 meters away from the first level at 8 meters in between each sample. The aim was to determine how grain sizes, hence sediments, are related to wave energy and erosion at various levels away from the shore. These samples were taken between 4:00 and 5:00 pm to take advantage of high tides. From the shoreline (water level) to adjoining land at the coast is about 18 m.

At the Gold Hill beach in Komenda, samples of sediments were taken at 2 levels from the shore. From the shoreline (water level), samples were taken at an interval of 10m each. Another was taken 7 m away from the first level at 10 m between each sample. From the shoreline to the end of the adjoining land at the coast is about 19 m.

At Sekondi, samples of sediments were also taken at two levels from the shoreline at intervals of 8 m in between each sample. First samples were taken close to the shoreline. From there, three other samples were taken 6 m ahead of the first level. The distance from the shoreline to the adjoining land is 15 m. Apart from samples of sediments and pebbles, abrasion platforms were measured while elevations were also taken with the help of Global Positioning System (GPS). Information on changes along the shoreline was gathered through the use of topographical maps, satellite images and Global Positioning System (GPS) survey as in (Thieler, Himmelstoss, Zichichi & Ergul, 2009). In addition, five separate measurements were taken from the Lower Water Mark (LWM) to the Higher Water Mark (HWM) in both the rainy season and dry season at each of the three study sites. This helped to determine the rate of changes along the shoreline between the rainy and the dry seasons. The measurements for dry season were done in January while those of rainy season were done in June. The aim was to analyse the short-term and episodic changes in shoreline of the study area as was espoused by (Gibeaut, Hepner, Waldinger, Andrews, Guiterrez, Tremblay &

Smyth, 2001). This is because in the rainy season there is generally high tide while generally low tides occur during the dry season. In all the three sites, photographs were also taken. The instruments used in the field work were Global Positioning System (GPS), digital camera, tape measure, digital calipers, permanent markers and semi-structured interview guide, among others.

Data Analyses and Presentation

The study involved several laboratory analyses. Both descriptive and statistical techniques were employed in the analysis. The length, breadth, thickness and other dimensions of pebbles were measured with digital caliper. Aerial photographs from the Survey Department covering the study area were used to determine the changes that have occurred along some parts of the coastline. Satellite images and topographical maps were all used. Graphs were used to represent the data.

The extent of coastal erosion, the impact on the coastal morphology and the extent of changes along the shoreline of the study area were analysed within the framework of Pebble Shape Analyses Cailleux, (1945), Wentworth (1922) Particle Size Classification of sediments and Digital Shoreline Analysis System (DSAS) using the End Point Rate (EPR) method (Thieler, Himmelstoss, Zichichi & Ergul, 2009).

Particle Shape Aanalyses

As stated in Chapter Two, the intensity of sea erosion and sedimentation can be determined by the size and degree of roundness and flatness of pebbles. In this regard, the indices of Cailleux (1945) for analysing pebbles were employed due to its reliability, simplicity and easier interpretation. The measurement and determination of these shapes and other parameters helped examine the extent and impact of sea erosion on the morphology and the lithological environments of the shoreline in the study area.

Thus, during the field work, 50 pebbles each of sandstone (iron stone) were collected at Turtle Cove near Sekondi and Komenda. That is, 50 pebbles each of Sekondi Sandstone were selected from Sekondi and Komenda for laboratory analysis. On the other hand, 50 metamorphosed schist were collected along the Cape Coast/Ekon beach. Thus, in all, 150 samples of pebbles were used for the study. The formulae used for roundness and flatness (Cailleaux Indices) are shown below:

Roundness Index R = $\sqrt{\left(\frac{2r}{L}\right)(1000)}$

Where R is the roundness of pebbles, r is the radius of the smallest curvature of pebbles; L is the diameter or length of pebbles.

Flatness Index: $F = \sqrt{\frac{L+b}{2E}}$

Where F is the flatness of the pebble, L is the length, b is the breadth and E is the thickness of pebbles (Krumbein & Sloss, 1963). Thus, based on the formulae stated above, the length of pebbles, breadth, smallest curvature, flatness and other dimensions were measured with the help of the digital caliper.

Grain Size Analyses

Sediment analysis was based on Wentworth Particle Size Classification (WPSC) which is related to rate of coastal erosion and wave energy at the various beaches of the study area. This is shown in Table 1.

Table 1: The Udden-Wentworth Scheme of Grain Size Classification

Category	Type	Size (mm)
Boulders	boulders	250-100
Gravel	cobbles, pebbles, granules	65-2mm
Sand	very coarse, coarse, medium, fine	2-0.0625
Mud	coarse silt, medium silt, fine silt,	
	very fine silt, clay, dust	0.031-< 0.0005

Source: Adopted from Masselink et al; (2011).

The samples were dried and weighed and then sieved with a 2 mm sieve to separate the fine earth from the gravel. The gravel was weighed and the percentage content determined. A 30 g of the fine earth was placed in a 500 ml beaker and 125 ml of Hydrogen peroxide was added to destroy organic matter in the sample. When frothing has ceased and there was no further reaction, the samples were heated to complete the destruction of the organic matter. The samples were allowed to cool and transferred quantitatively into plastic bottles and 10 ml of dispersing agent (50 g of sodium Hexametaphosphate and 7 g of sodium carbonate in a littre of solution was added to each sample. The stoppers of the bottles were tightly closed and shaken overnight on a mechanical shaker to disperse the particles.

After dispersing the samples, a funnel was placed on a 200 ml sedimentation cylinder and a 212 μm sieve was placed in the funnel. The contents of the shaken bottles were quantitatively transferred into a beaker and the residue was washed with some distilled water into the sedimentation cylinders. The residue on the sieve after washing constituted the coarse sand which was quantitatively transferred into a 50 ml beaker of known weight and dried in an oven at a temperature of 105°C to constant weight.

The suspension in the sedimentation cylinder was topped to the 500 ml mark. The suspension comprised of silt, clay and fine sand. The suspension was rigorously stirred and placed on the bench. After 40 seconds, 25 ml of the suspension was taken at a depth of 10 cm from the surface of the suspension and transferred into a weighed 50 ml beaker and dried at 105°C to give the mass of silt + clay in the 25 ml of the suspension. After 5 hours, 25 ml of the suspension was again taken at a depth of 10 cm from the surface of the suspension and transferred into a weighed 50 ml beaker and dried at 105°C to constant weight to obtain the mass of clay in the 25 ml of the suspension.

After pipetting for the clay, the supernatant liquid was poured out and the sediment was quantitatively transferred into a 10 cm high beaker. Distilled water was added to a 10 cm mark on the beaker, stirred well, allowed to settle for 40seconds and carefully decanted retaining the sediment in the beaker. The stirring, settling and decanting were repeated till the supernatant was clear. Thus, all the silt and clay were washed out of the fine sand which was quantitatively transferred into weighed beaker and dried at 105°C to constant weight. The proportion of sand, silt and clay and were derived as follows:

Percent of Coarse Sand = $\sqrt{mass\ of\ coarse\ sand \frac{X100}{mass}\ of\ sample\ taken}$

Percent of Fine Sand = $\sqrt{mass\ of\ fine\ sand\ \frac{X100}{mass} of\ sample\ taken}$

Percent of Silt = $\sqrt{total\ silt\ \frac{X100}{mass} of\ sample\ taken}$

Percent of Clay = $\sqrt{total\ clay\ \frac{X100}{mass} of\ sample\ taken}$ (Rowell, 1994).

Even though, the analysis of the grains was mainly based on sand, it was also prudent to know the amount of gravel in the sediment to make an informed decision on the extent of erosion in the study area.

Digital Shoreline Analysis System for Shoreline Change

The analysis on changes along the landscape (land mass change) was done in relation to shoreline change and land cover change. With shoreline change analysis, the End Point Rate (EPR) method was used. This is one of the methods incorporated in Digital Shoreline Analysis System (DSAS), and ArcGIS model used by Thieler et al, (2013) in calculating shoreline change. Shorelines long Cape Coast-Ekon, Komenda and Sekondi were digitized. Three shoreline positions were identified, that is 1972, 2005 and 2013. These were the ones which could easily be accessed. The 1972 shoreline position was digitized from topographical maps otherwise called T-Sheet, the 2005 one was derived from satellite imagies and that of 2013 was derived from satellite images for Cape Coast and Sekondi while that of Komenda was surveyed with a Global Positioning System (GPS). The researcher could not get a topographical map neither satellite image of 2013 for Komenda, hence the use of GPS survey. All the three shoreline positions were digitized. The 1972 digitized shoreline position formed the base line. The base line was done with reference to low water mark/line. Each shoreline vector represents a specific position in time and is assigned a date in shoreline feature-class attribute table. The distances from the baseline to each intersection point along a transect area was used to compute the selected statistics. The rate of change was based on measured differences between shoreline positions through time. The reported rates were expressed as metres of change along transect per year. The EPR was calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (Thieler et al; 2009). The EPR is measured in metres as follows:

$$\text{Thus EPR} = \sqrt{\frac{distance}{time\ between\ the\ oldest\ and\ most\ recent\ shoreline}}$$

This was done for each of the shorelines of the three study sites chosen for the study. Thus, 41 years is the time between the oldest and the recent shoreline, that is, 1972-2013. For Cape Coast–Ekon, 148 transects were laid with 250m distance. The distance for the shoreline in Komenda was 300 m with 154 transects while that of Sekondi was 97 transects and a distance of 300 m. The transects and distances were based on the accessibility, nature of the terrain, the orientation of the coast and features/structures along the coastline. The transects were aligned along the coast from east to west.

The extent of change was interpreted with reference to the degree of erosion and or accretion that is whether it is extreme/maximum erosion, or moderate to minimum erosion or maximum to moderate accretion. Negative values indicate erosion while positive values indicate accretion. One advantage of this method is that it is easy to compute as one needs only two shoreline dates. The major disadvantage according to Crowell et al; (1997) and Dolan et al; (1991) is that where more data are available, the additional information can be ignored. The method described above had been used by the United State Geological Survey (USGS) to analyse shoreline change along some parts of the US coastline such as the Commonwealth Massachusetts coastline (Thieler et al, 2013 and the Gulf of Mexico (USGS, 2004). The choice of this method, among other things is the fact that it gives accurate information on historical shoreline fluctuations and also it is easy to interpret and understand.

Digitization of Aerial Photographs Using ESRI ArcGIS for Land Cover Change

Land cover change analysis was done for Cape Coast and Sekondi. That is, the study assessed the changes in various land use/cover types between the years 2005 and 2013 in Cape Coast and Sekondi. Aerial photographs and topographic maps were obtained from the Survey Department of Ghana. Each photograph was registered to a map (geo-referenced) to bring it to the same scale and frame of reference as other data sets. Then images were then projected from the Accra Ghana Grid to the Ghana Meter Grid.

Through on on-screen digitizing in ESRI ArcGIS 10.1 of aerial photographs, a classification scheme was formulated to identify six specific land use/cover categories as shown in Table 2.

Table 2: Adopted Land Use Categories for the Study

Category	Description
Vegetation	Area with natural undisturbed vegetation
Built-up	An area densely covered by houses or buildings
Quarry	Areas used for mining of sand or gravel
Bare Area	Areas of land covered with gravel and bare soil
Farm	Areas where crops are cultivated
Water	Water bodies in the study area

Source: Field survey, (2014).

The digitized vector maps were converted to raster models and the areas of all land use/cover categories in both years were extracted. The change in land use/cover was calculated by subtracting the areas of land uses in 2005 from that of 2013. The analysis and results were partly presented in the form of maps, tables, charts and graphs, plates, percentages and linear regression and matrix tables among others.

CHAPTER FIVE

RESULTS AND DISCUSSION

This section of the study investigates the influence of sea erosion on sedimentation in the study area. It also includes the analysis of pebbles through roundness and flatness parameters. The intention was to analyze the extent to which sedimentation along the coastline and particle sizes reflect the energy of the waves in relation to erosion and accretion. The analyses on shoreline change and land cover change were also done in this chapter. The final part of this chapter discusses the impact and management of sea action.

Erosion, Accretion and Sedimentation of Grains Along the Study Area

The analyses and discussion of findings are presented in the ensuing paragraphs. The percentage of gravel in the sediment for near shore is shown in Figure 5.

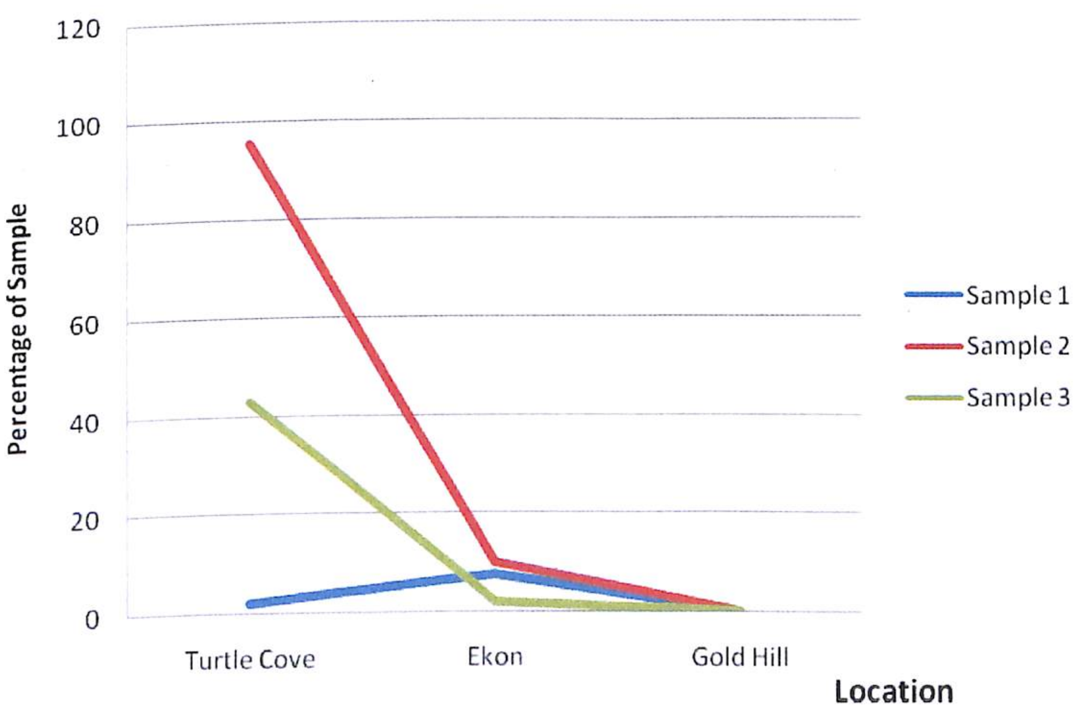

Figure 5: Percentage of gravel at near shore Source: Field data (2013)

From Figure 5, more gravel was identified at Turtle Cove near Sekondi than the other two locations. This is followed by Ekon near Cape Coast while the least was recorded at Gold Hill near Komenda. With the exception of Sample 1, in which 1.8% was recorded for Turtle Cove as against 7.3% and 0.0% for Ekon and Gold Hill respectively, significant amount of gravel was found at Turtle Cove at the near shore for Samples 2 and 3 which recorded 95.3% and 43.1 respectively as against that of Ekon and Gold Hill. In the case of Gold Hill, the amount of gravel deposited at near shore was highly insignificant. Thus, in all the three samples of sediments, laboratory analysis indicates that less gravel was deposited at the near shore of Gold Hill (Komenda) beach while a significant amount was deposited at Turtle Cove (Sekondi). Before any conclusion is drawn from Figure 5, it is important to compare the information with the samples taken inland away from the near shore, that is, upper beaches. This is shown in Figure 6.

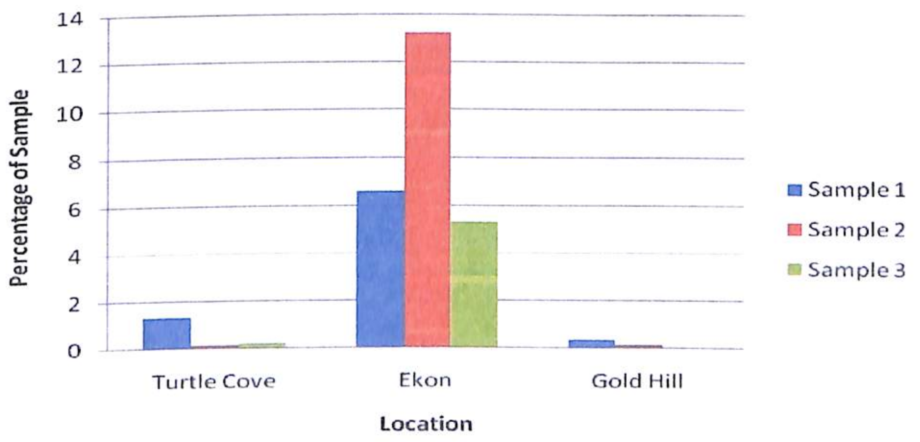

Figure 6: Percentage of gravel inland (Upper reaches). Source: Field data (2013).

From Figure 6, at the upper beaches, significant amount of gravel was eroded deeper into the inland beach at Cape Coast-Ekon than the other two places. In all the three samples taken at the upper beaches, 6.6%, 13.2% and 5.3% were recorded at Ekon for Samples 1, 2 and 3 respectively. Comparatively, 1.3%, 0.1% and 0.2% were recorded at Turtle Cove as against 0.3%, 0.1% and 0.0% at Gold Hill for Samples 1, 2 and 3 respectively.

Comparing the results in Figures 5 and 6, it is very clear that the sea was not able to deposit high amount of gravel into the inner beaches of Turtle Cove but rather at the near shore. This may signify that wave action was not very strong at this area hence the inability to transport and deposit at the interior of the beach. On the other hand, some amount of gravel was recorded at the near shore of Ekon though not very high as compared with that of Turtle Cove. In the upper reaches of the beaches, a very significant amount of gravel was transported and deposited at Ekon than the other places. Thus at Ekon, gravel was progressively deposited as distance increases from the beach inland, signifying that sea erosion is more intensified than the other two places. This means that erosion at Ekon/Cape Coast is likely to be stronger than the two other places with Gold Hill recording the weakest rate of erosion.

Several reasons may account for the results obtained aside the strength of ea erosion. In the literature, it was identified by Waugh, (1995) that, the rate of sion depends on several factors such as the geology of the area, the coastal ation, the slope and a host of others. Thus the differences in response to mong the three study sites may have accounted for the rate of erosion.

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Several reasons may account for the results obtained aside the strength of sea erosion. In the literature, it was identified by Waugh, (1995) that, the rate of erosion depends on several factors such as the geology of the area, the coastal orientation, the slope and a host of others. Thus the differences in response to erosion among the three study sites may have accounted for the rate of erosion.

Turtle Cove and Gold Hill Beaches are mostly rocky while Ekon has an open beach. This might have accounted for the ability of waves to travel with sediment far inland before depositing them (Waugh, 1995).

Samples of coarse sand for both near shore and upper reaches were also identified for the three study sites.

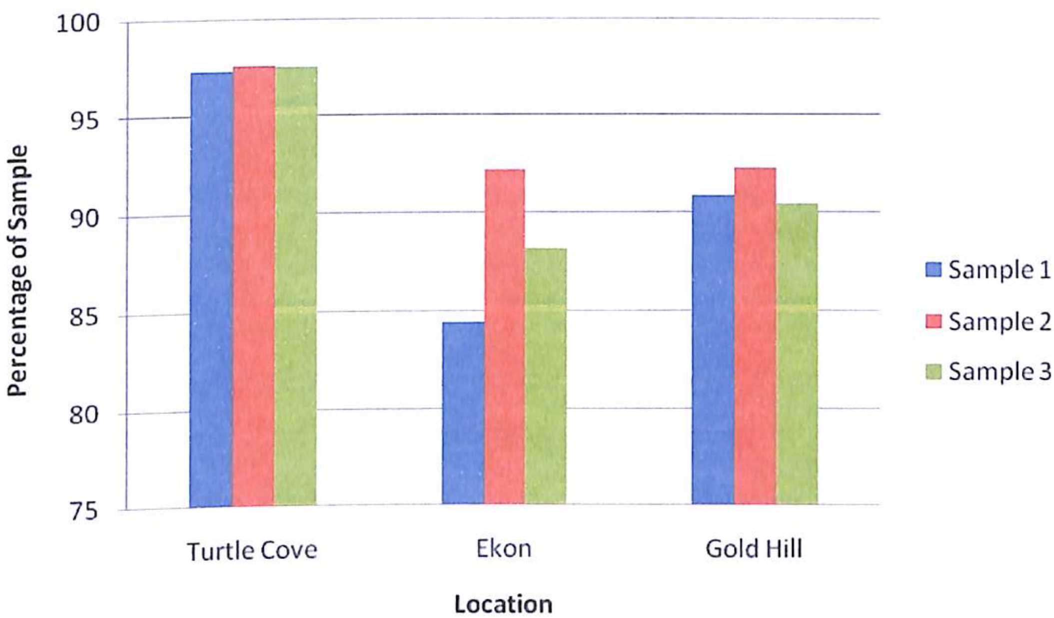


Figure 7: Percentage of coarse sand in the near shore. Source: Field data (2013).

In all the three samples of coarse sand at the near shore, large quantities were recorded at Turtle Cove than the two other locations, that is, Ekon and Komenda (Figure 7). It is followed by Gold Hill and then Ekon. In Sample 1, 97.3% was recorded at Turtle Cove as against 90.8% and 84.4% for Gold Hill and Ekon respectively. The differences in total percentage recorded at the three places were not very significant. The total percentage for all the three samples for each of the locations was 35.2% for Turtle Cove, 32.9% for Gold Hill and 31.9% for Ekon.

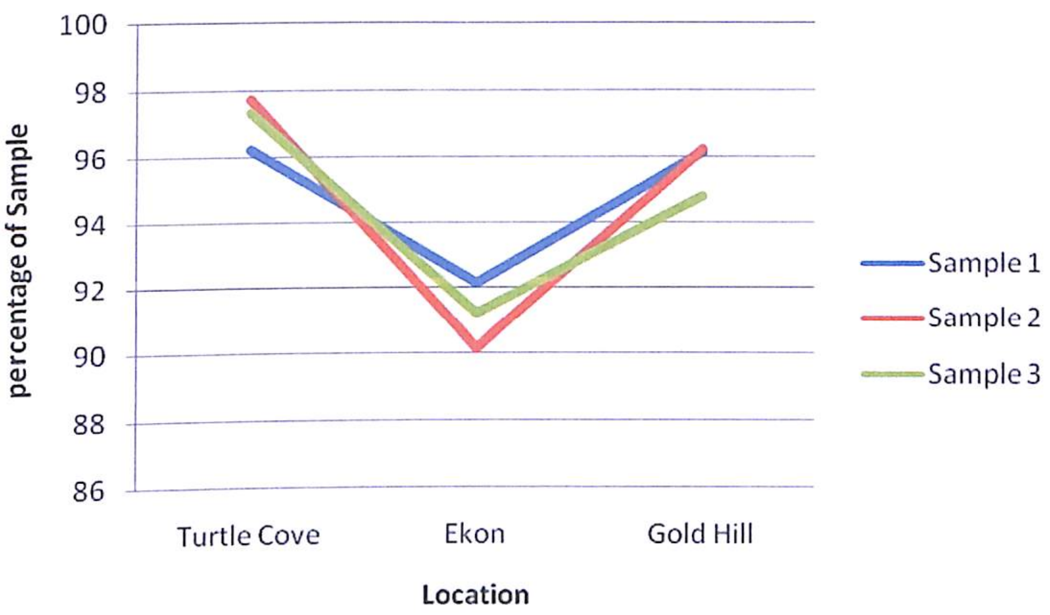


Figure 8: Percentage of coarse sand in the upper reaches. Source: Field data (2013).

In the upper reaches, the highest amount of coarse sand was found around Turtle Cove near Sekondi followed by Gold Hill with the least recorded at Ekon as in Figure 8. The differences in total percentage recorded at the three places were not very significant. The total percentage for all the three samples for each of the locations was 34.2% for Turtle Cove, 33.7% for Gold Hill and 32.% for Ekon. It is slightly higher at Turtle Cove followed by Gold hill with least occurring at Ekon. Inferring from the above analyses, it can be concluded that sea erosion is more intense at Komenda and Cape Coast than Sekondi due to the fact that the amount of coarse sand deposited at the upper beaches slightly increased over those deposited at the near shore. That of Sekondi rather decreased slightly from that of the near shore. What this means is that at Sekondi, heavier materials decreased as distance increases inland which is normal with the rules regarding sedimentation (Komar, 1977). On the other hand, heavier sediments were transported inland of Komenda and Ekon than Sekondi. Several factors as mentioned earlier may have accounted for this situation. For very elaborate results, quantities of fine sand were also identified in the samples. The results are shown in Figures 9 and 10 for near shore and upper beaches respectively.

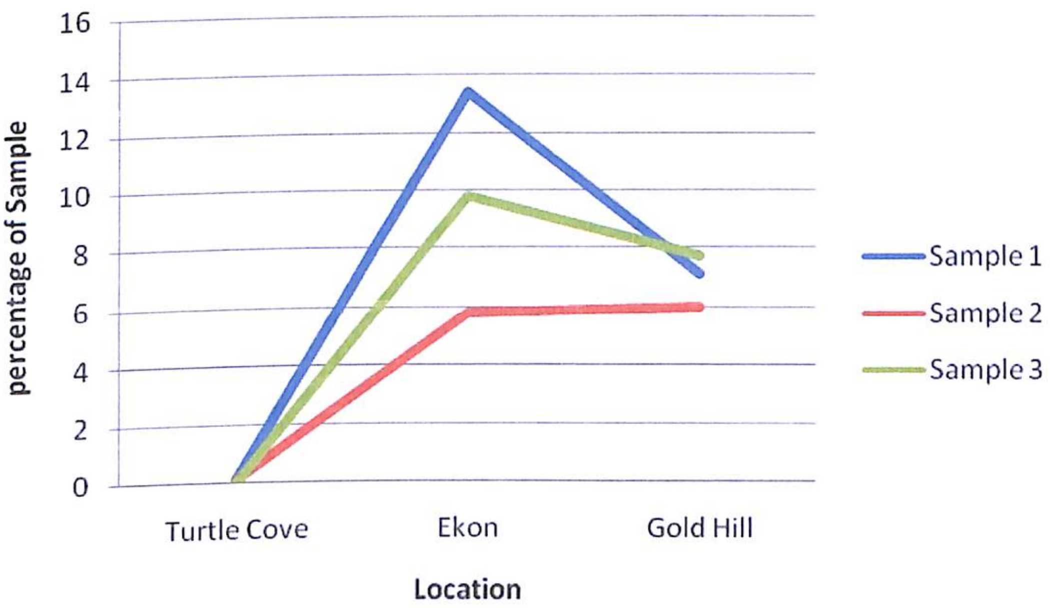


Figure 9: Percentage of fine sand in the near shore. Source: Field data (2013).

With fine sand, the highest amount was recorded at Cape Coast, followed by Komenda with the least occurring at Sekondi for samples collected at near shore. At the upper beaches, Cape Coast still recorded the highest amount of fine sand followed this time round by Sekondi while the least was recorded at Komenda.

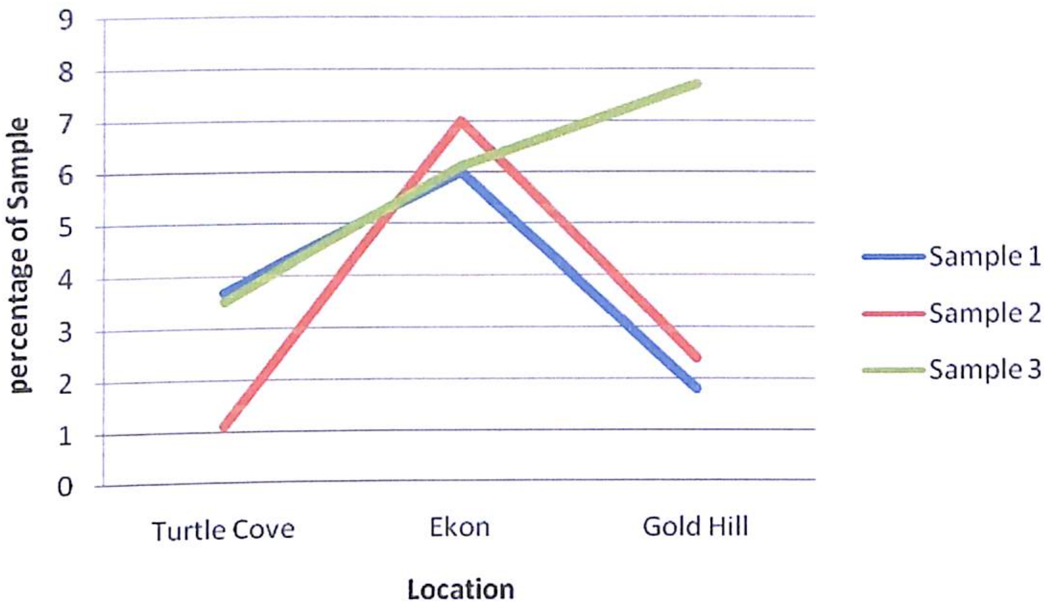


Figure 10: Percentage of fine sand in the upper reaches. Source: Field data (2013).

Total percentages for all the three samples for each location at the near shore are Ekon, 58.1%, Gold Hill, 41.5% and Turtle Cove, 0.4%. At the upper beaches, they are Ekon, 54.7%, Turtle Cove, 23.8% and Gold Hill, 21.5%. From these it is realized that at Cape Coast and Komenda, as distance increases from the near shore inland, the amount of fine sand though higher than that of Sekondi, there was a slight decrease as against a significant increase at Sekondi between the near shore and the upper beaches. In all, it can be said that erosion is stronger between Cape Coast and Komenda than Sekondi. This is because at Sekondi, only a few finer materials were transported and deposited at the upper beaches while large amount of coarse and heavier materials were earlier deposited at near shore. It means that either sea erosion was not strong enough to send heavier materials inland or the finer materials are few. It could also mean that there was not enough heavier materials around Cape Coast and Komenda or erosion processes of abrasion and attrition are so strong to reduce the materials to their finest state. The proportion of silt was also identified in the samples at the laboratory. Results for near shore are shown in Figure 11.

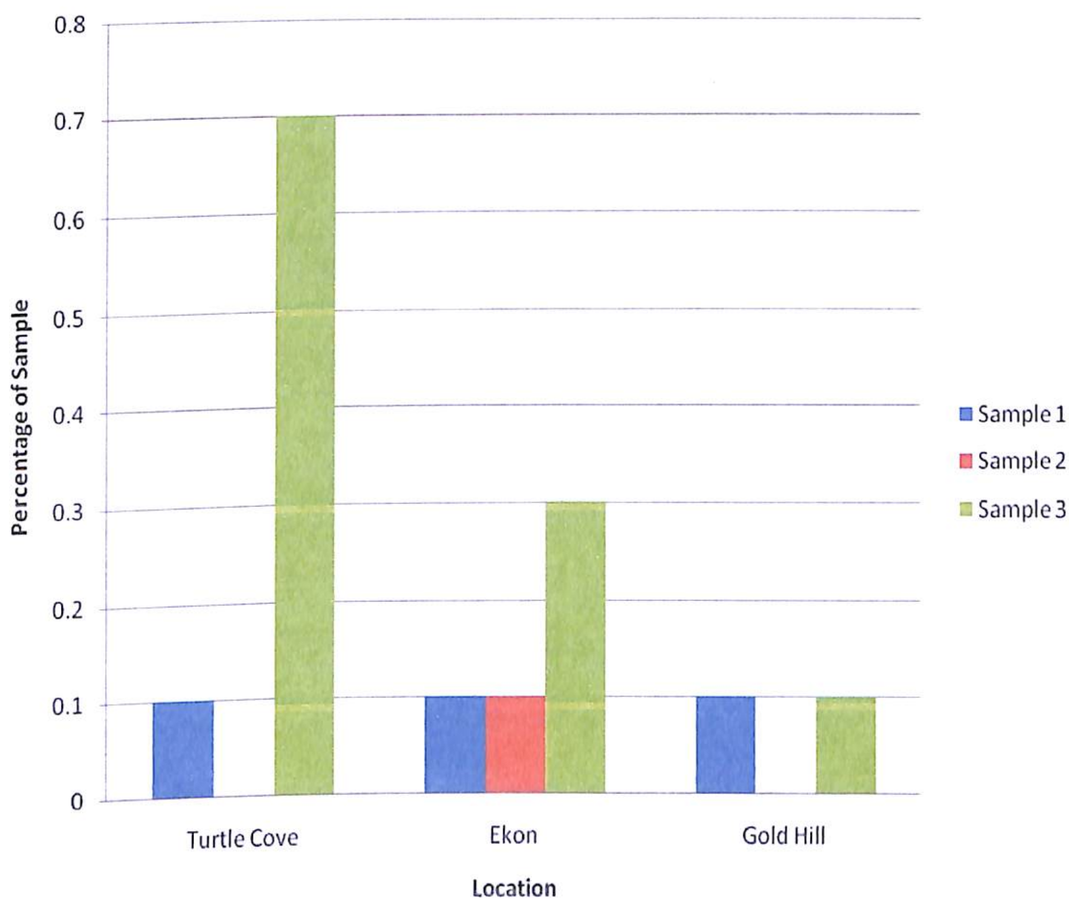


Figure 11: Percentage of silt in the near shore. Source: Field data (2013).

In sample 1, the same amount of silt was found in all the three locations while in sample 2 it is only Ekon which recorded 0.1%. In Sample 3, 0.6% was recorded at Turtle Cove, 0.1 at Ekon with nothing at Gold Hill. In all, the highest was found at Sekondi, followed by Ekon with the least recorded at Komenda.

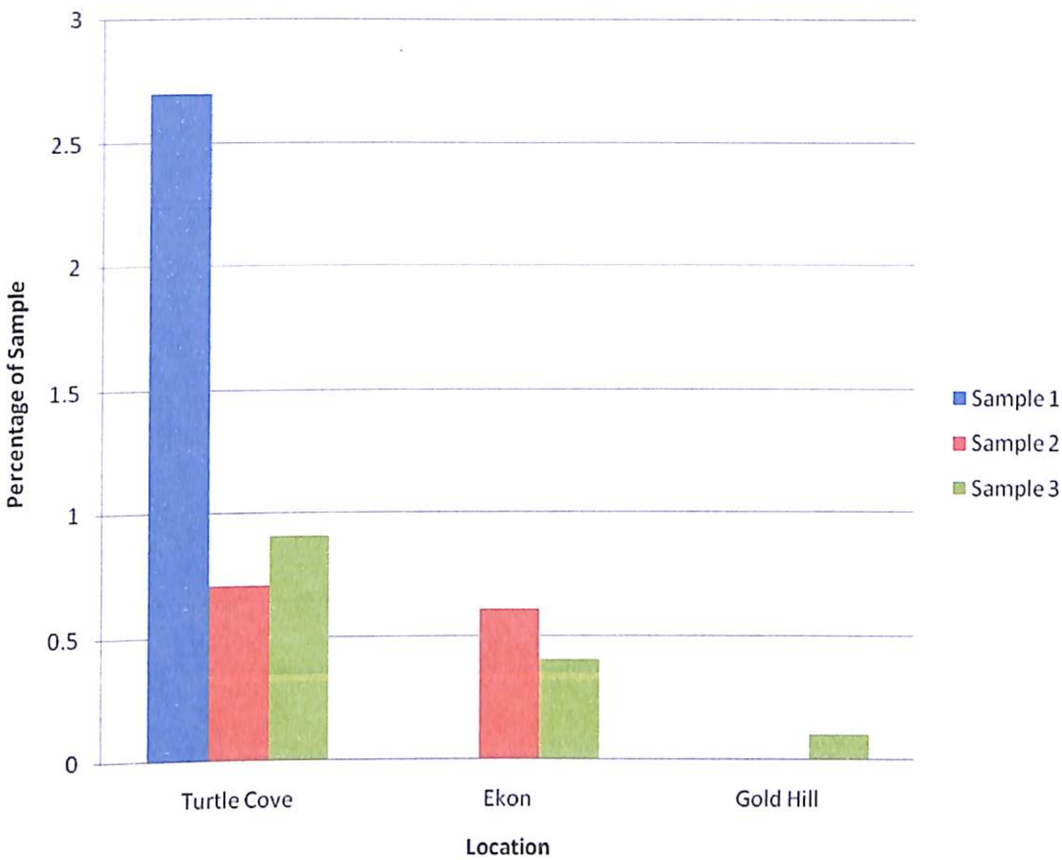


Figure 12: Percentage of silt in the upper reaches. Source: Field data (2013).

A similar trend that was found at near shore for the tree locations was also recorded at the upper beaches. In both samples 1 and 2, nothing was recorded at Komenda as compared with Sekondi and Ekon. In all the three samples, some amount of silt was recorded at the upper beaches of Sekondi but that of Cape Coast and Komenda was very insignificant. This shows that sediments were gradually deposited at the Sekondi beach which is in line with the normal rule regarding erosion and sedimentation identified by Komar, (1977) while that of Komenda and Cape Coast signifies that due to the strong nature of the waves, there are fewer finer materials. The analysis for clay which is the very finest of all the sediments was done. The results are shown in Figures 13 and 14 for near shore and upper beaches respectively.

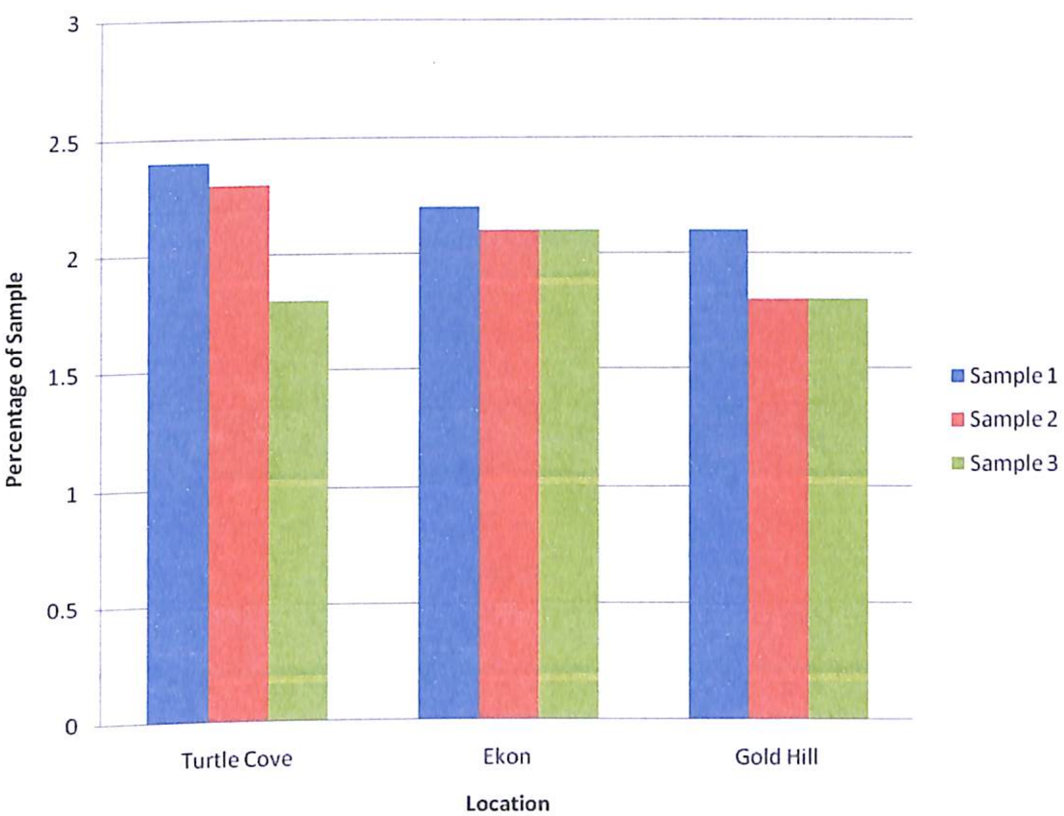


Figure 13: Percentage of clay in the near shore. Source: Field data (2013).

The quantities of clay in all the three samples for the tree locations show slight differences at the near shore. It is highest at Sekondi, followed by Ekon with the least at Komenda. The same trend repeats itself at the upper beaches as depicted in Figure 14.

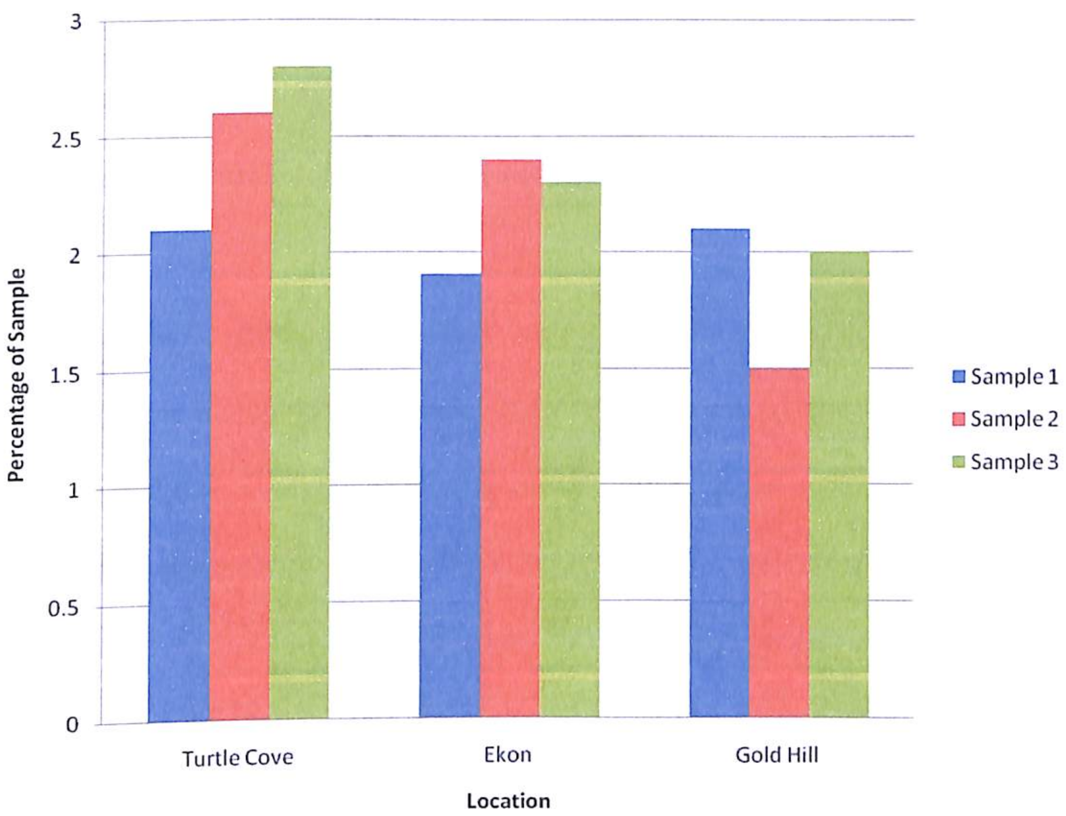


Figure 14: Percentage of clay in the upper reaches. Source: Field data (2013).

Several deductions can be made in that there is possibility of more clay in Sekondi Sandstone outcrops found in Sekondi than those of Komenda. It can be understood that since Cape Coast is dominated by igneous and metamorphic rocks, one does not expect to see large quantities of clay. Moreover, due to the intense nature of sea erosion around Komenda and Cape Coast, relatively coarse materials are discovered far inland than finer materials. In all, it can be concluded that sea erosion is very strong between Cape Coast and Komenda based on the sedimentation analysis, yet other local factors such as coastal orientation, geology, human activities and other natural and anthropogenic factors may have accounted for such revelations. The ensuing paragraphs of this chapter discuss grain size and intensity of sea erosion based on roundness and flatness values/index.

Grain Size/Shape and Intensity of Sea Erosion (Roundness and Flatness Index/Values)

Roundness and flatness values were calculated for Sekondi, Komenda and Cape Coast using the Cailleaux indices as stated in the methodology. Roundness values for Turtle Cove in Sekondi are shown in Table 3.

Table 3: Roundness index for Turtle Cove (Sekondi Sandstone)

Description	Range (mm)	Frequency	Percent
Less round	up to 500	15	30
Moderately round	501 – 1000	29	58
Extremely round	above 1000	6	12
Total		50	100

Source: Field data (2013).

From Table 3, 70% of grain samples were moderate to extremely round with 30% less round. This indicates that most of the particles had suffered from friction and other processes of sea erosion. With flatness, as indicated in Table 3, 80% of grain samples were found to be moderately to extremely flat with only 20% less flat. This also shows that sea erosion is intense in Sekondi. The roundness and flatness values for Komenda are also shown in Tables 4 and 5 respectively.

Table 4: Flatness index for Turtle Cove (Sekondi Sandstone)

Description	Range (mm)	Frequency	Percent
Less flat	up to 2	10	20
Moderately flat	2.1 – 3.0	17	34
Extremely flat	above 3	23	46
Total		50	100

Source: Field data (2013).

Table 5: Roundness index for Gold Hill, (Sekondi Sandstone)

Description	Range (mm)	Frequency	Percent
Less round	up to 500	2	4
Moderately round	501 – 1000	30	60
Extremely round	above 1000	18	36
Total		50	100

Source: Field data (2013).

From Table 5, only 4% of the sampled pebbles were found to be less rounds. Ninety-six percent was found to be moderately to extremely flat.

Table 6: Flatness Index for Gold Hill, (Sekondi Sandstone)

Description	Range (mm)	Frequency	Percent
Less flat	up to 2	12	24
Moderately flat	2.1 – 3.0	29	58
Extremely flat	above 3.0	9	18
Total		50	100

Source: Field data (2013).

From Table 6, 24% of pebbles were found to be less flat while 58% is moderately flat with 18% extremely flat. Though roundness values were higher for moderate and extremely round, indicating intense erosion, the flatness values are rather in favour of moderately flat yet as high as 76% of sampled pebbles was found to be moderately to extremely flat. These also show that there is intense erosion at Komenda (Komar, 1977).

Initially, no pebbles were found around Cape Coast upon several visits along the coast until finally samples were secured during the latter part of 2013. Tables 7 and 8 give details of roundness and flatness values for Cape Coast-Ekon study site.

Table 7: Roundness index for Cape Coast/Ekon (Metamorphosed Schist)

Description	Range (mm)	Frequency	Percent
Less round	up to 500	01	02
Moderately round	501 – 1000	43	86
Extremely round	above 1000	06	12
Total		50	100

Source: Field data and (2013).

From Table 7, roundness values for Cape Coast-Ekon range from 2% through 86% to 12% for less, moderately and extremely round. Based on these values, one may be inclined to believe that erosion is moderate around this study area. On the other hand, erosion could be intense, yet, with most of the pebbles, as much as 86% being moderately round, it means that pebbles were more resistant to erosion. Erosion could be at its maximum, yet because Cape Coast/Ekon is mostly dominated by igneous rocks they prove more resistant to friction.

Table 8: Flatness index for Cape Coast/Ekon, (Metamorphosed Schist)

Description	Range (mm)	Frequency	Percent
Less flat	up to 2	46	92
Moderately flat	2.1 – 3.0	4	8
Extremely flat	above 3.0	0	0
Total		50	100

Source: Field data (2013).

From Table 8, almost all the pebbles collected did not lend themselves to friction, especially wave erosion processes of attrition and abrasion. The pebbles were found to be more rounded than flat. Forty-six out of the 50 pebbles representing 92% were found to be less flat with the remaining 8% moderately flat. What this means is that due to the resistant nature of these igneous and metamorphic rocks, it is difficult to smoothen the surfaces through solution as they lack soluble minerals compared to sedimentary rocks. Thus they are more angular and rounded than flat. Comparative analyses among the samples for the three locations are shown in Tables 9 and 10.

Table 9 gives a comparative analysis of roundness among the three study sites. It could be deduced that there is not much difference among the roundness values for the three study sites as most of the samples were found to be moderately round that is, 86%, 60% and 58% for Cape Coast/Ekon, Komenda and Sekondi respectively.

Table 9: Roundness index in % for Cape Coast/Ekon, Komenda and Sekondi

Description	Range (mm)	C/Coast	Komenda	Sekondi
Less round	up to 500	02	04	30
Moderately round	501 – 1000	86	60	58
Extremely round	above 1000	12	36	12
Total		100	100	100

Source: Field data (2013).

The highest value for extremely round was recorded at Komenda while Cape Coast and Sekondi recorded 12% each. This means that the rocks at Komenda were found to be more susceptible to sea erosion than that of Cape Coast and Sekondi. It should be noted that Sekondi and Komenda have the same rock outcrops that is, Sekondi Sandstone while Cape Coast is made up mainly of igneous rocks, yet there was not much significant difference in their resistance to erosion. This depends on several factors such as the distance in relation to the origin of the pebble, the amount of materials involved, level of friction and the duration of erosive activities. Comparison on the basis of flatness is also shown in Table 10.

With flatness, the level of resistance of the pebbles to erosion is so glaring between Cape Coast/Ekon on one hand and Komenda and Sekondi on the other hand. Form Table 9, it is clear that as much as 92% of pebbles found around Cape Coast/Ekon were found to be less resistant to erosion as none was found to be extremely flat.

Table 10: Flatness index in percent for Cape Coast/Ekon, Komenda and Sekondi

Description	Range (mm)	C/Coast	Komenda	Sekondi
Less flat	up to 2	92	24	20
Moderately flat	2.1–3.0	08	58	34
Extremely flat	above 3.0	-	18	46
Total		100	100	100

Source: Field data (2013).

On the other hand, more than three quarters of pebbles for Komenda and Sekondi were found to be moderately to extremely flat. This shows a clear difference between the resistance level between igneous outcrops and that of sedimentary rocks, which are outcrops of sandstone. The sedimentary outcrops for Komenda and Sekondi were found to be very flat because they are more susceptible to sea erosion processes of abrasion and solution as they could contain soluble minerals which are easily drained in solution.

A further comparative analysis was made between the samples for Sekondi and Komenda though they have similar lithology. Values for roundness and flatness were found to be higher in Komenda than Sekondi though both locations have outcrops of Sekondi Sandstone. The total percentage value for both flatness and roundness for Komenda was 96% while that of Sekondi was 70%. With higher values found in the pebbles around Komenda, it therefore presupposes that erosion is more intense in Komenda than Sekondi as was observed in the grain size analyses.

This notwithstanding, it may depend on several factors such as the origin of the pebbles, mineral composition, and the original size after weathering before it was picked by the sea and the distance it travelled from the source to the destination. These factors may vary between these two locations. It can therefore be deduced that the outcrops of Sekondi Sandstone found in Komenda may have minerals that are more susceptible to erosion than Sekondi Sandstone found in Sekondi. It may also mean that those in Komenda were picked by the sea at a longer distance than those in Sekondi as espoused in the literature (Masselink, Hughes and Knight, 2011). More importantly, the rate of weathering may have also accounted for such a situation. Thus, one cannot use only one factor to determine the degree and rate of sea erosion but a multiplicity of factors as mentioned above. The ensuing paragraphs discuss the results from shoreline change analysis.

Shoreline Change Analysis Based on Field Measurements Along the Coast of Cape Coast to Sekondi

The rates of erosion, accretion and the extent of change along the shoreline were examined and analysed through manual field measurements and Digital Shoreline Analysis System (DSAS) using End Point Rate (EPR) method (details discussed in the methodology). These were done separately for each of the three locations.

The manual field measurements were meant to demonstrate the rate of change along the shoreline by erosion, accretion and other factors with reference to seasonal changes, that is, dry and wet seasons from the Lower Water Mark (LWM) to the Higher Water Mark (HWM). The LWM and HWM indicate the limit of waves at low tides and high tides respectively. The field measurements were also meant to analyse short-term and episodic changes in shoreline along the coast of the study area as discussed in the literature (Gibeaut, et al; 2001). Table 11 gives details of rate of erosion and shoreline change from the LWM to the HWM between the rainy and dry seasons.

Table 11: Rate of erosion and change in shoreline (in Metres) from the LWM to the HWM between the rainy and dry seasons

Location	Dry season	Rainy season	Rate of change
Ekon	24.9	30.1	5.2
Cape Coast	26.7	34.2	7.5
Komenda East	17.5	22.0	4.5
Komenda West (Gold Hill)	20.0	25.5	5.5
Turtle Cove	15.2	19.4	4.2
Ngyiresia	26.4	35.4	9.0
Total	130.7	166.6	35.9

Source: Field data, (2013-14).

During the rainy season, the distance from the LWM to the HWM was 30.1m at Ekon. In the dry season, the distance from the LWM to the HWM was 24.9m. This means that during the rainy season, the sea could erode up the beach to a distance of about 30.1m from the shoreline but this reduces during the dry season. Thus, the change in shoreline between the rainy season and the dry season in this area was 5.2 m. It was observed that erosion was intense around the Cape Coast Castle area and that for the rocky nature of a beach, most part of the shoreline would have been eroded. There was a high deposition of sediments west of the Cape Coast Castle leading to the development of a raised beach measuring 0.5m high above the previous beach.

On the western coast of Komenda around the Gold Hill beach, HWM was located at a distance of 25.5 m away from the LWM in the rainy season. In the dry season, the distance from the LWM to the HWM reduces to about 20.0m. In the cliff area, most part is directly and continuously under wave attack except the main cave (Plate 1) which is a bit distant away from the eroded area. There was more deposition at the extreme east and west of Gold Hill due to the sandy nature of the beach. The cave is made of Sekondi Sandstone which, due to increased weathering, has become highly limonitized turning yellow, pink and brownish rusty due to oxidation. The present location of this cave, the weeds growing around it and effects of sub-aerial processes are indication of the change in the landmass, the shoreline and retreatment of the sea in recent times.

From the field survey, the distance from HWM to the entrance of the main cave in the rainy season is 13.3m while that of the dry season is 21.3m. The cave is also protected by a headland-like jetty on its immediate south western part.

Plate 1: The main cave at Gold Hill Beach in Komenda. Source: Field survey, (2013).

Average distance from the LWM to the cave is 38.8m. Out of this, the sea could erode up to 25.5m after which deposition begins. Thus the change between eroded and deposited areas is 13.3m. This means that at the time the cave was being formed, the sea could erode for extra distance of 13.3m but now it does not. In the dry season, it has to erode for an extra 17.5m. It could thus be inferred that the sea has generally retreated though the waves continue to grow stronger and stronger. On the other hand, the total collapse of the cliff face around the Gold Hill beach has also caused the land to retreat further. This notwithstanding, some other parts of the cliff which are closer to the sea still suffer from wave attack but those further away from waves are more affected by sub-aerial geomorphic processes such as weathering and mass wasting.

On the eastern coast of Komenda, the distance from the LWM to the HWM in the rainy season was 22.0 m while that of dry season was 17.5 m. In the rainy season, the distance from the HWM to the nearest building was 8.3 m while that of dry season was 12.8 m. There is a raised beach which is 0.8 m above the previous beach on the eastern side of the Komenda coast. Thus the change in shoreline position between the rainy and the dry season was 4.5 m on the eastern coast of Komenda while that of the western coast was 5.5 m. The difference is not all that significant as the two beaches have similar characteristics that is, they are all sandy in nature.

At Sekondi, measurements were taken at Turtle Cove and Ngyiresia all located on the eastern side of the Sekondi Harbour. At Turtle Cove, during the rainy season, the distance from LWM to HWM was 19.4 m with sediment coverage of 1.9 m. This means that previously the sea was eroding up to about 21.3 m from the shoreline. In the dry season, the HWM is located 15.2 m away from the LWM. Sedimentation from the HWM is 6.1 m. There is a sea defense in this location which is just 2.0 m away from the HWM in the rainy season. This means that the area was under serious wave attack which necessitated the erection of the concrete sea defense by the local inhabitants. Any further rise in sea level which can cause high tides will lead to the collapse of the sea defense as parts of it have already been destroyed by the sea. There are also abrasion platform around this area with an average height of 0.8 m. Most part is covered during the rainy season when there is generally high tide but is exposed during low tides in the dry season.

At Ngyiresia, located at the immediate east of Sekondi Harbour, the distance from the LWM to the HWM in the rainy season was 35.4 m. Thus from the LWM to the raised beach is 40.1m. In the dry season, the distance from the LWM to the HWM was 26.4 m. Thus in the dry season, the distance from the HWM to deposited area is 13.7 m. One observation was that the central portion of Ngyiresia is sandy with heavy deposition and as a result most of the dwelling houses are concentrated. On the other hand, erosion was found to be very intense on the extreme west and east which are also rocky. The eastern portion is so seriously affected by erosion that the road leading to the Sekondi Fishing Harbour came under threat of being eroded until a sea defense project was done. These notwithstanding, it can be said that though erosion is so intense in this area, the inhabitants do not face any threats of coastal erosion or possible inundation unless there is an extreme natural phenomena such tsunami, hurricane and massive earth movements. The field survey also confirmed, as the inhabitants told this researcher, that occasionally their canoes are taken away by the waves during periods of high tides, yet the area for many years has never been flooded. The extent /length of deposition from the HWM to the end of the beach for both the rainy and dry seasons were also measured. The details are shown in Table 12.

Table 12: Extent of deposition from the HWM and distance (in meters) to the nearest human dwelling between the dry and rainy seasons.

Location	Deposition	Distance in dry season	Distance in rainy season
Cape Coast/Ekon	8.3	13.0	7.8
Komenda	5.2	12.8	8.3
Sekondi	4.7	20.2	15.0
Total	18.2	46.0	30.0

Source: Field survey, (2013).

Around Cape Coast and Ekon, the average distance from the HWM through the deposited area to the edge of the raised beach was 8.3 m. This means that from the HWM, deposition of sediments continues for a distance of 8.3m before the edge of the beach where waves no more occur. It can invariably be inferred that, previously, the waves were very strong and could reach that far but due to the retreatment of the sea the waves are limited to a distance of 8.3m from where they could previously reach. The beach has been raised by 1.2 m high at Ekon and 0.5 m at Cape Coast west of the Castle. The distance from HWM in rainy season to the nearest building is 7.8 m while that of dry season is 13.0 m. It can be concluded that this area faces a great deal of threat from the sea as it needs to erode for a distance of just 7.8 m to reach the nearest dwelling houses, especially around Ekon. Asked whether they sense any danger from the sea, 8 out of the 15 people interviewed representing 53.3% said there is no threat from the sea as it comes up and later retreats. The other 7 respondents (46.3%) said they fear the sea will one day cause problems to them as it happened about 6 years ago when most part of the beach covered by coconut trees flooded and most of the coconuts trees got uprooted. From the field survey and personal observation, this researcher can conclude that but for the raised beach the area would have been under serious threat of being inundated by the sea. As it is now, it will be a bit difficult for waves to cross over the raised beach unless there is an unusual natural occurrence such as earth movements or very strong waves from tsunamis and hurricane. One other activity that can create problems here is sand mining and quarrying at the beaches around Cape Cost and Ekon. At Ekon and some parts of Cape Coast, blocks are laid at the beach using the sand. This could cause an advancement of waves.

At Komenda, especially on the eastern coast of Gold Hill beach, the distance from the HWM through recent deposited sediments to the raised beach is 5.2 m. Thus the length of sedimentation/deposited materials is 5.2m which means that the sea has to erode for further 5.2 m before it could reach the end of the beach. In the dry season, it has to erode for a distance of 12.8 m while in the rainy season it has to erode for a distance of 8.3m before it can reach the nearest house. In this area, 12 (80%) of the respondents said there is no threat from the sea as it has drastically retreated. Only 3 (20%) said there could be danger in the near future since it is difficult to predict the future. The beach is also raised to about 0.8 m above the previous beach. From the survey and from personal observation, this researcher believes that this area seem not to suffer much from erosion as the sea has retreated as compared with previous years.

At Sekondi, deposition from the HWM extends for about 4.7 m to the raised beach which is 0.6 m high. The distance from the HWM to the nearest building in the rainy season is was 15.0 m while that of dry season was 20.2 m. Asked whether they feel threatened by the sea, the general response was no since erosion and deposition occur every day. In fact, the distance involved also makes it very convincing that it may be difficult for sea erosion to easily reach the dwelling houses as the raised beach may also serve as a barrier.

Shoreline Change Analysis Based on End Point Rate for Cape Coast, Komenda and Sekondi

The subsequent paragraphs discuss the analysis of shoreline change through the use of DSAS based on End Point Rate formulae as discussed in the methodology. The interpretation was done with reference to the degree of erosion and accretion as they reflect changes along the shoreline from extreme or maximum erosion through moderate to minimum erosion and hence accretion. Figures 15 and 16 show the shoreline positions and change for Cape Coast/Ekon study site between 1972 and 2013.

From Figure 15, it could be deduced that the shoreline since 1972 had been fluctuating. Between 1972 and 2005, there was an advancement of the sea inland as shown by the green line. On the other hand, the current shoreline, that is the shoreline position for 2013 shows a retreat of the sea. The rate of advancement and retreatment of the sea was almost the same along the shoreline. The extreme west and the extreme east of the shoreline could not be significantly eroded due to the rocky nature of the coast.

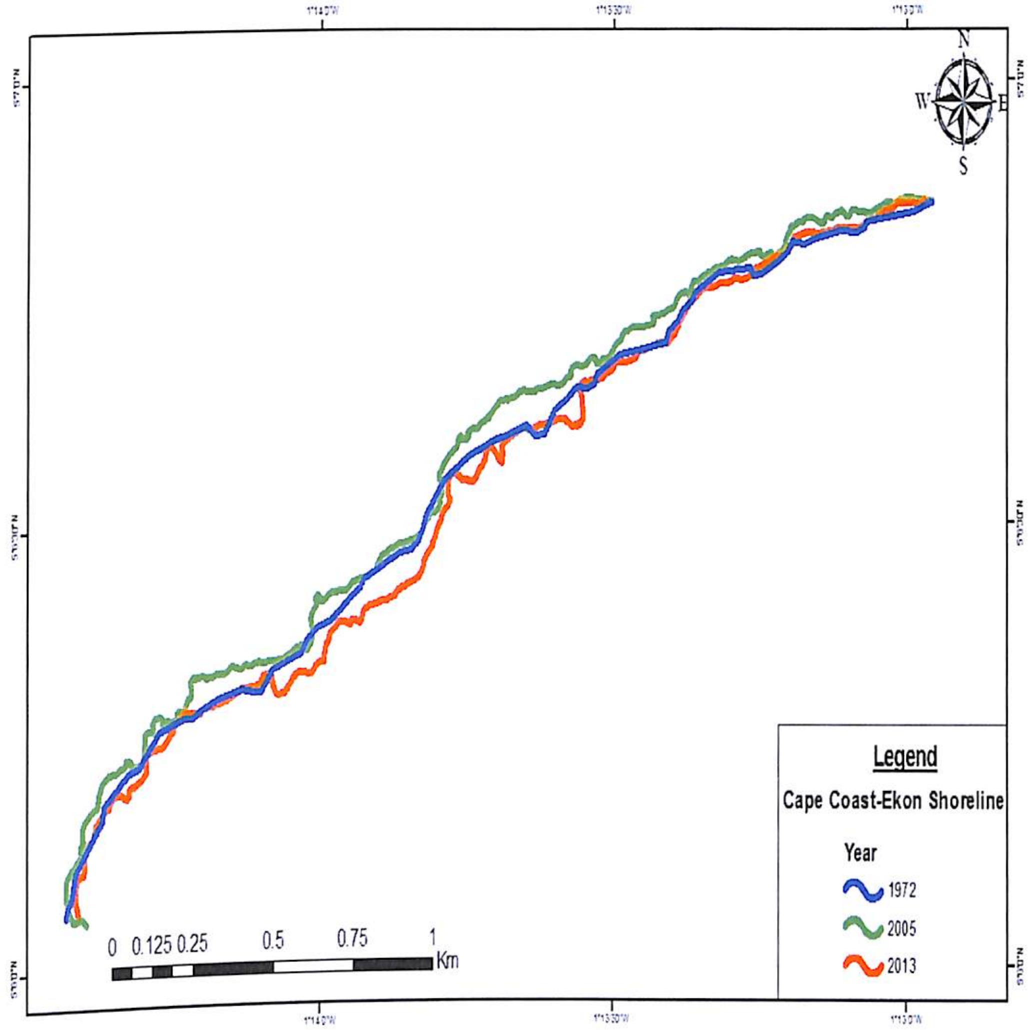


Figure 15: Shoreline positions in Ekon and Cape Coast for 1972, 2005 and 2013. Source: Field survey (2014).

The middle portion is very sandy hence the sea was able to erode deep into the land by 2005 and at the same time it was also able to significantly retreat by 2013. Figure 16 shows the rate of change along the same coastline based on the level of erosion and accretion.

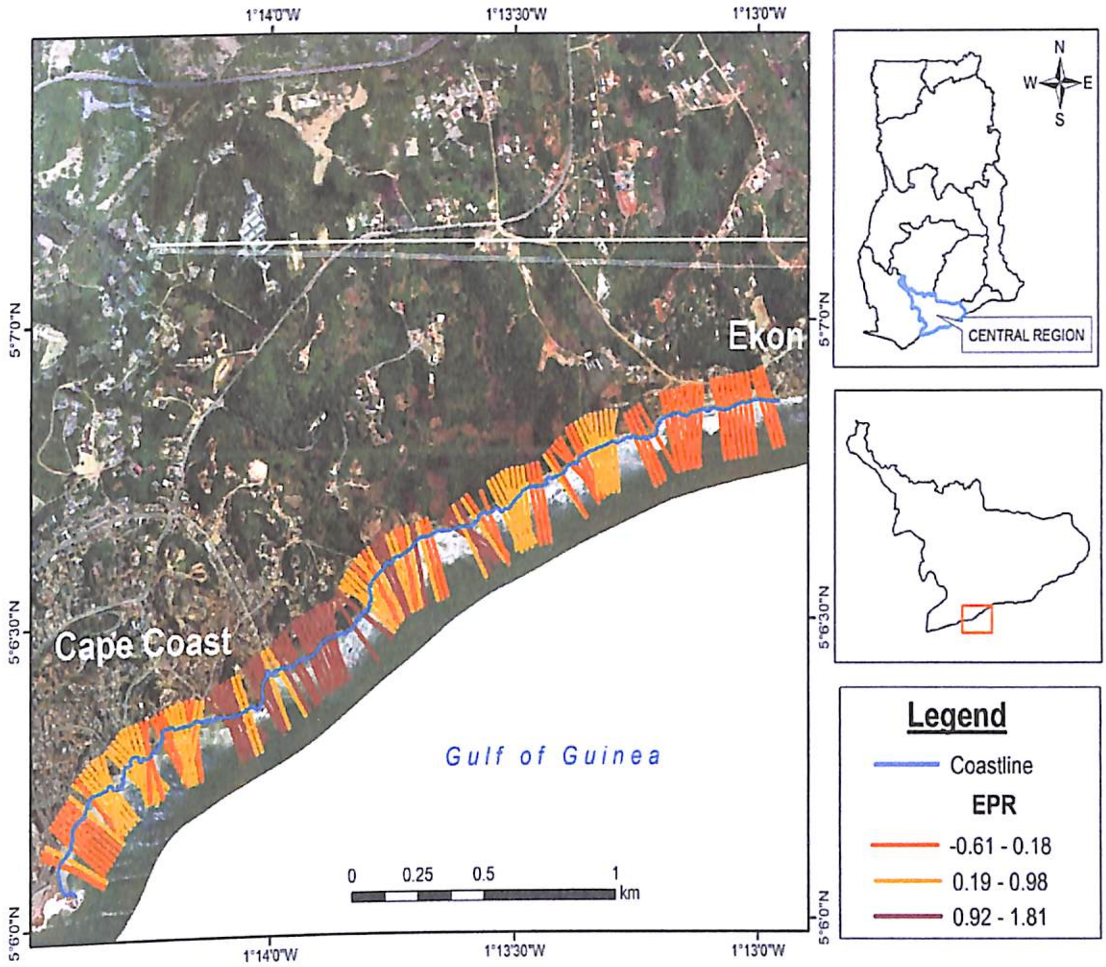


Figure 16: Shoreline change along Cape Coast/Ekon coastline based on rates of erosion and accretion. Source: Field survey and laboratory analysis, (2014).

Note: ***The negative values indicate maximum erosion while positive values indicate minimum erosion and hence, accretion. The blue line indicates current shoreline, that is, 2013 while the transects depict rates of erosion and accretion.***

Figure 16 shows the extent of shoreline change around the coast of Ekon and Cape Coast based on the rates of erosion and accretion. The rate of change is between -0.61 and 1.81m/yr. From Figure 16, it could be deduced that between Cape Coast and Ekon, maximum erosion occurred around Ekon with maximum erosion leading to the advancement of the shoreline between -0.61-0.18m/yr. In other words, the eastern portion of the coast was under serious erosion but the rate of erosion becomes moderate as one move towards Cape Coast, which is the western end of the shoreline. Erosion again intensifies at the extreme west of the coast around Cape Coast just before the Cape Coast Castle. Thus, erosion was at its maximum around Ekon, reduces as one moves westwards towards the Cape Coast Castle and then increased around the extreme west. It can therefore be said that between Cape Coast and Ekon, there was minimum erosion.

The main reason that could be assigned for intense erosion around Ekon was that, most part of the coast was observed to be sandy and open. As a result, the waves have easy access to the beach without much obstruction. In between, there was minimum erosion and hence more accretion due to the rocky nature of the coast. The highest accretion rate was recorded around the rocky beach since the rocks served as barrier. This notwithstanding, there was a serious stone and gravel quarrying at the beach west of Ekon behind the regional office at Cape Coast. These activities threaten the coastline since they make the coast more susceptible to erosion. Apart from the result from the shoreline analysis, interviews conducted also confirmed that there has been serious erosion around the Ekon beach. The residents confirmed that about five years ago, there was a beach resort with summer huts built at the beach. Unfortunately, the project had to be abandoned due to the fact that the whole beach was inundated and the summer huts destroyed by the sea. When one visits the area, there are visible signs of the abandoned projects. It was found out that since then, the sea had been retreating due to increased accretion.

Further, analysis of the rate of erosion and accretion in relation to net shoreline movements through linear regression also confirmed that there had been high rate of accretion than erosion in recent times hence the sea has been retreating as shown in Figure 17.

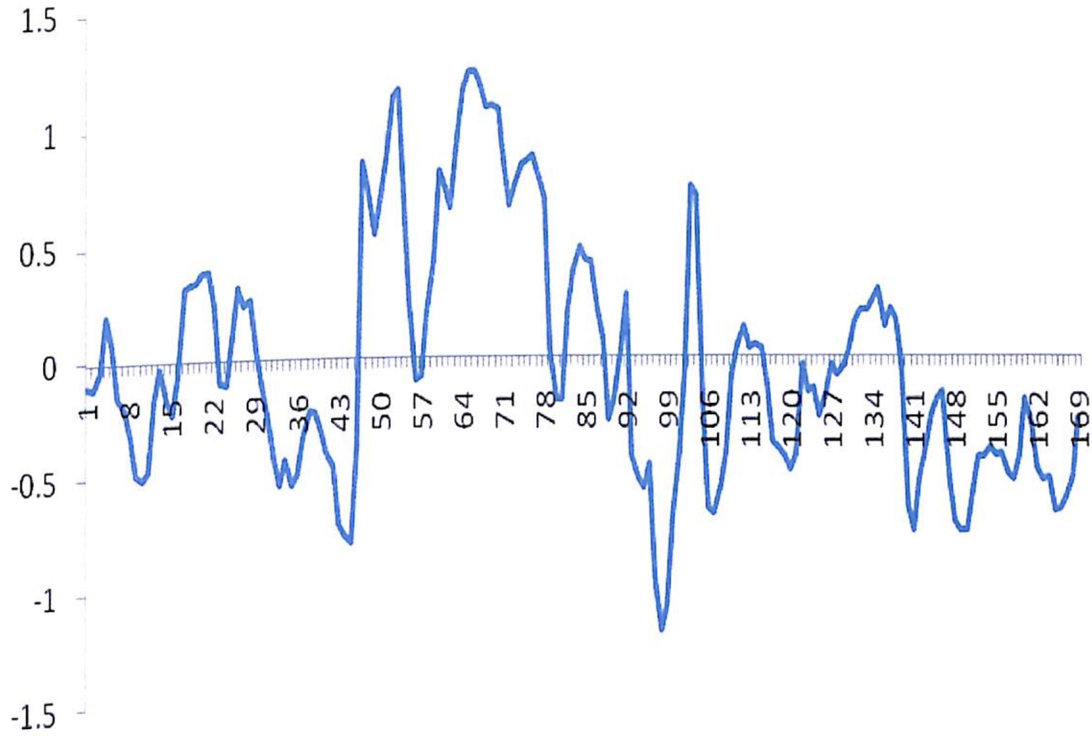


Figure 17: Linear regression of shoreline movement at Cape Coast/Ekon

Source: Field survey and laboratory analysis, (2014).

The ensuing paragraphs discuss the rate of erosion and accretion in relation to shoreline change for Komenda as shown in Figure 18.

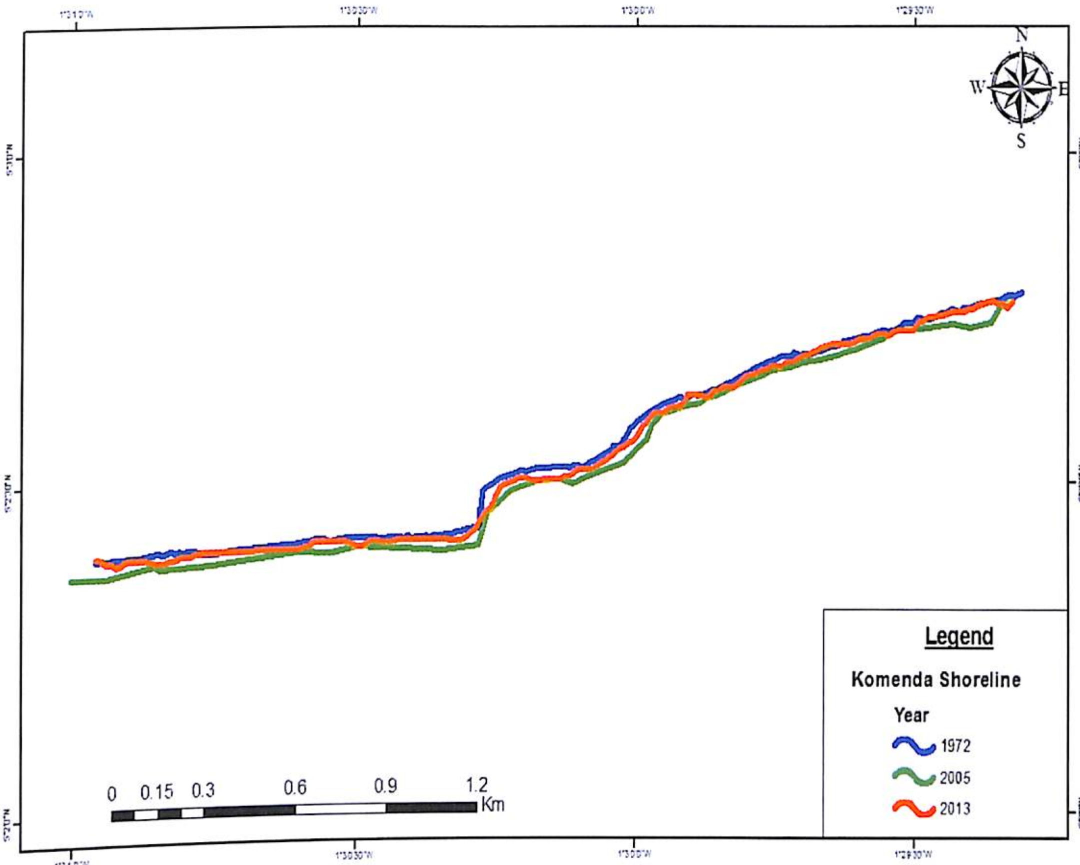


Figure 18: Shoreline positions of Komenda for 1972, 2005 and 2013

Source: Field survey and laboratory analysis, (2014).

From Figure 18, the general observation is that the coastline of Komenda did not experience much change as compared with that of Cape Coast and Ekon. From the base line that is 1972, it could be seen that the sea had been retreating rather than advancing. The fluctuation is not very significant. The eastern portion of the coast is sandy while the western part around Gold Hill is rocky. The rocks had always acted as barrier to erosion hence the eastern portion is likely to suffer from erosion than the western part. In all, it can be said that the difference between and among the positions of the three shorelines were not very significant. Figure 19, shows the rate of change in the shoreline around Komenda.

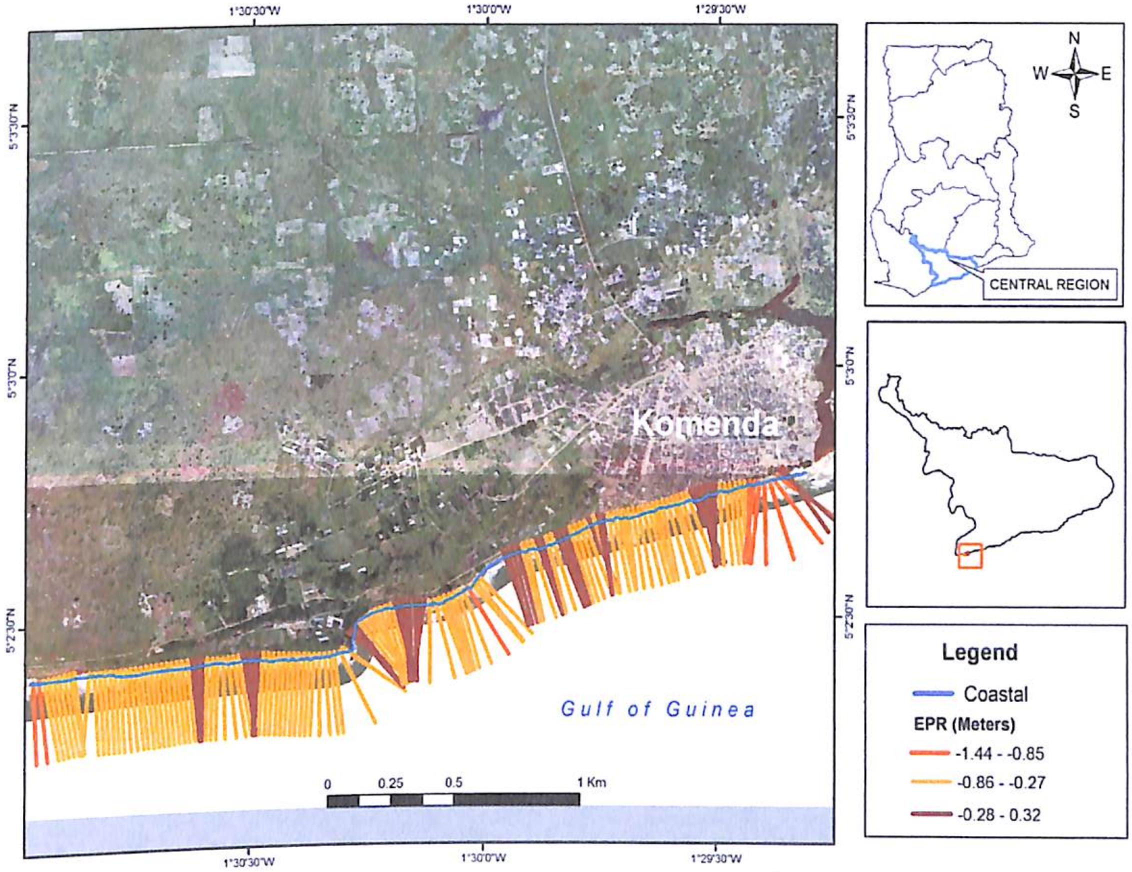


Fig. 19: Shoreline change along Komenda for 1972, 2005 and 2013

Source: Field survey and laboratory analysis, (2014).

The shoreline change was computed for 154 transects with 300 meters distance. The highest long-term erosion change was -1.44 to -0.28m/yr while the highest long-term accretion rate was 0.32m/yr. Maximum erosion was restricted to a small portion of the eastern coastline. Several areas along the beach experienced moderate to minimum erosion. Though most areas along the beach are experiencing accretion rather than erosion in some decades ago, recent data shows that the extreme east is under maximum erosion compared to the middle and the west. Figure 20 shows that on average, the entire coastline along this part of the study area had been experiencing erosion than accretion. What it means is that the sea around Komenda had been advancing due to intense erosion between 1972 through 1995 until recent times when accretion had become more dominant than erosion.

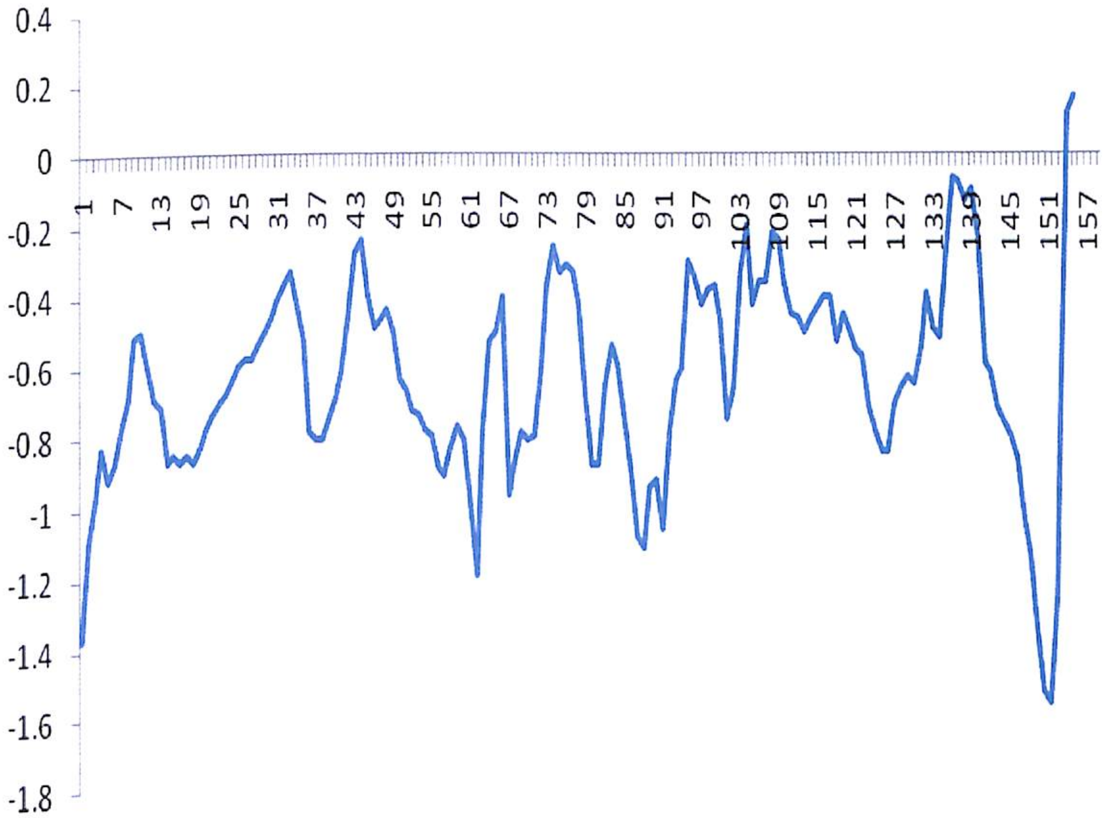


Figure 20: Linear regression of shoreline movement at Komenda

Source: Field survey and laboratory analysis, 2014

Figures 21 and 22 also give detailed information on the extent of erosion and accretion through shoreline change analysis for Sekondi.

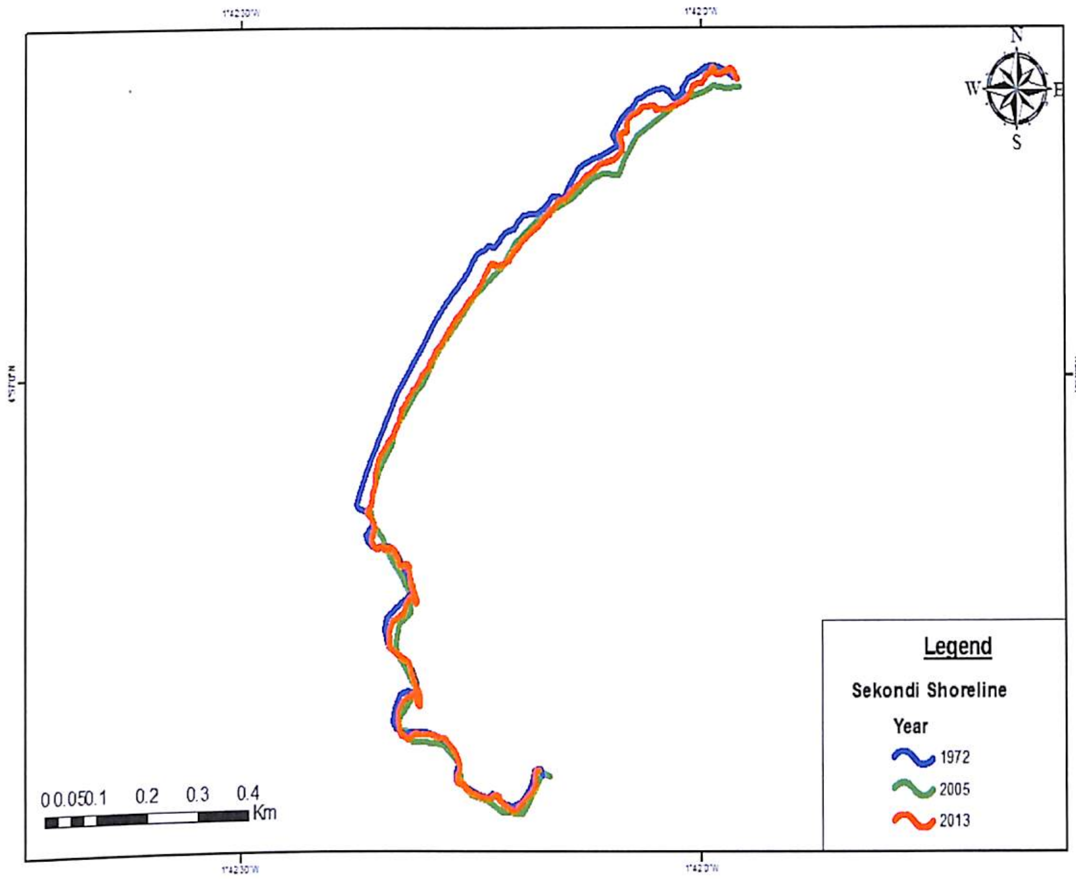


Figure 21: Shoreline positions of Sekondi for 1972, 2005 and 2013

Source: Field survey and laboratory analysis, 2014

From the base line, it could be seen that between 1972 and 2005, the sea retreated from the original position but began to advance towards the land again. The advancement through erosion was not sustained to catch up with the original position of the shoreline in 1972. In the extreme east, there was a vast difference between 1972 and 2005 but there was more deposition than erosion between 2005 and 2013. There is not much difference between the shoreline positions in the extreme west.

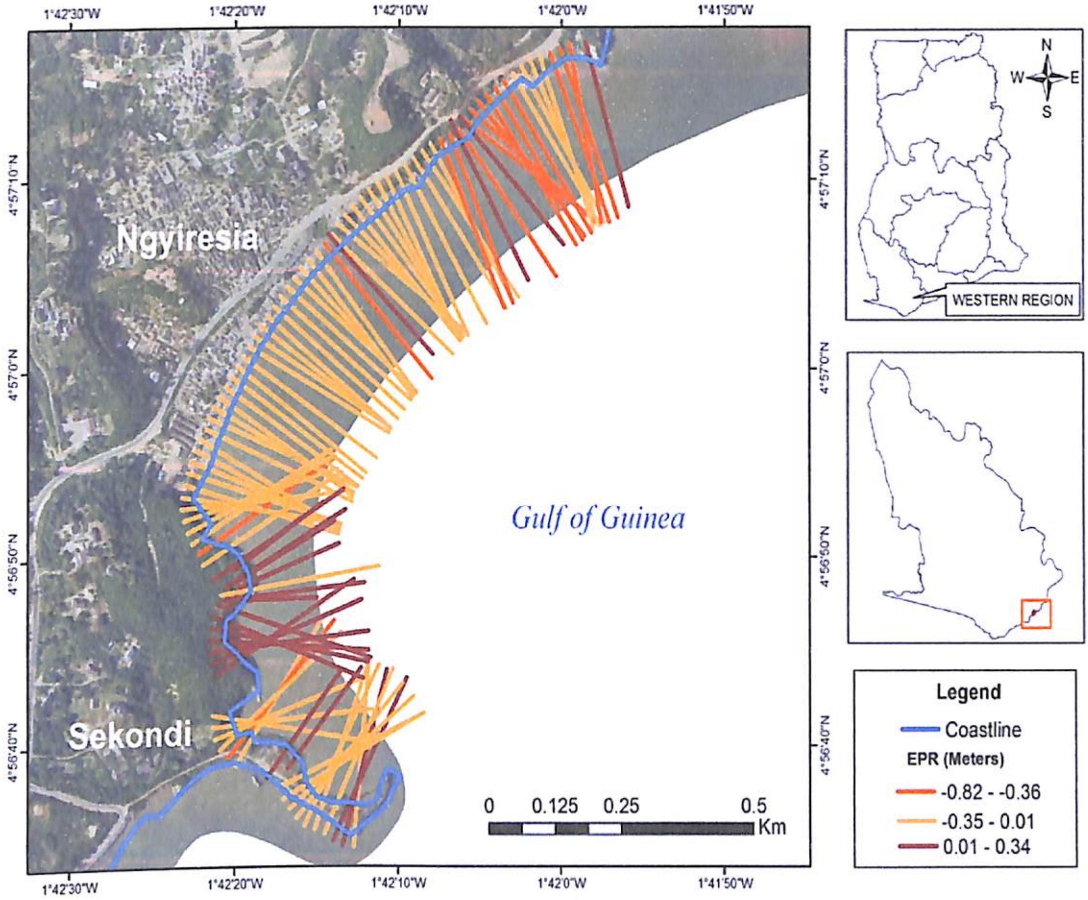


Figure 22: Shoreline change along Sekondi for 1972, 2005 and 2013

Source: Field survey and laboratory analysis, (2014).

The coastline of Sekondi was measured at 97 transects along approximately 300m. The maximum erosion rate was -0.82 to -0.35 on the eastern side of the coast. Erosion was moderate with highest accretion occurring in the area around Ngyiresia beach. The long term accretion rate was between 0.01 and 0.34m/yr. The extreme west was also accreting. It is thus realized that, on the average, the coastline of Sekondi has been accreting than eroding though there are physical evidence of serious erosion several years ago. This was also discovered during the community interaction. This necessitated the erecting of sea defenses such as groins through the use of granites. This has contributed significantly to reduction in the advancement of the sea. The question this study posed was 'could the intensification of erosion around Sekondi-Takoradi be attributed to the construction of the Takoradi and Sekondi harbours? To some extent it could be said that the existence of these harbours may have contributed to the high rate or erosion that extended inland some years ago until sea defenses were erected along the coast. In like manner, as in the case of the Tema Harbour which is believed to have contributed to the intense erosion around Keta, one may not be far from right to also attribute the high rate of erosion around Sekondi, Nkontompo which also lie on the eastern side of the Takoradi Harbour. Figure 23 shows the rate of erosion and accretion in relation to net shoreline movements.

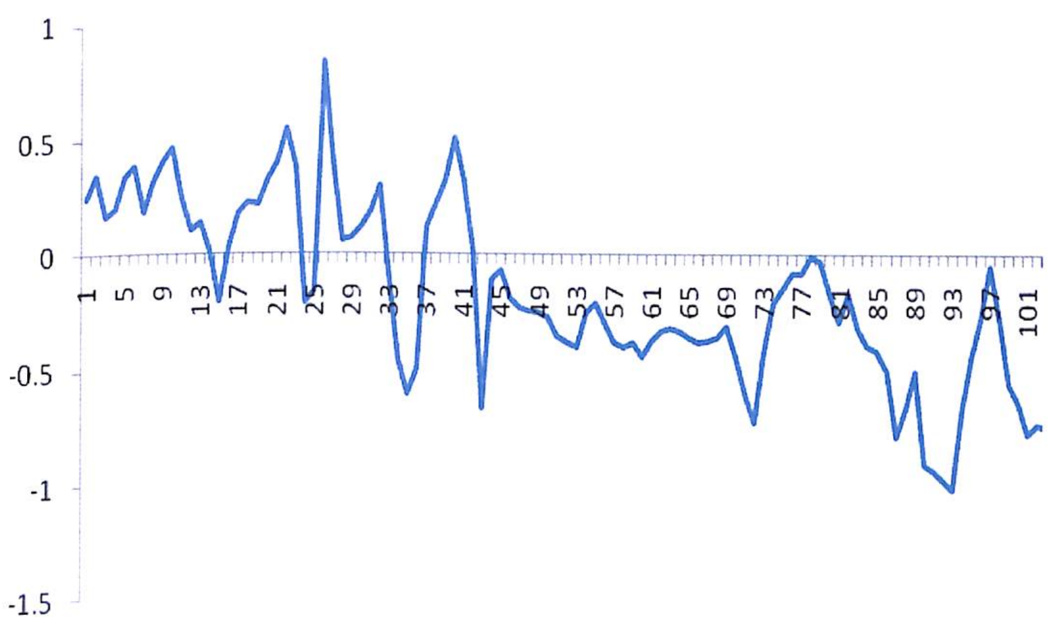


Figure 23: Linear regression of shoreline movement at Sekondi

Source: Field survey and laboratory analysis, (2014).

The advancement of the sea through erosion has reduced due to more accretion than erosion as shown in Figure 23.

Throughout the fieldwork, it was observed that the coastline under study, like other coastlines has been undergoing some changes. This is mainly due to the incidence of alternating and constant erosion and accretion. As a result, the shorelines kept fluctuating. In all the three study sites, it came out that erosion becomes very strong between May and August. The inhabitants could not give any scientific explanation but believed that it is a normal behaviour of the sea. This study thus concludes that due to the rainy season during this period, that is May to August, much water is supplied from inland rivers and streams that augment the sea's ability to move sand through strong waves, winds and currents thus contributing to changes along the shorelines. This is in line with the assertion of Gibeaut, et al., (2001), when they argued that "the changes along a shoreline are caused by changes in the forces that move the sand, namely wind, waves, and currents and by the supply of sand while short-term and long-term relative sea-level changes also control shoreline movements". Waves, for instance, change the coastline morphology and form the distinctive landforms.

The physical shoreline change is also influenced by coastal engineering structures and other human activities. In all the three study sites, it was observed and also confirmed through the survey that there had been a retreat of the sea. This is because the beach had been raised due to hitherto erosion and subsequent accumulation of beach materials.

At Sekondi, the retreat was between 20 and 30 meters from the shoreline. Previously, the sea was found close to residential area, later flooded the beach and now has retreated for a distance of about 25 meters. Between the Sekondi fishing harbour and Nkontompo, the story is different. There is evidence of coastal inundation and strong wave erosion. At Komenda, there is also an evidence of raised beach due to hitherto strong waves and subsequent accumulation of sediments. According to the local inhabitants, for about three years, the sea has never gone beyond a certain level though occasionally erosion becomes so serious which they attributed to the fact that sometimes the gods are annoyed.

At Cape Coast-Ekon, there is also evidence of advancing sea. There has been massive accumulation of sediments along the coast leading to an upliftment of the beach. It can therefore be said that there had previously been serious erosion which was followed by continuous accumulation of beach materials hence the development of raised beaches. Evidence of the advancing sea along the study area are the upliftment of the coastline due to massive accumulation of beach materials higher up the beach. The distance between the cliff face as well as dwelling houses and the present lower water mark is very short. During the community consultations/interviews, it was revealed that the advancement of the sea towards the beach has been very rapid between the last two and five years. This is because the beach which used to be recreational grounds for tourists and holyday makers has been lost to the sea. Summer huts and other structures which were erected at the beach are no more. The beach was full of coconut trees but now you can count not more than ten coconut trees around Ekon.

Around Sekondi and Komenda, it came out that though the sea has advanced; there also seems to be a retreatment of the sea. At Gold Hill Beach around Komenda for instance, presently, it is very difficult for sea erosion to seriously attack the entire cliff due to an increasing distance between the land and the sea. This shows that previously, the sea was very close to the cliffs hence the total collapse of the cliff face. Moreover, there is also the presence of artificial barriers some of which are now further from the sea. There is also evidence of structures which were previously under serious wave attack but are now found at some distances away from the sea. All these point to the fact that the sea is retreating between Komenda and Sekondi more than Cape Coast/Ekon. Tables 13 and 14 give an overall summary of the rate of erosion, accretion and mean shoreline movements for the three study sites.

From Table 13, it can be deduced that the maximum shoreline movement from erosion occurred around Cape Coast and Ekon followed by Komenda. In like manner, maximum end point rate and linear regression rates are all higher in Cape Coast and Komenda than Sekondi indicating that sea erosion has been intense in these two study sites than Sekondi.

It can also be found from Table 14 that net shoreline movement from accretion is higher in Cape Coast followed by Sekondi with the least occurring in Komenda. The highest end point rate, as well as linear regression rate, was all recorded around Cape Coast and Ekon indicating that there had been a significant movement in the sea through both erosion and accretion.

Table 13: Net shoreline movements from erosion for the three study sites

Shoreline Erosion				
Net Shoreline Movements				
Zone	No. of transects	Min NSM	Mean NSM	Max NSM
Ekon	55	-24.88	-10.44	-1.14
Komenda	150	-59.72	-21.53	-0.72
Sekondi	62	-33.85	-10.12	-0.71
End Point Rate				
Zone	No. of transects	Min EPR	Mean EPR	Max EPR
Ekon	57	-0.6	-0.24	-0.03
Komenda	150	-1.44	-0.52	-0.02
Sekondi	62	-0.82	-0.24	-0.02
Linear Regression				
Zone	No. of transects	Min LRR	Mean LRR	Max LRR
Ekon	100	-1.19	-0.38	-0.3
Komenda	153	-1.55	-0.64	-0.07
Sekondi	82	-1.01	-0.3	0.25

Field survey and laboratory analysis (2014/15)

It further means that among the three study sites, Cape Coast and Ekon experienced significant land loss through erosion as well as significant land gain through accretion. It can therefore be concluded that Cape Coast/Ekon had been experiencing short-term to episodic net shoreline movements while Komenda and Sekondi had been experiencing all the three types of shoreline movements identified in the literature by Gibeaut et al; (2001) that shoreline change and movements can be short-term, long-term and episodic.

Table 14: Shoreline accretion for the three study sites

Shoreline Accretion				
Net Shoreline Movements				
Zone	No. of Transects	Min NSM	Mean NSM	Max NSM
Ekon	114	0.02	25.72	74.82
Komenda	5	0.86	5.8	13.31
Sekondi	41	0.17	9.4	33.62
End Point Rate				
Zone	No. of Transects	Min EPR	Mean EPR	Max EPR
Ekon	112	0.03	0.63	1.81
Komenda	5	0.02	0.14	0.32
Sekondi	41	0.04	0.22	0.81
Linear Regression				
Zone	No. of Transects	Min LRR	Mean LRR	Max LRR
Ekon	69	0.02	0.49	1.23
Komenda	2	0.11	0.14	0.16
Sekondi	21	0.12	0.36	0.84

Field survey and laboratory analysis (2014/15)

The ensuing paragraphs present the analysis and discussion on land cover change in Cape Coast and Sekondi.

Land-Cover Change Analyses Along Cape Coast–Sekondi Coastline

Land cover change analysis was done for Cape Coast and Sekondi for 2005 and 2013. The images in the 2013 aerial photographs for Komenda were not very clear hence, it was not included in the analysis. Classes of land use/cover types identified in Cape Coast between 2005 and 2013 were bare area, built up, beach, farm, vegetation and water (Figures 25 and 26). Table 15 shows the sizes of land-use/cover for Cape Coast in 2005 and 2013.

Table 15: Land use/cover sizes for Cape Coast 2005 and 2013

Cover Type	Area (2005)	Area (2005) Percent	Area (2013)	Area 2013 Percent
Bare Area	1483480	2.31	2127600	3.31
Built-up	20290800	31.61	25246200	39.33
Beach	416191	0.65	380843	0.59
Farm	1745320	2.72	460738	0.72
Shrubs & Grass	38582600	60.10	33633900	52.39
Water	1380250	2.15	1660220	2.59
Wetland	299279	0.47	688459	1.07
Total	64197920	100.00	64197960	100.00

Source: Field Survey, (2014).

The total land cover/use for Cape Coast in 2005 was 64,197,920 m^2 while that of 2013 was 64,197,960 m^2. Thus, from Table 15, it is obvious that the total land use/cover for Cape Coast in 2013 was 41m^2 larger than that of 2005. This represents a percentage increase of 0.6% as shown in Table 16.

Table 16: Sizes and percentage change in land use/cover for Cape Coast from 2005 to 2013

Use/Cover Type	Area (2005)	Area (2013)	Change (2005_2013)	Percent Change (2005_2013)
Bare Area	1483480	2127600	644120	43.42
Built-up	20290800	25246200	4955400	24.42
Beach	416191	380843	-35348	-8.49
Farm	1745320	460738	-1284582	-73.60
Shrubs & Grass	38582600	33633900	-4948700	-12.83
Water	1380250	1660220	279970	20.28
Wetland	299279	688459	389180	130.03
Total	**64197920**	**64197960**	-	-

Source: Field Survey, (2014).

From Table 16, it is found that land cover/use for Cape Coast between 2005 and 2013 varies among the various land cover types identified. Land use/cover increased from 2005 to 2013 for bare area, built up and areas covered by water, including wetland. On the other hand, areas covered by beach, farms and vegetation decreased. What these mean is that, there was loss of beach, vegetation and farms to built up, water and bare area. Some farm lands and vegetation were cleared for dwelling houses thus changing to built up. Part of the beach either became bare after the retreat of the shoreline or parts were utilized for other purposes including buildings. On the other hand, the decrease in the size of the area covered by beach could also be attributed to coastal inundation since there were increases in the area covered by water and wetland from 2.15% and 0.47% in 2005 to 2.59% and 1.07% in 2013 respectively as shown in Table 15 with percentage change of 20.28% and 130.03% for water and wetland between 2005 and 2013 as shown in Table 16.

Table 17 gives detailed result of the extent/size of change for the various land cover type/use identified and selected for the study in a matrix form for easy identification and description. Table 17 indicates that bare areas mainly changed to built up, farms and vegetation. That is, parts of the bare areas were used for buildings, for crop cultivation and sometimes too, vegetation naturally grew in hitherto bare areas. Beaches mainly changed to built up and water meaning that shoreline advancement leads to loss of beaches. On the other hand, when shorelines retreated, more land was exposed but in this circumstance, the exposed beach was not left to fallow but dwelling structures were put up. Farms also mainly changed to bare area, built-up and vegetation. When crops are harvested and the farms are abandoned, the natural vegetation will grow under the natural climatic condition hence the hitherto farm in 2005 has changed to vegetation (shrubs and grass) occupying an area of 1,384,200 m^2 as indicated in Table 17. Farms change to bare area when they are abandoned and the vegetation is burnt or the surface soil is removed through construction. Farms also change to built-up when houses are built on the land. In the field survey, it was observed that when the land is secured, it is sometimes utilized for crop cultivation until the owner is ready to put up a building thus changing from farm to built-up finally.

Vegetation cover (shrubs and grass) experienced varied changes than any other land cover type for Cape Coast. Some of the areas covered by vegetation became bare through bush burning and construction activities. Parts of the vegetation is also cleared for housing projects hence changing to built up which is 4,746,850m^2 (Table 17). Parts of the vegetation very close to the sea and other water bodies such as the Fosu Lagoon were covered by water including wetland. This was due to the advancement of these water bodies due to erosion and inundation. Some vegetation also changed to beach as indicated in Table 17. Water bodies such as the parts of the sea, lagoons and wetlands were converted or changed to built up, beach and vegetation among others. In all, most parts of the land were used for or changed to built up.

Figures 24 and 25 also further show details of the varied land use/cover types and sizes for Cape Coast in 2005 and 2013 respectively.

Table 17: Land use/cover change in Cape Coast from 2005 to 2013 matrix

		Land use/cover 2013							
		Bare Area	Built_up	Beach	Farm	Shrubs & Grass	Water	Wetland	Total
	Bare Area	704344	163163	-	14973.2	601000	-	-	1483480.2
	Built_up	-	20290800	-	-	-	-	-	20290800
Land use/ cover 2005	Beach	-	87.6	378180	-	-	7068.8	-	385336.4
	Farm	72112	57001.6	-	231999	1384200	-	-	1745312.6
	Shrubs & Grass	1348930	4746850	609.6	213766	31588700	237850	445855	38582560.6
	Water	-	1283.2	807.6	-	4591.6	1366260	7308.8	1380251.2
	Wetland	-	-	-	-	13896.8	56078.4	229304	299279.2
	Total	2125386	25259185.4	379597.2	460738.2	33592388.4	1667257.2	682467.8	64167020.2

Source: Field survey, (2014).

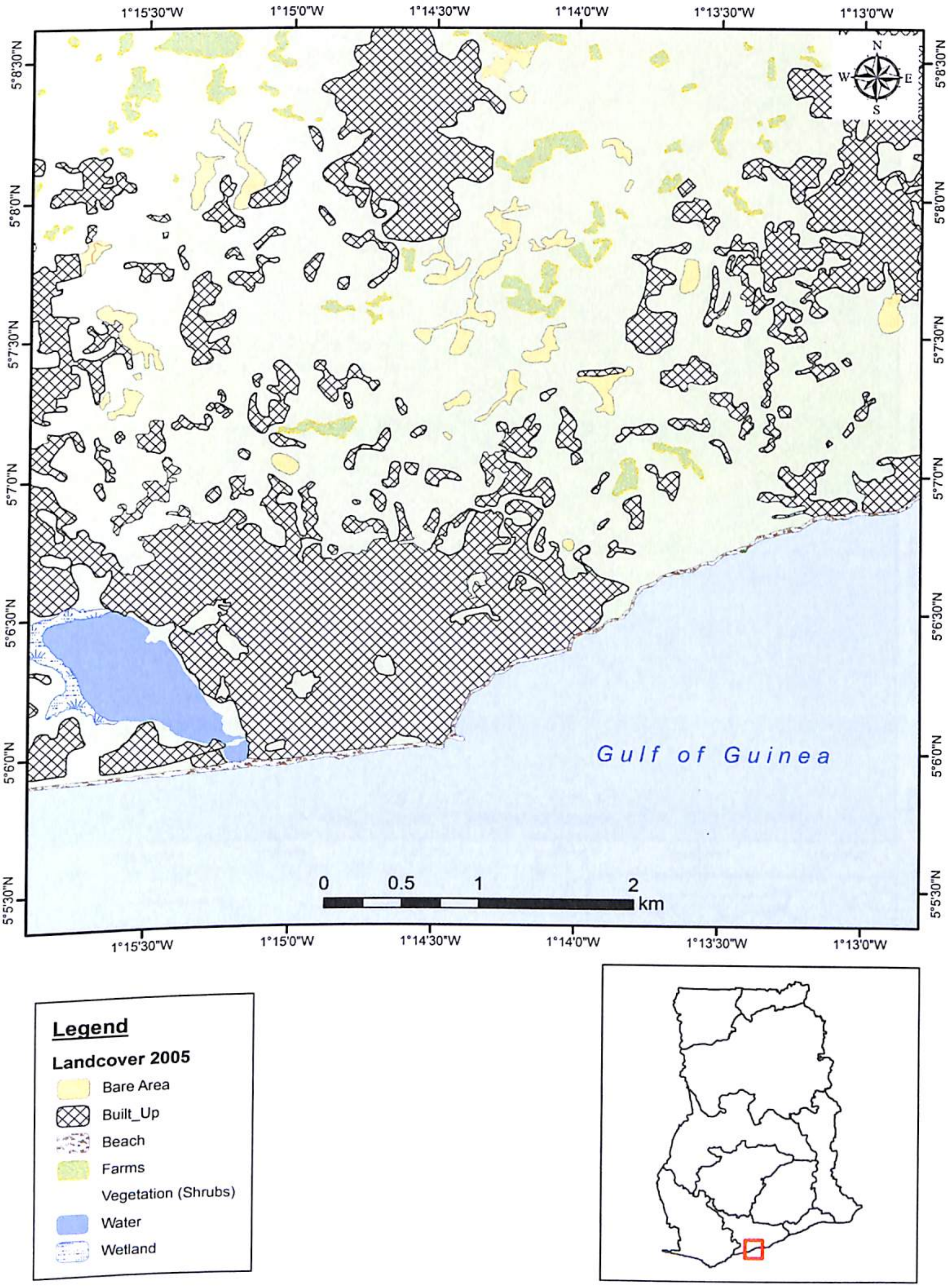


Figure 24: Land use/cover for Cape Coast in 2005

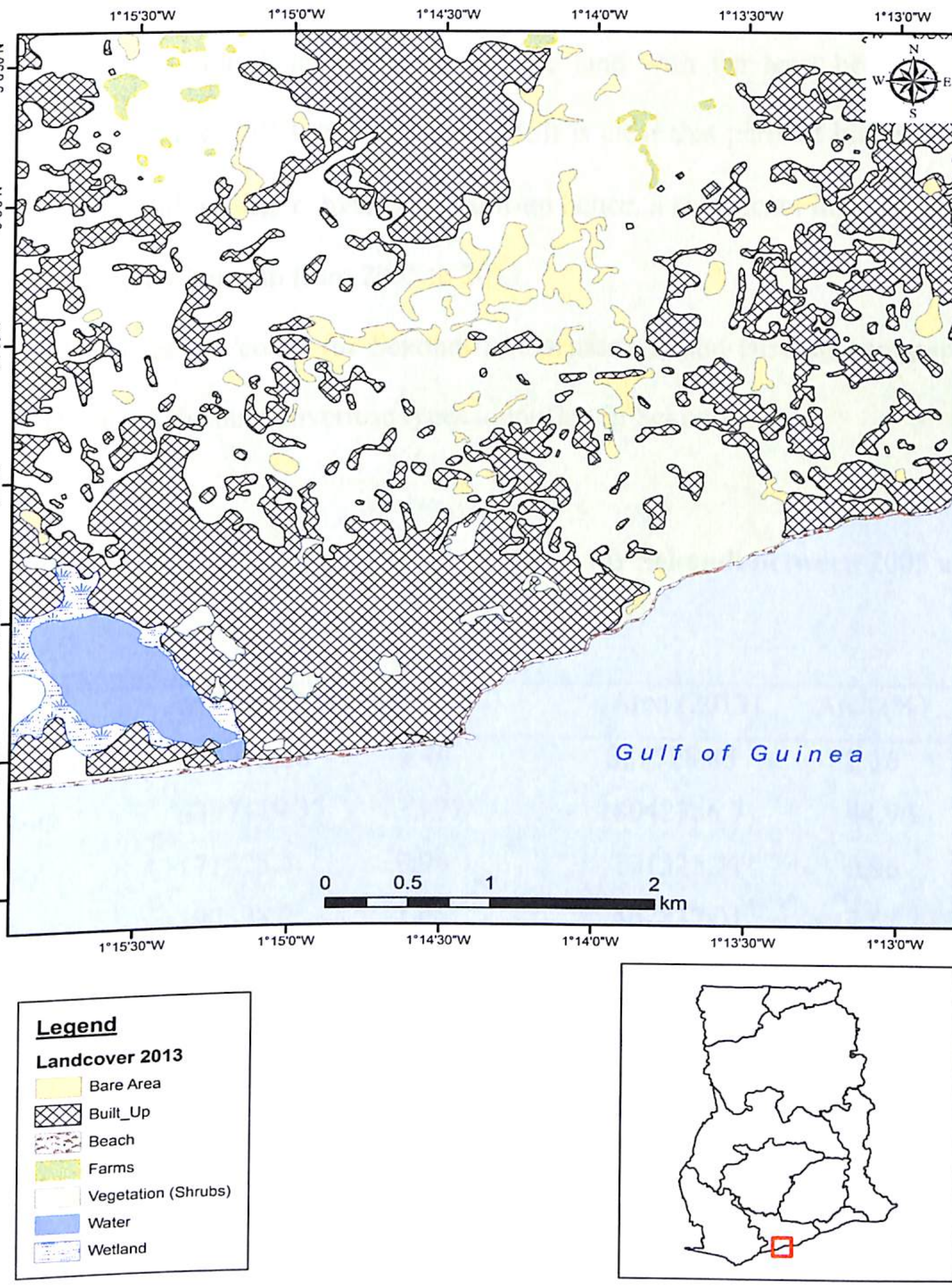


Figure 25: Land use/cover for Cape Coast in 2013

From Figure 24, it s seen that built-up areas occupy most of the land area. Bare areas and farms are scattered all over the area. Vegetation, that is shrubs and grass, occupy a significant proportion of the land with the least being water. Compared to that of 2013, that is Figure 25, it is clear that parts of hitherto bare land and vegetation were converted to built-up hence, a significant increase in the areas covered by built-up from 2005 to 2013.

The land use/cover for Sekondi is discussed in the ensuing paragraphs. Table 18 shows the land cover/use types identified in Sekondi.

Table 18: Percentage change of land use/cover for Sekondi between 2005 and 2013

Cover	Area (2005)	Area (%)	Area (2013)	Area (%)
Bare area	792713.53	4.46	385728.83	2.16
Built-up	6397119.33	35.77	8042386.71	44.96
Quarry	171525.4	0.96	171525.41	0.96
Farm	190398.2	1.06	462837.01	2.57
Shrubs & grass	10272928.67	57.44	8754877.93	48.95
Water	54608.46	0.31	66437.7	0.37
Total	17883793.59	100.00	17883793.59	100.00

Source: Field survey, (2014).

Table 19: Percentage change of land use/cover for Sekondi between 2005 and 2013

Use/cover	Area (2005)	Area (2013)	Change area	Change %
Bare area	792713.53	385728.83	-411484.7	-51.62
Built-up	6397119.33	8042386.71	1645267.38	206.38
Quarry	171525.4	171525.41	0.01	0.00
Farm	190398.2	462837.01	272438.81	34.17
Shrubs & grass	10272928.67	8754877.93	-1518050.74	-190.42
Water	54608.46	66437.7	11829.24	1.48
Total	17883793.59	17883793.59	-	-

Source: Field survey, (2014).

From Table 19, it is seen that most of the bare areas and areas covered by vegetation were lost to other land cover/use types. In other words, built up and farms increased in size while bare areas and vegetation were converted to other uses. In all, there was no gain nor loss in the total land area available due to the fact that the beach was not significantly affected between these two periods. Table 20 gives detailed result of the extent/size of change for the various land cover type/use identified and selected for the study in Sekondi.

The general picture was that bare areas were converted to built-up, farms and vegetation. This means that, parts of the bare areas were used for buildings or residential area, for crop cultivation and sometimes taken over by vegetation. For example, the change from bare area to built up between 2005 and 2013 was 380,837m² but only a small area was converted to farms, about 603 m² as shown in Table 20. It is also deduced from Table 20 that farms only changed to vegetation.

Vegetation cover in Sekondi, like that of Cape Coast, also experienced varied changes than any other land cover type found in the study area. Some of the areas covered by vegetation became bare probably through bush burning and construction activities. Parts of the vegetation is also cleared for housing projects hence changed from vegetation to built up with the size of 1,266,149.59m² as seen from Table 20. Parts of the vegetation very close to the sea and other water bodies were covered by water. Part of the vegetation was also used for farming activities. Some areas covered by water also become bare area mainly due to the retreat of the sea and drying of some water bodies such as the Essei Lagoon or Sekondi Lagoon.

In all, it can be deduced that most parts of the land cover types were converted to built up or residential areas. Figures 26 and 27 also show details of the varied land use/cover types and sizes for Sekondi in 2005 and 2013 respectively.

Table 20: Land use/cover change in Sekondi from 2005 to 2013 matrix

		Land use/cover 2013						
	use/cover	Bare Area	Built-up	Farm	Shrubs & Grass	Water	Quarry	Total
Land use/cover 2005	Bare Area	236333	380837	-	603	179574	-	797347
	Built-up	-	6397112	-	-	-	-	6397112
	Farm	-	-	73460	116936	-	-	190396
	Shrubs & Grass	149385	1266149.59	388754	-	17175	-	1821463.59
	Water	5354	-	-	-	49264	-	54618
	Quarry	-	-	-	-	-	171515	171515
	Total	391072	8044098.59	462214	117539	246013	171515	9432451.59

Field survey, (2014).

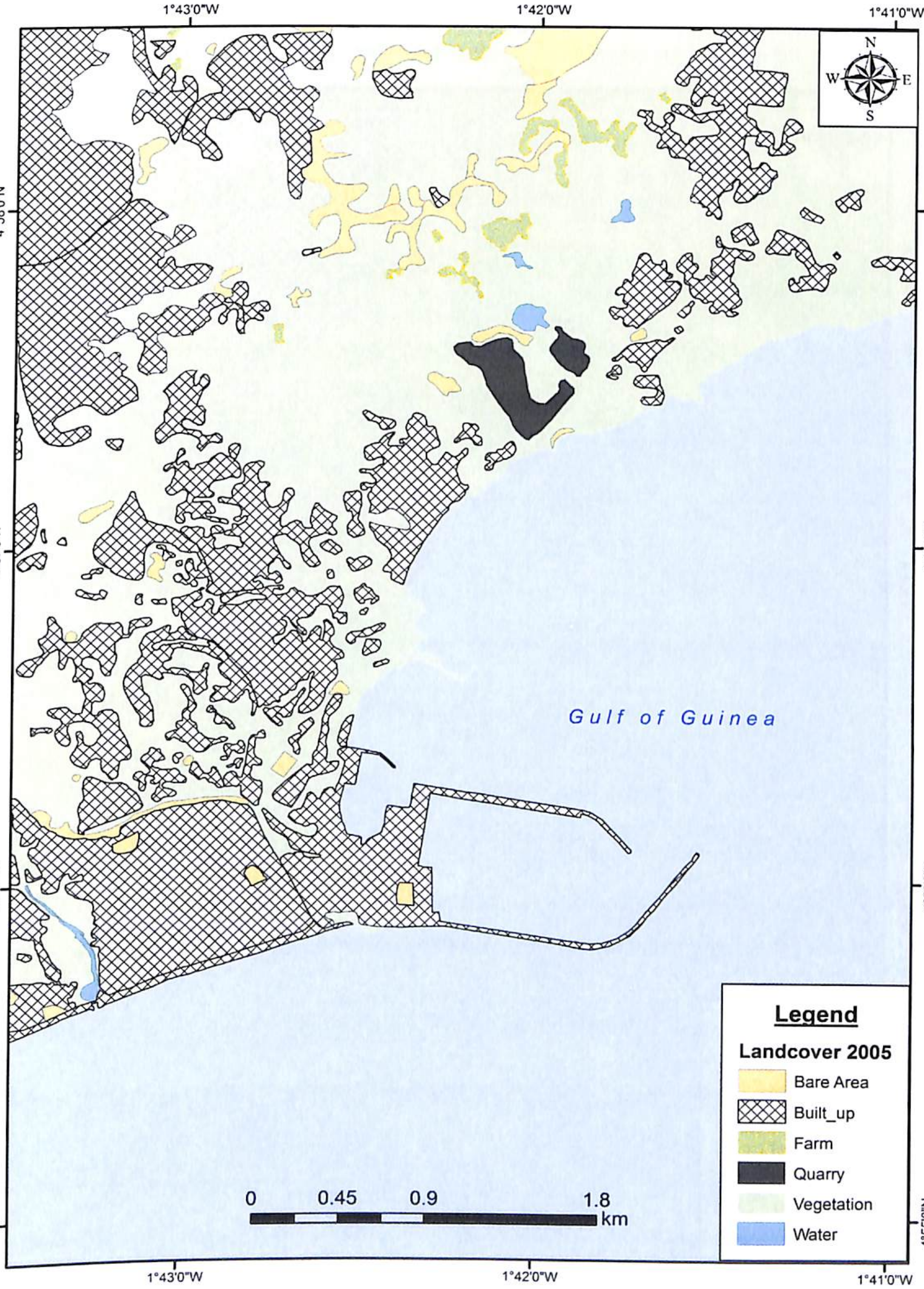


Figure 26: Land-cover for Sekondi in (2005).

From Figure 26, it is found that built-up and vegetation makes up the largest land use/cover for the area with scattered farms and bare areas.

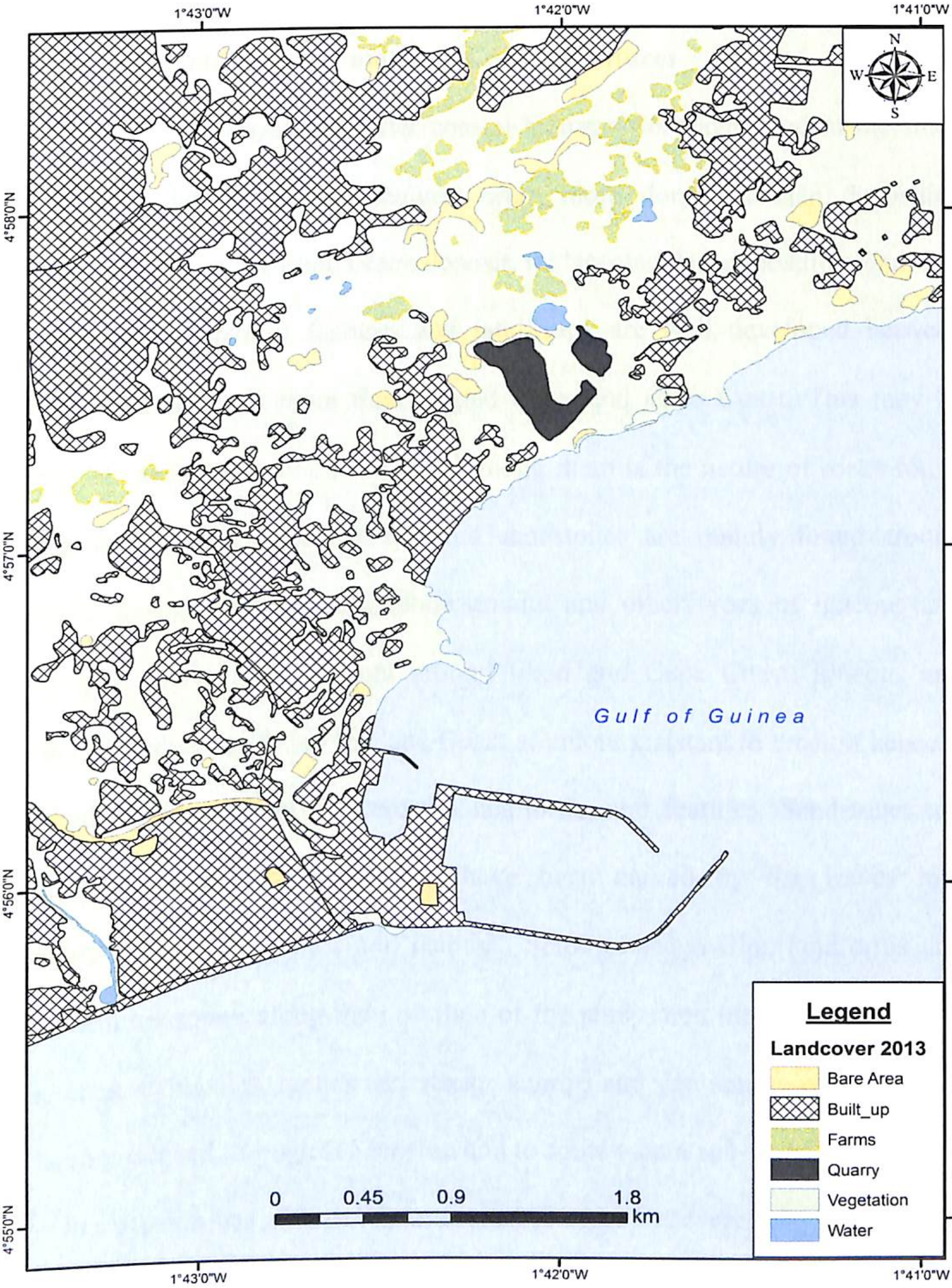


Figure 27: Land cover for Sekondi in (2013).

From Figure 27, it can be deduced that areas covered by built-up continue to make more gains as compared to that of 2005. Bare areas, vegetation and farms were lost to built up hitherto unused lands are now utilized for human structures.

Impact of Sea Action on Geomorphic/Coastal Features

Several landforms and other coastal features were identified in the study area. Erosion landforms and features were more dominant than deposition features. Apart from the usual beach deposit, no 'spectacular' deposition landform was identified. Erosion features and landforms are well developed between Komenda and Sekondi more than around Ekon and Cape Coast. This may be attributed to several factors. Prominent among them is the nature of rocks found in these two coastal stretches. Sekondi sandstones are mainly found around Elmina, Komenda and Sekondi while granite and other types of igneous and metamorphic rocks are dominant around Ekon and Cape Coast. Igneous and metamorphosed schist found in Cape Coast are more resistant to erosion hence it is difficult to carve them into erosion landforms and features. Sandstones are generally easily eroded hence they have been carved by the waves into spectacular erosion landforms and features. Some of the erosion landforms and coastal features found along the coastline of the study area include cliffs, caves and notches, blowholes, arches and stacks, stumps and geo among others. These have been produced through sea erosion and to some extent sub-aerial processes.

Sea erosion has affected these coastal features in several ways. Along the study area, some of the rocks are well exposed. In areas where the rocks seem less resistant to erosion, bays and coves with alternating headlands have developed.

Bays and headlands are very common around Cape Coast and Sekondi. Sea erosion easily erodes the less resistant rocks into bays while the more resistant rocks remain in place as headlands and promontories. At Sekondi, around the Turtle Cove, it was observed that the Sekondi Sandstone are underlined by more resistant rocks. As a result, less resistant surface rocks have been eroded leaving the underlying resistant rocks as abrasion platforms. These platforms are very extensive with the major one measuring about 15m breadth, 80.5m wide/length and 0.8m high and have been undergoing several changes. Their formation is in line with the theory of sub-marine origin whereby the platforms had been formed at some depth under the sea but due to the fact that the sea has retreated, they have been exposed. Parts of the platforms are higher than 0.4m above sea level, especially during the dry season. Invariably, parts of the platforms are covered during high tides while most parts are exposed during low tides when sea level falls. During the field work, the respondents also alluded to the fact that the sea has generally retreated. The fact that extensive parts of the abrasion platforms are exposed goes a long way to confirm that the sea has indeed retreated as was revealed during the field interview. The presence of raised beaches at some parts of the three major study sites also confirms the fact that the sea or shoreline has indeed retreated since raised beaches are indication of different stages in shoreline development.

Erosion and sub-aerial processes such as weathering and mass wasting and to some extent human activities such as sand mining and quarrying continue to modify these landforms and features. Notches and caves were found around

Sekondi and Komenda. This is due to the similarity of the rocks found in these areas. Sea erosion at the base of the cliff and headlands has eroded deep into the rocks creating notches and eventually caves. They are more developed along the coast of Komenda than Sekondi. This is due to the nature of the rocks. That is, the sandstones at Sekondi are more resistant to erosion than those at Komenda. As a result sea erosion is able to erode deep into the rocks at Komenda hence well developed caves. At Komenda, a blowhole has developed due to continuous compression of air into the cave. Erosion has taken advantage of weaker parts of the rocks to create an opening at the top of the cave. In all, erosion landforms are well developed around Gold Hill in Komenda compared to the other two study sites. Geo, arch, stack and stumps were all found around Komenda. As has been said earlier, most of these landforms and features are a bit distant away from the waves and as a result, sub-aerial processes are now active in modifying them rather than waves. Around Cape Coast, the rocks are constantly under wave attacks but due to the fact that they are more resistant, erosion landforms are not well developed. Granite and metamorphosed schist are dominant. One can conclude that, generally, sea erosion seems stronger between Cape Coast and Komenda, yet the coast between Ekon and Cape Coast is more protected except where there is sand due to the presence of igneous rocks and metamorphosed schist while the portion between Elmina through Komenda to Sekondi is seriously under attack from waves due to the presence of less resistant sedimentary rocks like Sekondi Sandstone.

There are both physical and human impacts. On the physical environments, there is the development of various landforms and other coastal features. Around Sekondi and Komenda, due to the dominance of sedimentary rocks, mainly sandstone, the rocks are easily eroded and have thus been developed into coastal erosion landforms. Examples are caves, blowhole and total cliff face collapse, especially around Komenda. Comparatively, the rocks along the coastline of Cape Coast, though exposed, are not seriously eroded because they are more of igneous and metamorphic rocks especially granite and metamorphosed schist. These rocks are more resistant to sea erosion and as a result erosion landforms are not well developed here as compared with Komenda and Sekondi.

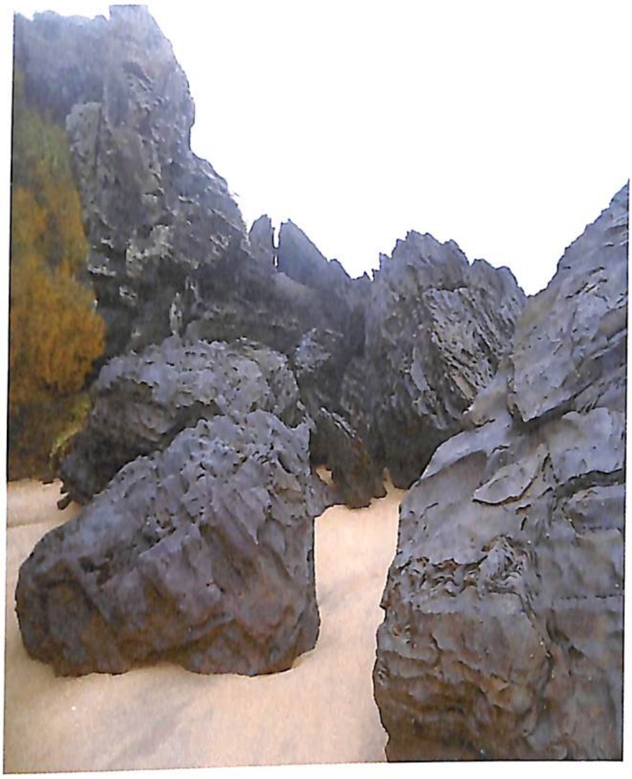
These are caused by sub-aerial geomorphic processes such as erosion, weathering, mass wasting and to some extent human activities such as sand mining and quarrying among others. Sub-aerial processes (SAP) are very prominent in the development of coastal erosion landforms along the coast of the study area, especially between Komenda and Sekondi. At Komenda for example, it was observed during the field study that the distance between the lowest water mark from the shore is about 20 meters while the beach has also been raised due to sand accumulation. As a result it is very difficult for wave action to continuously work on the cliffs. It was also observed that sub-aerial processes are very active at working on the existing landforms and other coastal features.

Thus, the impact of coastal erosion and other processes on the physical environment and human habitation of the study area can be summarized as follows:

1. Increased accretion with raised beaches.
2. Exposure of rocks, total collapse of cliff face and landform development.
3. Destruction of vegetation, as erosion sometimes causes coconut trees to tumble over.
4. Fluctuations in shoreline movements. That is, advance and retreat of shorelines.
5. Destruction human-made structures, including collapse of dwelling houses.
6. High tides leading to occasional floods and inundation, though episodic in nature.

Plates 2, 3, 4, 5 and 6 show some of the impact the sea has on the coastal environments under study.

From Plate 2 A and B, it can be seen that the dynamics of coastal erosion, including sub-aerial processes have acted on the rocks for a long period of time thus exposing them. It was also revealed by the local inhabitants that these rocks come under serious wave attack during high tides.



A B

Plate 2: Exposed rocks along the coast of Komenda (A) and Cape Coast/Ekon (B). (Field photograph, 2014).

Plate 3: Sea erosion threatens residents of Komenda as it attacks both dwelling houses and destroys vegetation. Field photograph, (2014)

From Plate 3, it is seen that the effect of sea erosion was very intense from 1972 up to about 2005 but has been retreating in recent times. Human habitation had been threatened and coconut trees uprooted. In the field survey, it was found that the sea had been accreting in recent times and hence has retreated leading to raised beaches as revealed in Plate 3. In Plate 4 A, a dwelling house was abandoned in Komenda due to erosion and inundation.

Plate 4: A dwelling house is abandoned at Komenda due to sea eroaion. (Field survey, (2014).

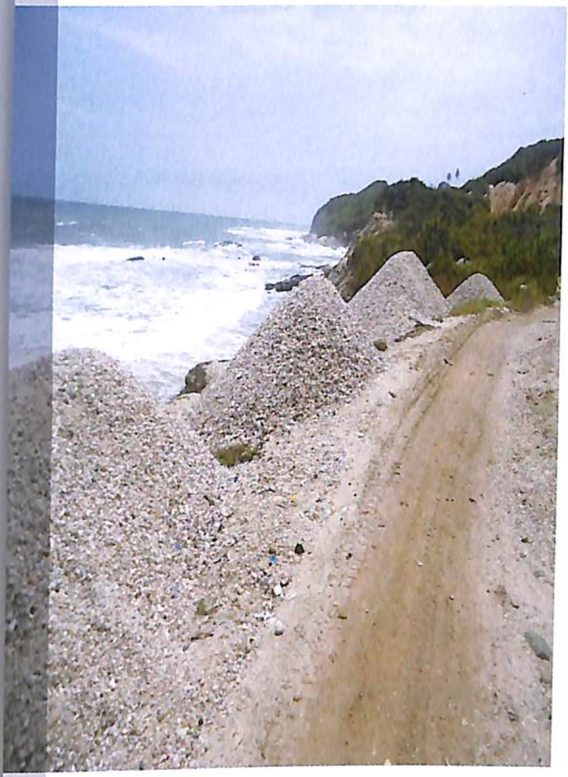
Plate 5: Seriousness of sea erosion at part of Cape Coast beach. Field photograph, (2014).

In Plate 5, coastal erosion is so intense that the residents have used boulders, sand bags and nets to check the advancing sea in Cape Coast. Ironically, some of the residents at the same time mine sand from the beach laying blocks. Some of the blocks are parked as shown in Plate 4 B. Asked why they have been mining sand at the beach, one of the residents/respondents retorted

"*We can mine sand or lay blocks at the beach for our personal use but one cannot do it on commercial basis*".

This notwithstanding, the study found that though there is a ban on commercial sand mining along the coast of the study area, the activities still go on. This is because there is no enforcement of the law. As seen from Plate 5, quarrying activities and sand mining are carried out at the beach. These contribute to changes in shoreline, land cover and impact on the rate of erosion and accretion as shown in Plate 6. This confirms that human activities contribute to changes in the coastal landmass as was identified in the conceptual framework used for the study.

Plate 6 also shows quarry sites along some parts of Cape Coast beach.



A B

Plate 6 A and B: Sand mining and quarrying sites at the extreme eastern side of the beach in Cape Coast. Field photograph, (2014)

The formation, modifications, present conditions of the coastal and geomorphic features have been explained severally, especially when they are related to the theories discussed in Chapter Two. There are several abrasion platforms along the coast of the study area. Explaining their origin based on the theory of submarine origin as espoused by Davis, (1909), Johnson, (1919) & Thournbury, (1954), it is important to consider the complex factors that might have contributed to their current state. They are more developed around Sekondi than Cape Coast in the sense that they are very extensive and broader around Sekondi. In this situation, the depth at which they were formed though significant, the lithological make up of these structures is very important. The platforms and benches in Sekondi are mainly sandstone while those of Cape Coast are schist which is metamorphic in nature. Comparatively, sandstone is more susceptible to wave erosion than schist; hence, abrasion becomes more effective in sandstone than schist.

In relation to the theory of Water-Level or Water-Layer Weathering (Bartrum & Turner, (1928), Bartrum, (1935), Wentworth, (1938, 1939). This researcher also observed during the field survey as part of this work that parts of the abrasion platforms closer to the lower water mark still suffer from both sea erosion and weathering by alternative wetting and drying. On the other hand, parts of the platforms and other lithological structures located further away from wave action are more prone to sub aerial processes such as weathering and mass wasting with little or no significant wave action. This was observed around Ekon, Cape Coast, around the Cape Coast Castle, Gold Hill beach in Komenda and also along the coast of Sekondi. In Sekondi and Komenda, sub-aerial processes have had significant impact on the lithology to the extent that there is total collapse of the cliff face, especially at Komenda. It can therefore be said that much as sea erosion is responsible for the current surfaces of platforms and benches along many coastal environments, one can also confidently say that these structures have been produced through a combined action of sea erosion with sub-aerial geomorphic processes such as weathering and mass wasting as was observed around Sekondi and Komenda.

The Theory of Wave Erosion has also been used, as discussed in Chapter Two, to explain the origin and current state of some coastal geomorphic features and landforms. Coastal structures and landforms are believed to be constantly under the influence of wave action.

From the field survey, this researcher observed that if Edward's (1951) submission is anything to go by, then one can confidently say that storm wave helped develop the coastal landforms along many coastal environments, but, with time other processes such as weathering, mass wasting and human activities aid in their alteration or what Edwards, (1951), described as destruction processes. A typical example is the total cliff face collapse around Gold Hill beach in Komenda where after wave action had carved the lithology into various erosion landforms, a combined action of waves and sub-aerial processes have completely modified the structures. Thus, the current state and characteristics of coastal features and the coastal environment as a whole could not be entirely attributed to wave action. It was thus important to consider changes in sea level in relation to changes in the land bordering the sea. In this regard, the theories/concepts of sea level change were also considered. It was realized that the origin and current state of the coastal features and landforms in the study, like any other coastal environments could not be fully explained based on any single theory discussed in this text. This is due to the complex and dynamic nature of coastal processes. It was thus appropriate to adopt the framework by Waugh, (1995), as depicted in Chapter Two.

After careful analysis, it was realized that the origin, the changes in shoreline, land cover, coastal features and landforms and their current state is a combine action of what is captured in Waugh's framework used for the study. Waugh, (1995), as already discussed, identified four broad factors that are responsible for changes in coastal landmass, namely marine, atmospheric, human and terrestrial. Thus, it can be said that, a combined action of these processes have influenced and will continue to impact on the current and future state of the shoreline, land cover, coastal features and landforms, the rate of erosion and accretion in the coastal landmass of the study area.

It must be noted that at any point in time depending on several local and other factors, each of these processes will have a dominating impact on specific sections of the coast. It can therefore be said that the most dominating factors causing changes in the study area are mainly marine and human. The impact of terrestrial and atmospheric was at a larger scale while those of marine and anthropogenic are more localized.

Management/Mitigating/Coping Strategies Against Sea Erosion Dynamics

Due to the devastating nature of the waves, there has been an attempt by both the government and the local inhabitants to mitigate the impact. Though the local inhabitants are the most affected, it was revealed that there is little they can do as none of their strategies is sustainable. They are all looking up to the government to initiate a programme to solve the problem. Sea defenses using granite and other concrete materials are very common in and around Elmina and Sekondi. The granite groins are a national programme while the concrete fences are much more localized. Some of the local initiatives are the use of sand bags and sticks which is very common around Ekon. There is also a ban on commercial sand mining though the local inhabitants mine the sand for their various activities. The sand is used to lay blocks and to mix concrete. The efforts at managing sea erosion along the coast of the study area can be summarized as follows:

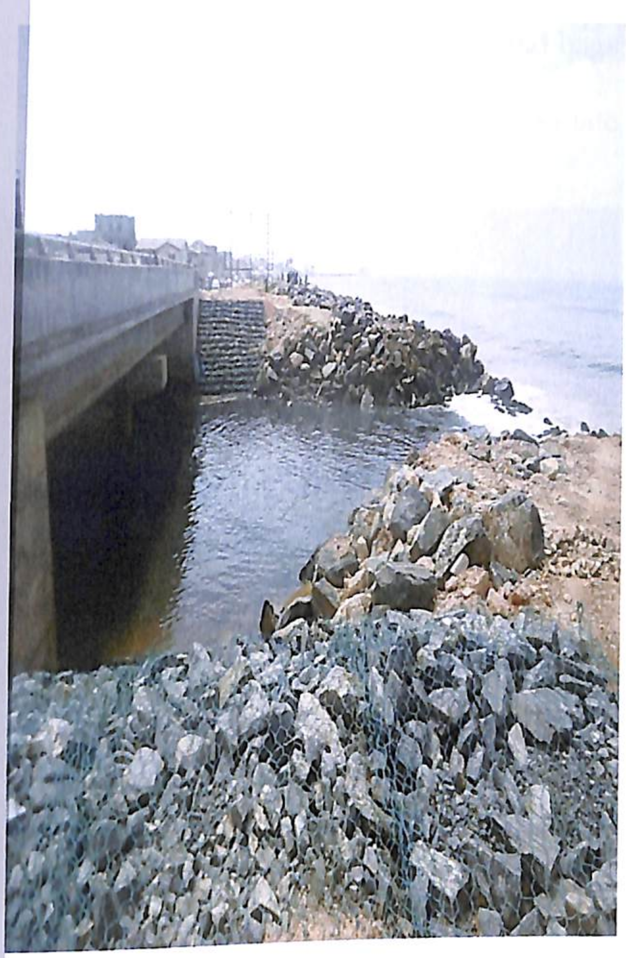
1. Fishermen avoid going to sea when they anticipate that the sea will be 'rough'. This is a coping strategy and not a concrete effort at managing sea erosion.
2. Ban on commercial sand mining.
3. Sea defenses through the use of granite, concrete, sand bags, bamboo fence and vegetation.
4. From Plate 7, 'A' is under attack from both waves and sub-aerial processes such as erosion, weathering and mass wasting. These have contributed to the collapse of that part of the concrete fence. 'B' is still intact with vegetation growing at the upper portions. In 2013, the entire structure was intact but a later visit to the place in May 2014 revealed that parts of it have collapsed.

A

B

Plate 7: Local initiative aimed at dealing with sea erosion at Turtle Cove (Sekondi). (Field survey, (2013-14).

Plate 8: The use of granites as sea defense backed by vegetation at Ngyiresia near Sekondi. Field survey, (2014).



A B

Plate 9: The use of granites as groynes for sea defense along the coast of Sekondi

Source: Field survey, (2013).

Plates 8 and 9 are all parts of the national sea defense projects being undertaken by the Ministry of Water Resources, Works and Housing. As was discussed in the literature, this is part of the Sekondi-Nkontompo-New Takoradi Coastal Protection Works/Sea Defense Projects in the Western region. On the other hand, in parts of Cape Coast and Ekon, it was revealed that the local inhabitants are concerned about the threat of wave action to the extent that, in their own initiative, they use sand bags, fishing nets, boulders and bamboo fences to control sea erosion as shown in Plate 10.

A (Cape Coast) **B (Ekon)**

Plate 10: The use of sand bags, stones, nets and bamboo fence as part of local initiatives at controlling sea erosion around Cape Coast and Ekon

Field survey, (2014).

The irony of the situation is that some of the inhabitants are at the same time engaged in sand mining and quarrying at the beach. As shown in Plate 10, some of the building blocks parked there were produced with sand from the beach.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter gives a summary of the main study, including the main findings, the conclusions and recommendations.

Summary

The research was conducted to investigate how dynamics of sea erosion impacts on coastal features and also the extent of changes along the coastline from Cape Coast to Sekondi. The study was carried out between 2013 and 2015 and the study area was Ekon/Cape Coast through Komenda to Sekondi. Three study sites were selected and the case study approach was used. Samples of sand and pebbles from the study sites were sent to the laboratory for analysis. In addition, 45 respondents, 15 from each study sites were purposively selected for community interactions. Wentworth scheme of grain size classification was used to analyze the sand samples while the pebbles were analyzed based on the Cailleaux indices. Analyses on landmass change were done on the basis of shoreline and land cover change. These were done to determine how erosion and accretion contribute to changes along the coast of the study sites. Tables and graphs were mainly used to present the data. Photographs and maps were also used.

Main Findings

- The extent of erosion was based on sand and pebble analysis. Different grades of sediments ranging from gravel to the finest particles were analyzed. With gravel analysis, it was found that more gravel was deposited at the near shore of Sekondi than the other study sites with the least recorded at Komenda (Gold Hill). On the other hand, at the inland beach, it was observed that more gravel was transported and deposited at the inland beach of Cape Coast/Ekon than the other two locations. It was found that at Ekon, gravel was progressively deposited as distance increased from the beach inland meaning that sea erosion was highly intensified and stronger than Komenda and Sekondi. It was discovered that Ekon has a more open beach, hence the ability of the sea to transport and deposit sediments far inland. Thus, one of the plausible reasons for the inland transportation of gravel at Ekon/Cape Coast was that the beach was more open while that of Komenda and Sekondi are more rocky.

- From the analysis of samples of coarse sand for both near shore and inland beach, it came out that sea erosion was more intensified at Komenda and Cape Coast than Sekondi. It also came out that at Sekondi, heavier materials decreased as distance increased which is in line with the normal rule regarding erosion and sedimentation. On the other hand, heavier materials were transported inland of Cape Coast and Komenda than Sekondi meaning that based on sediments analysis, erosion was found to be more intense in Cape Coast and Komenda than Sekondi.

Roundness and flatness parameters were also used to determine the extent of erosion in the study area. The roundness and flatness values were found to be higher in Sekondi and Komenda indicating that the pebbles were susceptible to weathering and friction and or abrasive action of the sea. Pebbles found in Cape Coast were more angular and rounded than flat indicating that they were more resistant to erosion and weathering.

- Among the three study sites, the highest value for extremely round was recorded at Komenda, that is, 36% while 12% each was recorded at Cape Coast and Sekondi. With flatness, there was a clear distinction between the resistant level of pebbles around Cape Caost/Ekon on one hand and Sekondi and Komenda on the other hand. As much as 92% of pebbles were found to be less flat with none found to be extremely flat in Cape Coast. On the other hand, 18% and 46% were found to be extremely flat for Komenda and Sekondi respectively. These figures show the clear distinction between sedimentary rocks, that is, Sekondi Sandstone found in Sekondi and Komenda and igneous rocks, that is Metamorphosed Schist and Gneiss found in Cape Coast/Ekon. Further analysis between the Sekondi Sandstone in Komenda and Sekondi revealed that those of Komenda were more susceptible to erosion than those found in Sekondi though they are all outcrops of Sekondi Sandstone.

- Extent of changes along the coastline was determined through shoreline analysis using DSAS with EPR method. It was thus determined through rate of erosion and accretion. In Cape Coast/Ekon, shorelines were found to be fluctuating, that is, an advancement and retreatment of the shorelines through erosion and accretion. Within the period 1972 and 2013, there was a shoreline change of -0.61-1.78m/yr around Cape Coast/Ekon. Erosion was at its maximum around Ekon and reduces as one move westwards towards Cape Coast and increases at the extreme west. In all, it can be said that the shoreline was extended inland by 2005 but has retreated since 2013. What this means is that there was serious erosion between 1972 and 2005 but the sea deposited a lot of sediments along the coast by 2013.

- In Komenda, the general observation was that the coastline did not experience many fluctuations as that of Cape Coast/Ekon. From the shoreline analysis, it was realized that the extreme east was under maximum erosion than the middle and the west which were found to be more rocky. The intense erosion at the eastern side of the coastline was evidenced by eroded structures including dwelling houses and coconut trees. At Sekondi, the major finding was that the beach had been accreting than eroding in recent times. This was as a result of the erection of sea defenses. This notwithstanding, there was evidence of serious erosion several years ago. This could be attributed to the existence of the Sekondi Fishing Harbour and the Takoradi Port.

- The shoreline analysis was supported with data from the community consultations/interactions. It was revealed that sea erosion had been very intense along the coast of the study area several years ago; meanwhile, the sea had been accreting than eroding in recent times. Continuous deposition of sediments had contributed to raising the beach. It also came out that the sea has generally retreated along the coastline as the distance between eroded structures and current shoreline is a bit distant. For example, at Cape Coast, the distance from the lowest water mark of the shoreline to the upper limit of the beach was 18meters. It was 19.3m for Komenda and 14.6m for Sekondi. Looking at the current nature of the shoreline and considering the current positioning of structures such as houses, coconut trees, retreating coastal cliffs and other features which were once under serious erosion and now distant from wave action, it is not far from right for one to say that the sea has retreated. This confirms both the results from the shoreline analysis as well as information gathered from the local inhabitants during the field survey.

- The major revelation made on land use/cover was that most of the bare areas and areas hitherto covered with vegetation in 2005, had become built-up in 2013.

- Impacts on both physical features and humans were identified. On physical impact, the sea, together with other geomorphic agents have contributed to the development of erosion landforms as well as destruction of physical structures. Coastal erosion features and landforms are properly developed between Komenda and Sekondi due to dominance of sedimentary rocks. Coastal cliffs are steep around Gold Hill and Turtle

Cove in Komenda and Sekondi respectively. At Komenda, there was total collapse of cliff face. Around Cape Coast and Ekon, though the rocks are exposed, they are not deeply eroded as those of Sekondi and Komenda. This is because the rocks found in Cape Coast are resistant igneous rocks.

- Sub-aerial processes such as weathering and mass wasting were also identified as contributing to development of landforms along the coastline. Some of the landforms identified along the coastline are caves, cliffs, blowholes, stack and geo among others. Apart from landform development, there was destruction of vegetation, human structures such as buildings and increased accretion with raised beaches. It was also gathered from the local inhabitants that there is occasional coastal inundation through episodic storm surge.

- On management of coastal erosion and coping strategies, both local and national initiatives and programmes were identified. In the field survey, it came out that the local inhabitants did not have well designed strategies for dealing with the problem of sea erosion. Most of their strategies such as the use of sand bags and sticks were found not to be sustainable. Commercial sand mining is also banned along the beach yet during the survey a number of 'block factories' were found at the beaches, especially around Cape Coast and Ekong. Fishing is also avoided during high tides. The national strategies are mainly sea defenses through the use of boulders. These are very common along the beaches of Cape Coast and Sekondi. Thus, the key findings are that sea erosion was very intense several years ago but has now abated. In other words, it was found that in recent times the sea is accreting more than causing erosion in the study area. In all. It can be said that the major factors identified to be responsible for landmass change in the study area are marine and anthropogenic with terrestrial and atmospheric being the minor ones as identified in the conceptual framework.

Conclusions

Coastal erosion has been a major problem to many coastal countries with its attendant physical and cultural problems. Many coastal towns have grappled with the problem for ages some of which are yet to find lasting solution. In Ghana, the problem is found in almost every coastal community but may not have received the needed attention. This study delved into how sea erosion influences sedimentation and the net effect on changes in the coastal landmass and features. The revelation made by this research points to the fact that the problems permeate the physical, social and economic systems of society. Sea erosion is either episodic or seasonal and whatever scale it takes will impact on the coastline. Sometimes there is erosion and sometimes there is accretion which increases the sediments at the beach. Sedimentation sometimes prevents the continuous advancement of the sea and hence leads to the retreatment of the waves. Due to fluctuations of the shorelines, it is important to continuously monitor the coastline in order to keep abreast of the changes that will occur either from erosion or accretion. The study of coastal erosion cannot strictly be done within the natural setting without considering the human dimension. It is therefore very imperative that the laboratory analysis be verified with the survey from the community interaction. This helps to understand the various dimensions of the issue. The views of the inhabitants are very important because they are the immediate victims of the actions of the sea. As a result, any plan towards the utilization of coastal resources as well as restoration of the beach needs to take into consideration both the natural and the cultural settings of the coastal zone. Thus, community participation in both national and local initiatives at tackling the problems associated with sea erosion and its related issues is highly recommended.

Recommendations

Based on the findings, the following recommendations are made:

- It is recommended that the lithology and coastal orientation of every coastal community should be studied and proper recommendations made into planning the development of coastal zones. This is because differences in both natural and anthropogenic factors contribute to the way every coastal environment responds to the impact of the dynamics of sea action.
- There should be public education on the need to regulate human activities that directly impinge on the coastline such as sand mining, quarrying, laying of blocks at the beach and indiscriminate dumping of rubbish. It is recommended that sand mining and quarrying should be banned by the respective local authorities. These activities contribute to the acceleration of erosion as is

happening around Cape Coast and Komenda. The affected district and municipal assemblies should lead this crusade.

- A few areas such as the coastline along Cape Coast and Sekondi have benefited from sea defenses. Though sea defenses have their own negative impact, it is recommended that these projects should be extended to other parts of the study area such as Komenda and the eastern coast of Cape Coast beyond Ekon. The opinion leaders in collaboration with the municipal and district assemblies can lobby at the national level through the Ministry of Works and Housing regarding the extension of the national sea defense project to such areas.
- It is also recommended that the residents and other developers should not erect structures such as buildings close to the sea. The tendency is that during high tides these structures can come under serious attack from sea erosion resulting in serious problems for the communities. It is also vital that property owners start by learning about more natural ways to control shoreline erosion to preserve the coastal zone.
- Moreover, it is recommended that serious attention should be directed at conducting research into sea erosion and its related problems so as to highlight such issues to the public. More funds should be channeled into such areas since several people who live along the coast are affected by such problems.
- There should be a holistic national policy towards solving problems associated with sea erosion through integrated coastal zone management practices so as

to tackle physical, social, economic and even political dimensions of the problem.

- The national sea defense projects that have concentrated on the eastern coast should be extended to the central and western coastal zones.
- Fluctuations in shoreline should be regularly monitored. Land use within the coastal zone should be regulated by the respective local authorities to keep abreast with changes in the land cover of the coastal area. It is also recommended that every project to solve the problems of sea erosion and related issues should take into consideration the physical and socio-cultural settings of the area.

Areas for Further Research

Sea erosion is a complex issue and needs a holistic approach in solving it. Several issues relating to sea erosion offer fertile grounds for research. Such areas as sediment budget for shoreline change, sea erosion and landform development as well as the impact of human activities on coastal zones are all areas that can be researched into. This research has laid a foundation for researches to be conducted into the issues mentioned above because it incorporated both natural and human factors in dealing with the subject matter. Thus, these and other issues are subject for further research.

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APPENDIX

UNIVERSITY OF CAPE COAST

DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING

INTERVIEW GUIDE FOR COASTAL DWELLERS BETWEEN CAPE COAST AND SEKONDI

This interview guide is helping to solicit your views on issues relating to sea erosion in your area. It is part of a research on the implications of sea erosion on landmass change in along Cape Coast-Sekondi coastline.

I will be very grateful if you could grant me audience to provide answers to the questions. Every information given is treated confidentially.

1. Sekondi Komenda Cape Coast
2. Sex............... Age.............. Occupation....................
3. Educational background........... Duration/years of stay in the community...........
4. Apart from fishing, what other activities are engaged at the coast?
5. Which of these activities has the tendency to increase the rate of sea erosion and why?
6. For the past 10 years until now, what changes have you observed along the coastline?
7. Which period of the year does sea erosion become serious and why?
8. What problems does sea erosion pose to the community?
9. What can be done to manage the problem of sea erosion in this community?

10. What are the localized mitigating measures against sea erosion in this community?

11. Are these measures effective and why?

12. Whose duty it is to make sure that the problem of sea erosion is properly managed