COASTAL EROSION IN GHANA: A CASE OF THE ELMINA-CAPE COAST-MOREE AREA

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DECLARATION

"I hereby declare that this thesis is my own work and that, to the best of my knowledge, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made."

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LIST OF ABBREVIATIONS

CCMA: Cape Coast Metropolitan Assembly

DSAS: Digital Shoreline Analysis System

EPA: Environmental Protection Agency

EPR: End Point Rate

GIS: Geographic Information System

GPS: Global Positioning System

HWL: High Water Line

IPCC: Intergovernmental Panel on Climate Change

IUGS: International Union of Geological Sciences

LRR: Linear Regression Rate

MHWL: Mean High Water Line

NOAA: National Oceanic and Atmospheric Administration

NSM: Net Shoreline Movement

SCE: Shoreline Change Envelope

UCC: University of Cape Coast

US$: United States Dollars

USGS: United States Geological Survey

WGS: World Geodetic System

ABSTRACT

The extent and rate of erosion along the coastline of Elmina, Cape Coast and Moree were assessed from 1974 to 2012 and the major anthropogenic factors responsible for these changes identified. A shoreline change analysis was conducted using ArcGIS and DSAS tools in order to determine actual coastline changes that occurred during the period under analysis in the study area. Field surveys, questionnaire administration, two focus group discussions and key informant interviews were used to identify and ascertain factors responsible for the coastline changes, the perceptions of residents on coastal erosion issues as well as coastal management issues in the study area were assessed. A sand mining survey was conducted to determine the annual volume of sand mined by tipper trucks in the area. It was found that historic erosion rates for the periods 1974-2012, 1974-2005 and 2005-2012 averaged -1.10m/yr±0.22m, -1.20m/yr±0.23m and -0.85m/yr, respectively. The study identified three major forms of sediment mining practiced along the coast of the study area. These are beach sand mining, beach gravel mining and stone quarry. This study estimated that tipper truck-based beach sand mining activities alone account for the loss of about 285,376 m^3 of sand annually from the littoral zones in the Elmina, Cape Coast and Moree area. This study concluded that coastal sand and stone mining activities are the major anthropogenic factors responsible for coastal erosion in the area as it accelerates natural erosion factors and also interrupt natural coastal dynamics. It was also concluded that the lack of proper management interventions and poor coastal surveillance by legitimate state agencies is the major reason for the widespread practice of coastal sand and stone mining in the Elmina, Cape Coast and Moree.

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CHAPTER ONE

INTRODUCTION

4.1 Background

More than 44% of the world's population live within 150 km of coastlines (Syvitski *et al.,* 2005), clearly demonstrating the importance of the coastal zone. The multiplicity of use of the coast and coastal resources also attests to the importance of this area. Coastal tourism, one of the most common uses of the coast, is one of the fastest growing areas within the world's largest industry (Hall, 2001). There are many tourism developments all around the world that have been properly designed, and where the socioeconomic outcomes have allowed the native population to reach and maintain a certain standard of living (Alonso *et al.,* 2002). Unfortunately poorly planned projects in the coastal zone tend to have a damaging impact on coastal resources (Alonso *et al.*, 2002). Other natural impacts such as hurricanes/cyclones and coastal flooding and anthropogenic impacts including unplanned and haphazard development and used coastal space has led to coastline retreat.

Coastline retreat is a major threat to human beings (Xue *et al.,* 2009). During the last decades, coastline erosion has increased in many locations as a consequence of human activity (Sanjaume and Pardo-Pascual, 2005). Coastal erosion has been identified to be a global problem with at least 70% of sandy beaches around the world receding (Bird, 1985).

There is an increasing tendency towards coastline erosion worldwide. Progressive retreat of backshore cliffs and dunes as well as landward displacement of the coastline is confirmed (Sanjaume and Pardo-Pascual, 2005). These impacts on the coasts may be ascribed to a variety of causal mechanisms, including sea level rise, tectonic instability and subsidence, climatic change and numerous human activities (Carter, 1988). With climate change and global warming issues, sea levels are expected to rise and in so doing accelerate the erosion of coastal margins, threatening land and property (Walsh *et al.*, 2004).

Coastal erosion is not alien to the 550 km Ghanaian coastline. It has been a serious problem dating back to the 1970s (Dei, 1972), and continues to threaten many historical sites, tourism facilities, communities and many important social infrastructure. Since the coastal zone of Ghana houses about 25% of the nation's total population (Armah and Amlalo, 1998), the threat posed by the implications of the retreat of the coastline cannot be overemphasized.

The coast predominantly serves as a barrier between the land and the sea (Mensah, 1997) and also serves to reduce the wave energy that reaches the dune system. Coastal countries therefore have the ardent task of protecting coastal communities and facilities from coastal erosion. The International Union of Geological Sciences (IUGS, 2012) estimate that the United States spend 700 million US dollars annually to combat coastal erosion. In Ghana the government has over the years spent huge sums of monies in hard engineering ventures targeted at protecting coastal communities from inundation and the threat of the sea. The latest coastal protection investments being the 60 million Euro 25km Ada sea defence project. Accelerated erosion, disappearing beaches, increased frequency of flooding, degraded ecosystems, among others are all symptoms of an inability to provide competent coastal land management (Charlier & De Meyer, 2000).

Research indicates that the most notable cause of coastal erosion along the Ghanaian coastline is largely human induced (Nail *et al.*, 1993; Mensah, 1997; Boateng, 2006a). These activities include the widespread practice of unregulated beach sand and stone mining, locally known as "sand winning", for building purposes (Mensah, 1997; Boateng, 2006a). Beach sand mining has led to starvation of beach sediments and consequent retreat of Ghana's coastline (Boateng, 2006a). It is quite futile for governments to spend huge sums of monies to protect the interest of coastal communities while allowing sand mining activities to still persist (Mensah, 1997).

Human impact has increased spectacularly during the last century with coastal problems being one manifestation of environmental problems having ecological, economic, and social dimensions (Sanjaume and Pardo-Pascual, 2005). The history of Ghana is largely interconnected to the coast, especially the Elmina-Cape Coast-Moree coastline, thus the need to protect this national interest. This study assesses coastal erosion issues along the

Elmina, Cape Coast and Moree coastline and makes recommendations for action to ameliorate and curb the human factors largely responsible for the coastline changes.

4.2 Justification

The coastline acts as a natural protection and armor for coastal properties against storm surges and waves (Mensah, 1997). Other functions of the coast include the regulation of coastal freshwater and the provision of habitat for both marine and coastal organisms (Defeo *et al.*, 2009).

Several studies have suggested that the coastline of Ghana is retreating (Nail *et al.*, 1993; Boateng, 2006a; Appeaning Addo *et al.*, 2008; Appeaning Addo, 2009; Boateng, 2012). However, few studies have been conducted on the Elmina-Cape Coast-Moree coastline to establish the veracity of these claims about the area's coastline whilst identifying rates of coastline retreat as well as the factors that are accelerating this phenomenon.

Observations of many sections of Ghana's coastline, including the Elmina-Cape Coast-Moree coastline, also indicate a decline in the intrinsic quality of the area, a situation that has economic, social and ecological implications. These implications are of concern to coastal scientists, environmental managers as well as various government agencies and thus emphasize the need for more research to fill the data and information gap in the sector.

4.3 Aim

The aim of this study is to determine the extent and rate of change of the Elmina-Cape Coast-Moree coastline between 1974 and 2012 and identify the anthropogenic factors that are most responsible for these changes in the area.

4.4 Objectives

The specific objectives of this study are to:

1. estimate the extent and rate of coastal erosion in Elmina-Cape Coast-Moree from 1974 to 2012.

2. identify the anthropogenic activities that are responsible for the changes in the coastline in the study area.
3. determine the magnitude of sand mining activities along the Elmina-Cape Coast-Moree coastline.
4. ascertain the perceptions of residents about coastal erosion in the Elmina-Cape Coast-Moree area.
5. identify the coastal zone management issues in the Elmina-Cape Coast-Moree area.

CHAPTER TWO

LITERATURE REVIEW

2.23 The Coastal Zone

The coast is the area where the land and the sea or the ocean interact (Boateng, 2006b). Waves and winds along the coast are both eroding beaches and depositing sediment on a continuous basis, and rates of erosion and deposition vary considerably from day to day along such zones (Nelson, 2012). The energy reaching the coast intensify during storms; thereby making coastal zones areas of high vulnerability to natural hazards (Nelson, 2012). Several anthropogenic activities including building close to the coastline and beach sand mining tend to aggravate natural conditions in the coastal zone leading to an acceleration of coastal erosion.

2.24 Types of Coasts

The nature and shape of coasts is dependent on several factors, including the ease of erosion of the materials making up the coast, the input of sediments from rivers, the effects of eustatic changes in sea level, and the length of time these processes have been operating (Nelson, 2012). The most common types of coasts include;

- Rocky coasts
- Beaches
- Barrier Islands
- Reefs and Atolls
- Estuaries
- Tidal flats

2.2.1 Rocky Coasts

Rocky coasts are coast types with hard consolidated mineral matter taking up most of the space of the coastline. These can also include cliffed coastlines. A cliff is a high, steep bank at the water's edge composed primarily of rock (Cambers *et al.*, 1998).

2.2.2 Beaches

A beach is a zone of loose material extending from the low water mark to a point landward where either the topography abruptly changes or permanent vegetation first appears (Cambers *et al.*, 1998). Beaches occur where sand is deposited along the shoreline and can be divided into a foreshore zone (which is equivalent to the swash zone) and backshore zone (which is commonly separated from the foreshore by a distinct ridge called a berm) (Nelson, 2012). Behind the backshore may be a zone of cliffs, marshes, or sand dunes (Nelson, 2012). A dune is an accumulation of windblown sand forming a mound landward of the beach and usually parallel to the shoreline (Cambers *et al.*, 1998).

2.2.3 Characteristics and Types of Beaches

Sandy beaches are defined by the presence of sand, waves and tidal regimes, and range from narrow and steep (reflective) to wide and flat (dissipative); but as sand becomes finer and waves and tides larger most beaches develop into intermediate types (Short, 1999; Finkl, 2004). Reflective beaches are coarse-grained and have no surf zones, whereas dissipative beaches have finer sediments and extensive surf zones (Defeo *et al.*, 2009). Filtration volumes are higher on permeable reflective beaches, mainly driven by wave action, and lower on dissipative beaches, where tidal action drives most water throughput (Defeo *et al.*, 2009). The sand body of all open beaches is well flushed and oxygenated (McLachlan and Turner, 1994), thus making it possible for organisms to live within them.

Beaches are closely linked to surf zones and to coastal dunes through the storage, transport and exchange of sand; therefore impacts on beaches have consequences for these adjacent habitats (Komar, 1998). Sand is transported in the sea by the waves and by the wind on the dry beach and it tends to move rapidly seawards across the beach and surf zone during storms and to return more slowly landwards during calms (Defeo *et al.*, 2009). In this way, storm wave energy is dissipated and the soft coast is protected from permanent erosion (Short, 1999; Nordstrom, 2000).

2.2.4 Barrier Island

A barrier island is a long narrow ridge of sand just offshore running parallel to the coast, separated by a narrow channel of water called a lagoon (Nelson, 2012). They are constantly changing, grow parallel to the coast by beach and longshore drift and are eroded by storm surges that often cut them into smaller islands (Nelson, 2012; Finkl, 2004).

2.2.5 Reefs and Atolls

" Reefs are colonies of organisms, like corals, which secrete calcium carbonate. Because they can only live in warm waters and need sunlight to survive, reefs only form in shallow tropical seas. Reefs are highly susceptible to human activity and the high energy waves of storms" (Nelson, 2012; Finkl, 2004).

2.2.6 Estuaries

Estuaries are coastal river valleys flooded by sea water and are characterized by mixing of fresh and salt water (Nelson, 2012).

2.2.7 Tidal Flats

Tidal flats are zones along the coast that are flooded during high tides and form in the intertidal zones lacking strong waves (Nelson, 2012).

2.25 Competing Use of the Coast

The most common uses of the coast in Ghana are for recreation and docking of canoes by fishermen. However, because of the relative importance of the area, several other uses have been found for the coast. Since resources are scarce in relation to the demand for them, the scramble for the usage of resources within the coastal and marine space by man is ubiquitous and from antiquity (Boateng, 2006b), thus, accounting for the different competing users of the area. Figure 2.1 illustrates the various uses of the coastal area as identified by (Boateng, 2006b).

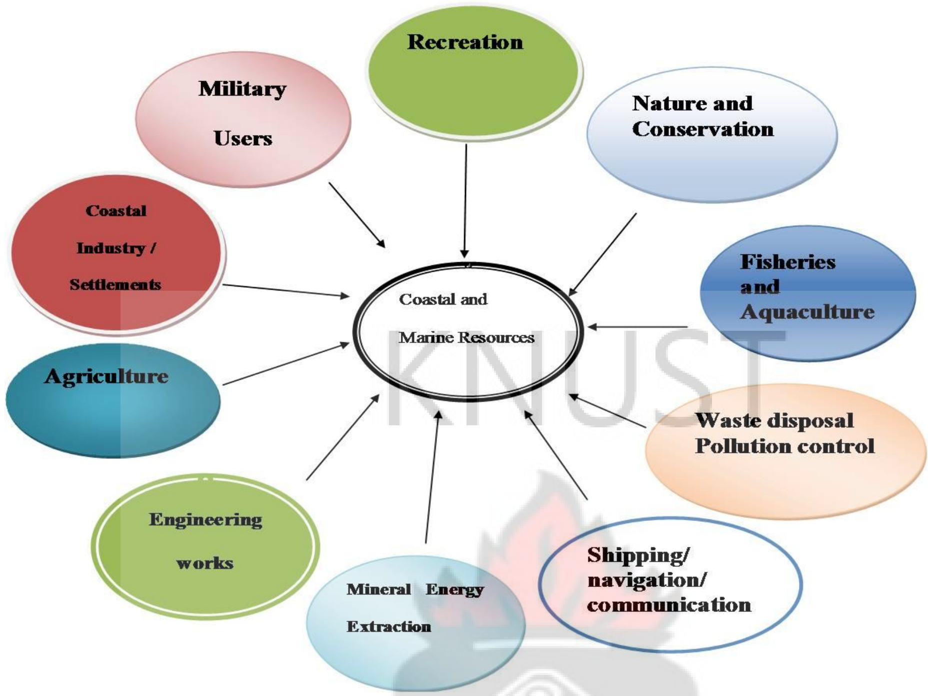

Figure 2.1 – Competing users of coastal and marine resources (Source: Boateng, 2006b)

2.26 General Functions of the Coasts

Coasts perform important regulatory, ecological, and economic functions. One such regulatory function of the coast is the natural protection and armor for coastal properties against storm surges and waves (Carter, 1991; Mensah, 1997). The area serves as a habitat for diverse biological species and provides recreational services.

Coastal dunes play an important role in regulating coastal groundwater; a permeable dune system acts like a barrier to landward salt intrusion (Carter, 1991). The freshwater lens is recharged both by direct precipitation and allogenic streams, and is discharged under low piezometric pressures into the beach or nearshore zone (Carter, 1991). While filtering water, the porous sand body and its biota mineralize organic matter and recycle nutrients, making beach ecosystems a crucial element in the nearshore processing of organic matter and nutrients (Defeo *et al.*, 2009).

According to Defeo *et al.* (2009) not only are beaches coupled to marine systems trophically, but they also interact physically and biologically with coastal dunes. Besides sediments, beaches and dunes exchange a variety of organic materials, and animals from both habitats move across the dune/beach interface to feed (Defeo *et al.*, 2009).

2.27 Ecological Functions of the Coast

The intertidal areas of beaches provide habitats for a diversity of fauna (Defeo *et al.*, 2009). The lacunar environment between the grains harbours interstitial organisms (bacteria, protozoans, microalgae and meiofauna), forming a distinct food web (Defeo *et al.*, 2009). Larger macrobenthic invertebrates burrow actively and include representatives of many phyla, but crustaceans, molluscs and polychaete worms are usually dominant and encompass predators, scavengers, filter- and deposit feeders (Defeo *et al.*, 2009).

Beaches that receive significant inputs of algae/seagrass wrack support a rich supralittoral fauna of crustaceans and insects (Defeo *et al.*, 2009). Most beach species are uniquely adapted for life in these dynamic systems including: mobility, burrowing ability, protective exoskeletons, rhythmic behaviour, orientation mechanisms and behavioural plasticity (Chelazzi and Vannini, 1988; Scapini *et al.*, 1995; Brown, 1996; Scapini, 2006).

According to Defeo *et al.* (2009) the composition and abundance of invertebrate assemblages are controlled primarily by the physical environment, intertidal swash and sand conditions. They observed that sand conditions are harshest on reflective beaches and more benign on dissipative beaches. Consequently, more species can colonize dissipative beaches, but fewer species, mainly robust crustaceans, can establish populations on reflective beaches (McLachlan and Dorvlo, 2005). Whereas the effects of ecological interactions (e.g. competition and predation) are overshadowed by physical factors on reflective beaches, they become more influential in structuring communities on dissipative beaches (Defeo and McLachlan, 2005).

Supralittoral zones are important nesting areas for turtles and shorebirds, and provide a favourable habitat for invertebrates on stable reflective beaches (Defeo *et al.*, 2009). The upper areas of exposed sandy beaches are typically inhabited by several species of amphipods, isopods, insects and ghost crabs (Brown and McLachlan, 1990; Barros, 2001). Burke *et al.*, (2001) noted that coastal ecosystems, found along continental margins, are regions of remarkable biological productivity and high accessibility and has made them centers of human activity for millennia.

2.28 Sandy Beach Ecosystem Services

Sandy beaches render a broad range of ecosystem services, many of which are essential to support human uses of sandy coasts. According to Defeo *et al.* (2009) the most important ecosystem services of sandy beaches include the following fourteen elements:

- sediment storage and transport
- wave dissipation and associated buffering against extreme events (storms, tsunamis);
- dynamic response to sea-level rise (within limits)
- breakdown of organic materials and pollutants;
- water filtration and purification;
- nutrient mineralization and recycling;
- water storage in dune aquifers and groundwater discharge through beaches;
- maintenance of biodiversity and genetic resources;
- nursery areas for juvenile fishes;
- nesting sites for turtles and shorebirds, and rookeries for pinnipeds;
- prey resources for birds and terrestrial wildlife;
- scenic vistas and recreational opportunities;
- bait and food organisms;
- functional links between terrestrial and marine environments in the coastal zone.

2.29 Beach Sediment Budget

"Beaches are trapped in a 'coastal squeeze' between the impacts of urbanization on the terrestrial side and manifestations of climate change at sea. While unconstrained, beaches are resilient, changing shape and extent naturally in response to storms and variations in wave climate and currents" (Schlacher & Thompson, 2007). However, human modifications of the coastal zone severely limit this flexibility (Nordstrom, 2000).

An active beach requires a steady supply of sediments in order to maintain sedimentary equilibrium. In their study of several coastlines across the world, Pilkey *et al.* (2004) made the observation that "each shoreline reach has a unique combination of sand sources. The most important ones are rivers, eroding cliffs adjacent to the beaches, and the adjacent continental shelf".

Sanjaume & Pardo-Pascual (2005) identified two main ways by which the supply of sand to the beach is reduced:

i. Sediment does not reach the sea; mainly because part of the fluvial sediment has been extracted for industrial uses, and also because the major rivers are regulated by dams, reducing the quantity of sediment reaching the river mouth and
ii. The direct extraction of material from the beach (sand mining).

Carter (1991) noted that under certain conditions marine sediment may accumulate sub-aerially as coastal dunes and that such development may be triggered by sea level fall, or domain shifts within the reflective/ dissipative continuum. The latter occur when the beach and shoreface angle alters, becoming flatter or steeper, perhaps due to fluctuations in sediment supply or the opening or closing of a nearby tidal inlet (Carter, 1991). Such secular variation in beach slope imparts a strong control over the mode (or domain in terms of area) of the form of the breaking waves (Carter, 1991). Beach profile steepening leads to more reflective conditions while profile flattening to more dissipative ones, which in turn are associated with types of dune morphology and development (Short and Hesp, 1982).

Sediments are constantly exchanged with adjacent environments as energy conditions fluctuate with dunes eroding during storm surges to replenish the nearshore profile while material is pumped through spit-estuary complexes to retain a hydraulic balance, or overwashed to rebuild barrier islands further inland (Carter, 1991). These are natural processes that occur within self-compensating coastal systems the world over though the rates of changes are different from site to site due to local coastal dynamics. All the components of the coastal sediment (Figure 2.2) are important to the local coastal dynamics. When any of the components is altered, the balance of the coastal system becomes affected.

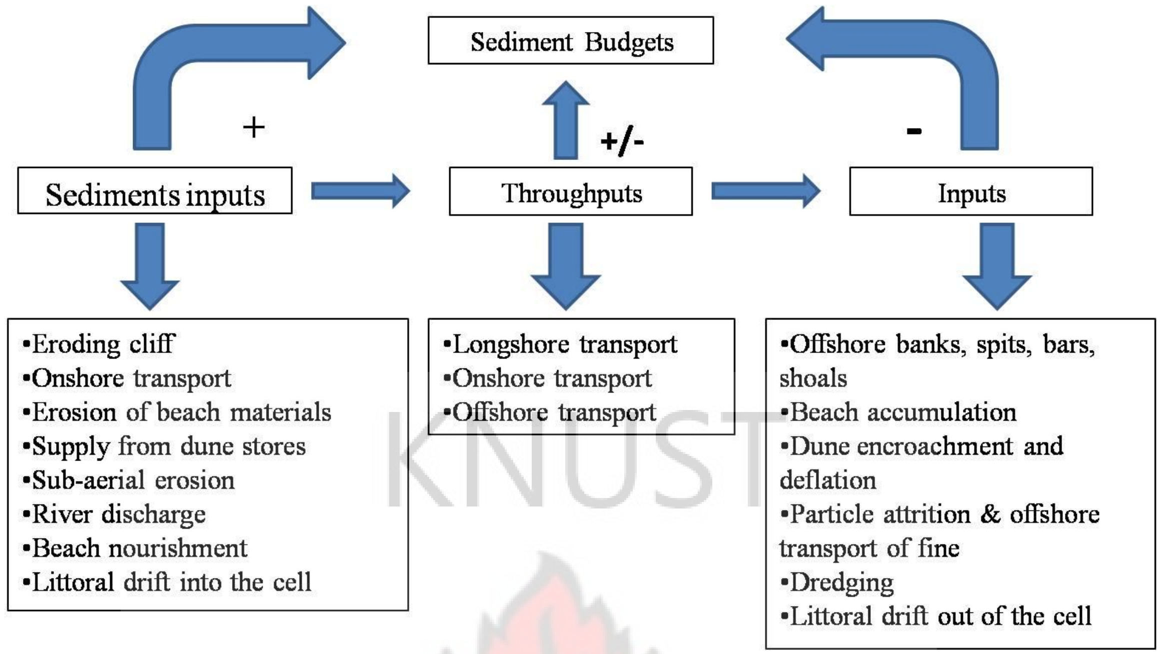

Figure 2.2: Components of Sediment Budget (Source: Boateng, 2006a)

When sediments input exceed sediments output, beaches accrete or widen. Carter (1991) stated that coastal dunes develop as accumulating systems with very positive sediment budgets (i.e. input far exceeds output). Outputs may arise from the returning of sediment to the coastal system, or through landward eolian transfers, or by human activities (sand mining) (Carter, 1991). When there is a negative budget, a dissected dune system characterised by erosional landforms such as blowouts, deflation hollows and plains, reactivation dunes, erosion scarps may be formed (Carter and Stone, 1989).

It appears that the interaction of dunes with the adjacent beach and nearshore provides the essential basis of a stable shoreline, through the regular exchange of nutrients and minerals (Carter, 1991). Coastal sand dunes are one manifestation of a suite of landforms associated with varying water levels and given an adequate sediment supply, material may accumulate at various locations within a coastal system with favoured sites including river or estuary mouths which attract sediment in order to achieve hydraulic equilibrium, within shore caustics (or shadow zones), and at the downdrift ends of transport cells (Carter, 1991).

2.30 The Shoreline

A shoreline is defined by Li *et al.*, (2001) as the line of contact between land and a body of water. This definition present the term as a very simple concept. However, shoreline is easy to define but difficult to capture, since the water level is always changing (Li *et al.*, 2001).

An idealized definition of shoreline is that it coincides with the physical interface of land and water (Dolan *et al.*, 1980); however, they are quick to add that despite the apparent simplicity, the definition is in practice a challenge to apply. Dolan *et al.*, (1980) provide the following argument to back their assertion:

> In reality, the shoreline position changes continually through time, because of cross-shore and alongshore sediment movement in the littoral zone and especially because of the dynamic nature of water levels at the coastal boundary (*e.g.*, waves, tides, groundwater, storm surge, runup, *etc.*). The shoreline must therefore be considered in a temporal sense, and the time scale chosen will depend on the context of the investigation. For example, a swash zone study may require sampling of the shoreline position at a rate of 10 samples per second, whereas for the purpose of investigating long-term shoreline change, sampling every 10–20 years may be adequate.

Another term that is often used in describing shorelines in coastal research is the *instantaneous shoreline*. This is the position of the land-water interface at one instant in time (Boak and Turner, 2005). As has been noted by several authors (List and Farris, 1999; Morton, 1991; Smith and Zarillo, 1990), the most significant and potentially incorrect assumption in many shoreline investigations is that the instantaneous shoreline represents ‘‘normal’’ or ‘‘average’’ conditions (Boak and Turner, 2005).

A shoreline may also be considered over a slightly longer time scale, such as a tidal cycle, where the horizontal/vertical position of the shoreline could vary anywhere between centimetres and tens of meters (or more), depending on the beach slope, tidal range, and prevailing wave/weather conditions. Over a longer, engineering time scale, such as 100 years, the position of the shoreline has the potential to vary by hundreds of meters or more (Komar, 1998 cited in Boak and Turner, 2005). The shoreline is a time-dependent phenomenon that may exhibit substantial short-term variability (Morton, 1991), and this needs to be carefully considered when determining a single shoreline position (Boak and Turner, 2005).

2.31 Shoreline Identification

Boak and Turner (2005) noted that due to the dynamic nature of the coast, their boundaries are not static; hence coastal investigators typically adopt the use of shoreline indicators. A shoreline indicator is a feature that is used as a proxy to represent the ‘‘true’’ shoreline position (Boak and Turner, 2005). Depending on coastal location, data source, and scientific preference, different proxies for shoreline position are used to document coastal change, including the high water line (HWL), wet-dry line, vegetation line, dune toe or crest, toe of the beach, cliff base or top, and the line of mean high water line (MHWL) (Morton *et al.,* 2004). The high water line (HWL) proxy is the most commonly used shoreline indicator (Boak and Turner, 2005) and is visually determined as a change in tone left by the maximum run-up from a preceding high tide (Smith and Zarillo, 1990; Anders and Byrnes, 1991; Crowell *et al.*, 1993).

The identification of a ‘‘shoreline’’ involves two stages (Boak and Turner, 2005), which are:

1. the selection and definition of a shoreline indicator that will act as a proxy for the land-water interface.
2. the detection of the chosen shoreline indicator within the available data source.

The most common shoreline detection technique applied to visibly discernible shoreline features is manual visual interpretation, either in the field or from aerial photography (Boak and Turner, 2005). For example, with aerial photography, the image is corrected for distortions and then adjusted to the correct scale before a ‘‘shoreline’’ is either traced directly or scanned into a computer, corrected, adjusted for scale, and digitized whilst in the field, a GPS receiver is used to digitize the visible shoreline feature *in situ* (Boak and Turner, 2005).

2.32 Shoreline Change Analysis

According to Hapke *et al.* (2010) before the development of global positioning system (GPS) and lidar technologies, the most commonly used sources of historical shoreline position in the United States of America were National Oceanic and Atmospheric Administration (NOAA) T-sheets and aerial photographs; where extraction of shoreline positions from these data sources involved georeferencing maps or aerial photographs, and subsequently interpreting and digitizing a shoreline position.

Shoreline data for shoreline change analysis could be obtained from a variety of dates and sources. In the United States Geological Survey's (USGS) National Assessment of Shoreline Change projects, data sources included topographic sheets dating back to the mid-1800s, aerial photographs and light detection and ranging (lidar) (Morton *et al.*, 2004; Hapke *et al.*, 2010). Appeaning Addo *et al.* (2008) used shoreline data that spanned a period of 98 years including a 1904 bathymetric map produced for the Ghana Harbours Authority from planetable surveys, 1974 and 1996 digital topographic maps and a 2002 digital topographic map. Other sources of shoreline data used by coastal investigators include historical land-based photographs, coastal maps and charts, beach surveys, GPS shorelines, remote sensing, multispectral/hyperspectral imaging, microwave sensors and video imaging (Boak and Turner, 2005).

Nguyen *et al.* (2010) posited that studies on shoreline dynamics are critically dependent on the spatial and temporal scale of analysis. A short time period of shoreline position and beach volume is carried out at small spatial scales with beach topographical profiling techniques employed and repeated at regular intervals to measure daily and annual variations, in periods less than 10 years (Anfuso *et al*,. 2007). Other useful sources, such as aerial photographs, satellite images, maps and charts, are used to reconstruct spatial and temporal shoreline changes at medium-term periods with duration between 10 and 60 years (Jimenez and Sanchez-Arcilla, 1993) and a long-term period, more than 60 years (Crowell *et al.* 1993). Esteves *et al.* (2002) noted that trends in shoreline movements can only be observed after decades of continued monitoring.

The following statistical methods described by Himmelstoss (2009) are commonly used by coastal investigators; though only the end point rate and the net shoreline movement methods were adopted for this study:

Shoreline Change Envelope (SCE) - the distance between the shoreline farthest from and closest to the baseline at each transect.

Net Shoreline Movement (NSM) - The NSM is associated with the dates of only two shorelines and reports the distance between the oldest and youngest shorelines for each transect.

End Point Rate (EPR) - The end point rate is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. The End Point Rate (EPR) is the simplest approach used in shoreline change analysis as it uses only two shoreline positions for the calculation. With the availability of multiple shoreline positions, combinations of EPRs can be computed.

Linear Regression Rate (LRR) – A linear regression rate-of-change statistic can be determined by fitting least-squares regression lines to all shoreline points for a particular transect. The rate is the slope of the line.

2.33 Coastline Changes

Research done on coastlines across the world indicate that most of the coastlines have been are retreating for decades (Bird, 1985). Studies conducted by the International Geographical Union Working Group on the Dynamics of Coastline Erosion (1972-76) and the succeeding Commission on the Coastal Environment (1974-84) across 127 coastal countries indicated that about 20% of the world's coastlines are sandy and out of this about 70% experienced net erosion the previous decades, less than 10% experienced progradation and the remaining 20-30% were stable or had no measurable change (Bird, 1985).

Forbes *et al.* (2004) noted that changes in shoreline positions could be due to either a single factor or a combination of many interrelated factors. Though spatio-temporal shoreline dynamics are caused by natural influences such as storms, marine currents and beach geomorphology (Gopinath and Seralathan, 2005), man-induced factors like coastal explosion, deforestation and engineering activities contributes considerably to the environmental impacts experienced by coastal zones (Anfuso and Pozo, 2009).

2.34 Coastal Erosion

According to Wong (2003) tropical coasts face threats not only from sea level rise, but also from human activities that destroy mangroves, degrade coral reefs and accelerate beach erosion. Basco (1999) described coastal erosion as the long term loss of the shore material (volume) relative to fixed reference line (baseline) and initial reference volume seaward of this line above some, arbitrary vertical datum.

Coastal erosion is a global problem (Cai *et al.*, 2009) with available evidence showing the escalating environmental threat caused by the phenomenon making it a cause for global concern (Bird, 1993; Hanson & Lindh, 1993). If the sea level rises in tandem with the occurrence of greater and more frequent storms, coastal flooding and erosion problems will become exacerbated in vulnerable coastal areas (Devoy, 2000).

One characteristic of the occurrence of coastal erosion on sandy beaches is the exposure of underground rocks. According to Cooper (1991) this is true only in two senses, that is, long-term erosion exposing beachrock some distance from the contemporary shoreline and beachrock exposed by sand scour from beaches during episodic storm events" (cited in Wong, 2003). Wong (2003) also suggested another possibility: the removal of beachrock by human action near contemporary shorelines causing some beach erosion. The assertions of Wong (2003) are probably true since in this study, it has been identified that areas where beach rocks are mined are amongst the most eroded beaches in the study area.

About 20% of the world's coast is sandy and backed by beach ridges, dunes, or other sandy depositional terrain (Viles and Spencer, 1995). Of this, more than 70% has shown net erosion over the past few decades (Bird, 1985; Viles and Spencer, 1995). In the United States of America, approximately 86% of the United States east coast barrier beaches (excluding evolving spit areas) have experienced erosion during the past 100 years (Zhang *et al.*, 2004).

It has been established that the problem of coastal erosion may extend its influence hundreds of kilometres alongshore in the case of large deltaic areas, and may even have trans-boundary implications (Özhan, 2002). However, in the case of pocket beaches, it could be a very local phenomenon affecting only the residents of a nearby town and/or the tourism industry (Özhan, 2002).

Wong (2003) observed that the factors influencing coastal erosion can be classified into two major categories; natural and human-induced. Climate change is seen as the major natural factor causing coastal erosion (Spencer, 1999) while human induced erosion is caused by removal of sand and pebbles from beaches and the erection of coastal structures (Mensah, 1997).

Coastal erosion is usually judged as "critical" when it presents a serious problem wherever the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological and other relevant factors, indicates that action to remedy (stop or slow down) erosion may be "justified" (Özhan, 2002). Hinrichsen (1990) suggested that coastal erosion was probably the most serious environmental problem facing West African coasts then while Özhan (2002) described it as one of the most important socio-economical problems that challenge the capabilities of states and local authorities since it causes significant economical losses, social problems, and ecological damages.

In West Africa, the effects of urbanization and the concentration of industrial and commercial activities along the coasts have resulted in an unprecedented exploitation of coastal resources such as coastal sand, mangrove forests, esturaries and seagrass beds (Mensah, 1997). The hazard posed to coastal communities in Ghana may be staggering. This is because many key industries, major residential settlements, tourism and conservation sites, heritage and historical monuments are located within a 200 m radius of the shoreline; moreover, many of the most densely populated coastal areas of the country are low-lying coastal plains susceptible to coastal flooding (Boateng, 2006a).

Coastal erosion has been identified in earlier studies to be a major problem especially in the Greater Accra Metropolitan Area and some parts of the Western Region with rates of erosion exceeding 2m per year in some critical areas such as Labadi (Biney *et al.*, 1993; Mensah 1997). Currently along the Accra coastline, an estimated 70 percent of the beach is eroding at rates exceeding one meter per year (http://coastalcare.org/2010/12/battling-ghanas-eroding-coastline).

Almost all of Ghana's sandy beaches are experiencing some level of coastal erosion in recent decades. A study that compared coastal surveys done in 1945 and 1972 showed that there were progradation only in sectors adjacent to breakwaters (New Takoradi; Nyiasia) and rocky headlands (Apam) where the Eastward drift of beach sand had been intercepted on the ends of spits bordering lagoon entrances and river mouths, all other parts of the coastline especially around the Volta delta were found to be retreating (Boateng, 2006a). In that same study it was revealed that sections of sandy coastlines that had previously prograded or accreted had altered to retreat, with beach rock exposed in places up to 45 meters offshore (Dei, 1972; Boateng, 2006a). By the early 1990s, it had been established that erosion was present along the entire coast of Ghana with as many as 25 locations with serious problems (Nail *et al*, 1993)**.** Only the most serious of these 25 'erosion hotspots' have been protected since then by a combination of gabions and boulder revetments (Boateng, 2006a). However, according to the Ghana Environmental Protection Agency (1991) the success of protection works along the coast has been limited, and therefore engineering options cannot provide long-term solutions to coastal erosion. Their observations indicated that the longshore drift mechanism was such that action in one section of the coast triggers erosion in adjoining sections (Ghana EPA, 1991).

2.35 Causes of Coastal Erosion

The causes of coastal erosion can broadly be categorized as into two areas; natural processes and human activities (Mensah, 1997; Özhan, 2002; Wong, 2003; Cai *et al.*, 2009). Regardless of these causes, erosion intensity and development depend to a high degree on the equilibrium state of coastal dynamics and beach stability (Cai *et al.*, 2009). Regarding the widespread beach erosion in the United States of America, Zhang *et al.*, (2004) however posited that three possible causes exist; these are sea level rise, change of storm climate and human interference.

According to Muehe (2006) who reviewed erosional issues in the Brazilian coastal zone, almost 80% of the causes of erosion are attributed to human impacts related to urbanization and interference in the sand budget through construction of rigid structures. He concluded that natural causes of coastal erosion seem to play a subordinate role, at least considering a short-term time span. Muehe (2006) observed that naturally the erosion of buildings constructed too close to the shoreline cannot be simply considered as an erosional trend; nevertheless, as soon as a sequence of erosional event takes place, the response of the property owners are through the construction of wood or stonewall, rip-rap or groins which accelerate and propagate the effect of these events (Muehe, 2006).

The causes of beach erosion can be found in a summary of coastal processes, where the most important ones are sediment supply, relative sea-level change, wave energy and shape and location of the beach (Pilkey and Thieler, 1992). This means that interference in the supply of sediments or the natural process of the coast will ultimately result in an eroding coast.

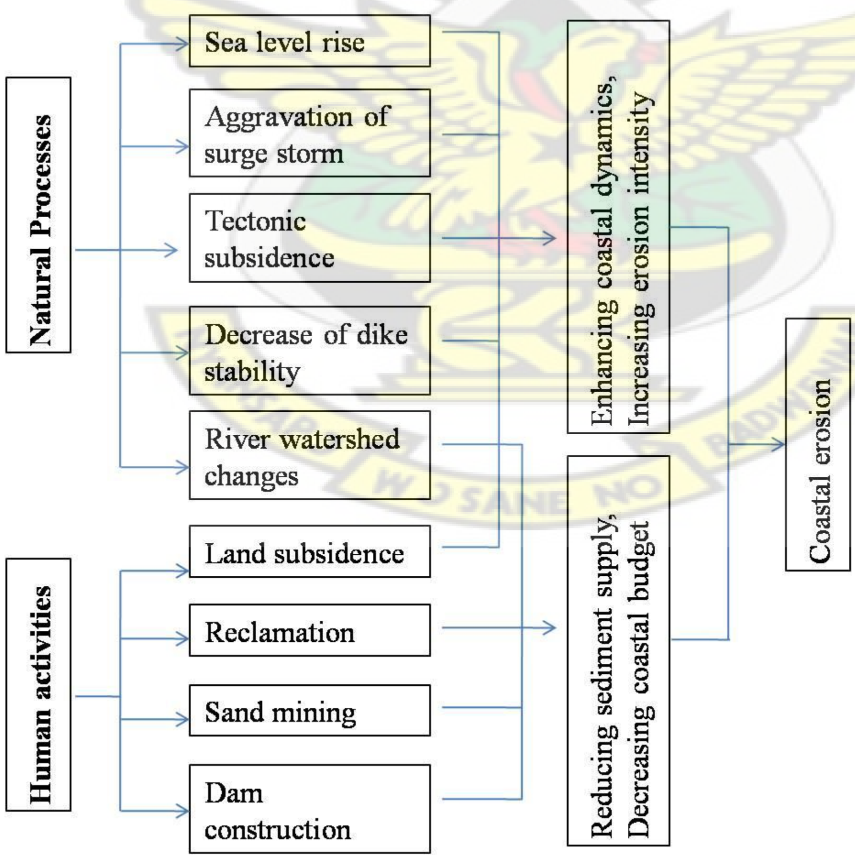

Figure 2.3: Framework of the causes of coastal erosion (source: Cai *et al.*, 2009)

Cai *et al.*, (2009) clearly presents all the major causes of coastal erosion, both natural and human, in figure 2.3.

In the following pages the causes of coastal erosion which can be attributed to the Ghanaian coast are discussed, these include sea level rise and aggravation of surge storms, river watershed changes, dam construction and coastal sand mining.

2.13.1 Sea Level Rise and Aggravation of Surge Storms

Over at least the last 150 years and probably for much of the late-Holocene, world sea level has been rising slowly (Carter, 1991; Cai *et al.*, 2009), a consequence of global warming. A number of future sea-level rise predictions have been estimated by various authors including the following:

- One metre sea-level rise by 2100 predicted by Ghana's EPA (2000) and IPCC, (2007)
- Two metres - upper limit prediction for sea-level rise by 2100 by Pfeffer *et al.* (2008)
- Five metres - worst case scenario involving catastrophic melting of west Antarctic ice sheet predicted by Vaughan (2008).

Bryant (1988) in commenting on earlier predictions made in that period stated that a sea-level rise of this magnitude can be very destructive, causing accelerated coastal erosion, permanent flooding of low-lying areas and higher water table baselines. Carter (1991) noted that the exact nature of the response of coastal dunes to the projected rise in sea level is still largely a matter of speculation, and it is probable that adjacent dune systems will react in different ways depending on both regional and local factors.

However, in Cai *et al.*, (2009)'s study they were convinced that global warming increases the frequency and intensity of hurricanes, storm surges, and floods, while a sea level rise directly enhances ocean dynamics and causes coastline retreat. In 1995, the Intergovernmental Panel on Climate Change predicted that anticipated climate changes will greatly amplify risks to coastal populations, and by the end of the 1990s, the global sea level rise will lead to the inundation of low-lying coastal regions, inducing more frequent flooding during storm surges and beach erosion" (IPCC, 1995). Carter (1991) was also sure that rising sea level will have a direct impact on coastal processes, effectively raising the plane of activity from which waves operate. This may be most evident during storm surges, when the frequency of attack at any level will increase markedly, so that the so-called 1 in 1000 year flood height in 1990 might reduce to the 1 in 30 year flood height by 2030 (Wigley 1989). Such increasing frequencies could lead to amplification of coast erosion, flooding and avulsion, as well as a general enhancement of sediment fluxes (Carter, 1991).

The IPCC may have been right in their prediction, since from the late 1990's to the early 2000's there had been the need to protect several communities mostly in low lying areas in Ghana against inundation by the sea. These communities included Keta, Nkontompo, Sakumonor, and Shama.

According to Özhan (2002), some of these factors such as waves, alongshore currents, rip currents, undertow and overwash usually combine together to reshape the sea bottom during a storm, causing an aerial pattern of erosion and accretion resulting in an overall gain or loss for the volume of beach sand.

The International Federation of Surveyors (2010) listed the following as possible impacts of sea-level rise on the coastal zone;

- Increased inundation (flooding) of coastal land, which may cause loss of life and property;
- More frequent storm-surge flooding, which may cause destruction of life, property and beaches and severe shoreline erosion
- Accelerated coastal erosion, which may also cause destruction of coastal properties and possibly loss of life;
- Seawater intrusion into fresh and groundwater sources thus reducing the supply of fresh water in coastal towns;
- Altered tidal range in estuaries and tidal river systems which may destroy estuarine ecosystems; and
- Change in sedimentation patterns

A sea level rise and the negative environmental effects caused by human activities aggravate the risk of coastal erosion and increase the environmental burden in these areas day by day (Cai *et al.*, 2009). They further posited that the trend of global warming is hard to reverse, and it appears that the global climate change will not be under control in the near future.

2.13.2 River Watershed Changes and Dam Construction

In the natural dynamics of the coastal zone, sources of sediments to the coast include rivers and watersheds. When these systems are interfered with, be it by man or through a natural process, the coastal sediment budget becomes altered.

Cai *et al.* (2009) observed that in the pursuit of enormous economic benefits, the main river watersheds of China had undergone increased exploitation, especially a series of large engineering projects such as the Three Gorges Dam project, the Xiaolangdi project, and the south-to-north water transfer project, which as a result had sharply decreased sediment discharge into the sea. Cai *et al.*, (2009) quoted an updated estimate presented by Chen and Chen (2002) that said that the amount of sediment discharge was almost 2000 million tons per year before the 1980s and it decreased to 1000 million tons, maybe only 500–700 million tons by the end of the 20th Century. These have resulted in notable changes in erosion or accretion evolution in estuary, deltas and adjacent coasts under the new dynamic environment and sediment conditions, thus reducing the sediment budget of beaches and eventually driving severe coastal erosion.

Boateng (2006a) also associated the problem of coastal erosion in the East coast of Ghana to the hydroelectric dam built on the Volta River in 1964, which according to Ly (1980) greatly reduced the supply of sediments to the beach.

2.13.3 Human Activities

Esteves *et al.* (2000) noted that despite the long and undeveloped coastal segments of Rio Grande do Sul coastline in Brazil, almost one-third of the state's shorelines have been impacted by human activities, such as urbanization in active dune areas, shore armouring, sand mining, and construction of jetties. Esteves *et al.* (2002) observed that these anthropogenic changes might be affecting local sand balance in a way that intensifies natural shoreline changes. Although the impact of human activities on the sediment balance is still unknown, it seems to play a role largely at a local level, enhancing natural trends rather than reverting them (Esteves *et al.,* 2002).

It is obvious that coastal development does not leave much space for natural beach dynamics to take place but rather increases the risk of structural damage during storms since urbanization in the active beach/dune system and coastal armouring usually tend to aggravate erosion along a long-term retreating shoreline (Esteves *et al.,* 2002).

2.13.4 Sand Mining

According to Mensah (1997), sand mining is a type of open-cast mining that provides material for the construction sector in Ghana. Beach sand mining is the removal of sand from the shoreface. Mensah (1997) observed that the construction sector in the coastal areas of Ghana relies heavily on coastal sand and pebbles in the building of houses, bridges and roads. No sand is cheaper and easier to obtain for the construction of buildings in the coastal zone than beach sand (Pilkey *et al.,* 2004). This probably may be due to the ease of access to the coast and the availability of large quantities of the product along the coast. This makes the industry very attractive especially to those who do not want to work within the confines of the law. Pilkey *et al.* (2004) further observed that often this form of mining takes the form of a truck load here, a wagon load there, and even wheelbarrow loads of sand which, when totaled can amount to a large sand loss to the beaches.

Sanjaume and Pardo-Pascual (2005) observed that the littoral dune system is an important factor in maintaining the sedimentary equilibrium of beaches; if dunes are removed the created imbalance may ultimately lead to increased beach erosion. In Portugal, sand accumulations on the up-drift sides of jetties are sometimes mined on a very large scale, but this is far less damaging to sand supplies than the removal of sand from natural beaches (Pilkey, *et al.*, 2004). Removal of sand and gravel directly from the coast by illegal quarrying could be a significant factor triggering coastal erosion and shoreline recession such as that of more than 100 meters in about 20 years along the town of Tyre in Southern Lebanon (Özhan, 1993).

Biney *et al.* (1993) noted that human induced erosion in Ghana was caused by the removal of sand and pebbles from beaches for construction purposes and erection of coastal structures such as harbours and lagoon inlets. According to Mensah (1997) coastal sand mining's contribution to Ghana's industrial output increased from 17.4% in 1986 to 20.8% in 1993 and this may have accelerated coastal environmental degradation to an alarming rate in many areas across the country.

2.36 Effects of Beach Sand Mining

In Mensah (1997)'s study on the causes and effects of sand mining in the Western Region of Ghana, he mentioned that both sand miners and non-sand miners recognized the main effects of uncontrolled sand mining, which are expatiated below;

2.14.1 Loss of Land and Destruction of Properties

It was clear that erosion had resulted in the significant loss of coastal land in the eastern coast of Ahanta West District with erosional rates of about 2.1 m per annum estimated by Mensah (1997). It was identified that many private and community properties including houses, footpaths, farmlands, cemeteries and church buildings located on the coastline had been destroyed. Mensah (1997) also realized that these problems had resulted in social disputes especially between those who had lost properties or were in danger of losing their properties and some traditional leaders and sand mining contractors on the other hand. These disputes arose when residents had the perception that their leaders collected monies from sand mining contractors and allowed them to mine sand from the beach which ultimately threatened their properties.

2.14.2 Destruction of Beaches

Mensah (1997) observed that the sandy beaches that existed in the eastern coast of the Ahanta West District of the Western Region had degraded into denuded beaches sitting about 2.5 m below an "artificial" cliff. He noticed in areas such as Nkotompo in the Shama Ahanta East District that coastal erosion had created a stack with a radius of about ten meters and a cliff measuring around three meters. Mensah (1997) mentioned that in the workings of the sand miners, they create paths and steps onto the beach by carving through cliffs to enable them carry their products. Mensah (1997) posited that such destruction of the beach had led to exposure of rocks which pose danger to landing canoes and had also reduced the scenic beauty of the beach which used to attract visitors and tourists.

2.14.3 Destruction of Roads and Land Conflicts

Mensah (1997) noticed that sand tipper trucks had caused considerable destruction to community roads, including the creation of pot holes and the collapse of culverts which had damaged vehicles, reduced the flow of passenger vehicles in such areas, increased the maintenance costs of road and resulted in social disputes.

2.14.4 Loss of Vegetation

Coastal sand and stone mining leads to the loss of coastal vegetation such as mangroves, cacti, raffia palm and coconut trees. Coastal Erosion, sand mining and the Cape Saint Paul Wilt disease have contributed to an 80% decline of coconut and other vegetation over the last 40 years (Biney *et al.*, 1993; Mensah, 1997). The usual practice of sand miners include clearing of vegetation on the beaches to create paths for the trucks through which many species of vegetation are destroyed.

Ozhan (2002) summed up the effects of coastal sand mining into the following;

- No sand reserve for natural beach storm response
- Dependency on coastal resources
- Aesthetics/Lunar landscape end result
- Destruction of the nearshore, marine ecosystem and ecological values of coastlines.
- Destruction of archaeological sites
- Increased shoreline erosion rates
- Loss of land and destruction of properties
- Coastal pollutions

- Destruction of roads and drains

2.37 Types of Coastal Erosion

According to Cai *et al.*, (2009) coastal erosion has different spatial and temporal forms. In the spatial scale 3 major forms exists, these are;

1. Coastline retreat - which occurs dominantly for soft coast without protection measures like seawall engineering,
2. Landward movement of the zero meter depth contour - which is caused by beach surface incision, usually occurring on a coast with a seawall, and
3. Downward erosion of the lower beach in the sub-tidal zone by tidal current with the upper flat maintaining its original shape.

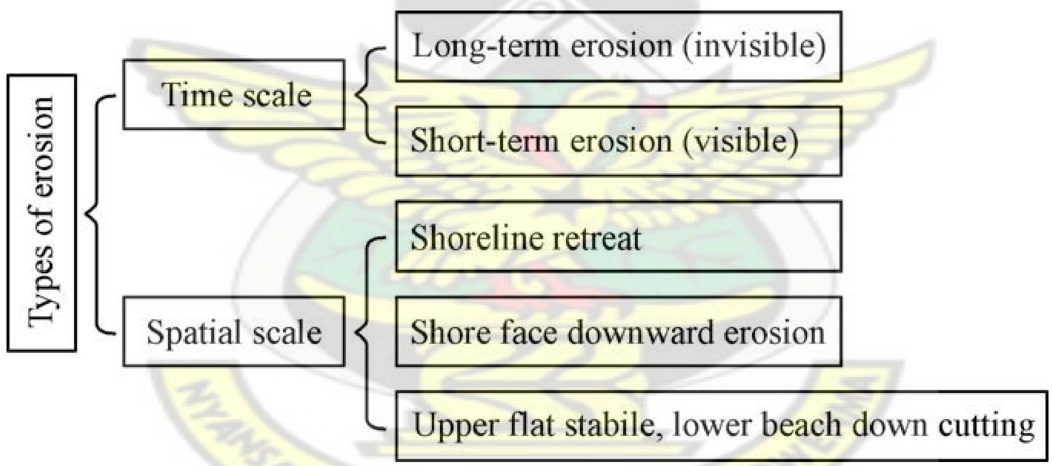

Figure 2.4: Framework of forms of coastal erosion (source: Cai *et al.*, 2009).

Coastal erosion can also be divided into two types in terms of time scale (Cai *et al.*, 2009). These are;

1. Long-term erosion (invisible) is the permanent change in the shoreline position due to events such as a sea level rise, river diversion or decrease in sediment discharge, which reduce the original sediment budget.

2. Short-term erosion (visible) can be caused by storm tides and storm surges without causing a permanent change in the shoreline position, but it brings enormous destruction.

2.38 Impacts of Coastal erosion

When coastal erosion/shoreline retreat occurs, adverse impacts to society, the economy, and the environment are to be expected. As a response, adaptation strategies are usually undertaken to address the hazard. These adaptations take the form of either protection or retreat/relocation which entail huge investments, and sometimes even have undesirable impacts and consequences. Coastal flooding is among the many negative results of coastal erosion. Coastal erosion in especially low lying communities reduces the effectiveness of the beach to act as the first line of defence against storm surges and freak tidal waves. Wolf (2009) describes coastal flooding as being generally caused by a combination of high water levels, which may be caused by tides and storm surges, together with waves, which can lead to overtopping of coastal defences and inundation of low-lying areas, potentially causing damage to life and property.

Past human impacts, inappropriate management interventions, climate change and sea-level rise have been identified as major contributory factors for coastal erosion, flooding and shoreline retreat along the coast of Keta (Armah, 1991; International Federation of Surveyors, 2010). Coastal erosion and flood risk to Keta was aggravated due to the shortage of littoral sediment which was created by the Akosombo dam built on the Volta River in 1964 (International Federation of Surveyors, 2010) which led to the reduction of fluvial sediment supply from the Volta River from about 71 million $m^{3/a}$ to as little as 7 million $m^{3/a}$ (Boateng, 2009).

The high flood risk is due to the fact that entire frontage and much of the hinterland of Keta Strip is extremely low-lying such that all the frontage could be submerged by 1 m rise in sea level, and 2 m rise in sea level may result in inundation of the whole frontage with some flood waters extending up to about 15 km inland (International Federation of Surveyors, 2010). Since, many of the most densely populated coastal areas are low-lying coastal plains susceptible to flooding (Boateng, 2006a), there is the need for effective management to address problems of shoreline retreat, coastal flooding and ill-informed use of coastal resources in Ghana.

2.39 Coastal ownership and protection responsibilities

The government of Ghana and the Local government are responsible for coastal protection and defence through the Local Government Act, 1993, Act 462 and Environmental Protection Agency Act, 1994, Act 490. In Ghana the ownership of the coastline is vested in the traditional chiefs who are custodians of the land; they in turn then lease the coastal lands to government and private institutions and individuals (Boateng, 2006a). Also, at every major fish landing site, there are chiefs called "Chief Fishermen" who are responsible for the local management of the coastal area as well as responsible for the local fishery and it related issues.

2.40 Coastal Management in Ghana

According to Aarninkhof *et al.* (2010) it is important to acknowledge that coastal areas are naturally dynamic zones that are vulnerable to anthropogenic interventions, hence, the increased pressure for developing these areas means that interventions need to be tuned to the natural situation and dynamics. Accelerated erosion, disappearing beaches, increased frequency of flooding, degraded ecosystems, etc, are all symptoms of an inability to provide competent coastal land management (Charlier & De Meyer, 2000).

Boateng (2006a) observed that there is no holistic policy and integrated plan for the management of coastal erosion and flooding in Ghana. He posited that management remains traditional, reactive, site specific, and dominated by hard engineering approaches, which are also fraught with their own peculiar problems to the environment. This current shoreline management regime in Ghana is not sustainable given the global perspective of climate change and associated sea-level rise. Mensah (1997) noted that coastal sand needs to be exploited to satisfy human demands; however, he noted that this requires efficient and effective resource management to ensure sustainable development.

Boateng (2006a) concluded that the adoption of a national coastal management policy will ensure the sustainable utilization of the coastal resources, curb the many unhealthy shoreline practices which are a threat to life and properties and in the long run allay the central government of unnecessary financial burden.

2.41 Coastal erosion mitigation

Because shoreline retreat brings beaches into conflict with human infrastructure, the mere threat of coastal erosion is enough to elicit a management response (Schlacher & Thompson, 2007). However, coastal erosion is a complex problem requiring equally complex solutions, oftentimes requiring not only technological/engineering expertise but policy/regulatory interventions as well. According to MAFF (1995) the generic options adopted for the appraisal of strategic defence options are:

- Do nothing; (non-intervention or perhaps small-scale intervention to protect public health and safety)
- Hold the existing defence line by maintaining or changing the standard of protection;
- Advance the existing defence line (reclaim some eroded land);
- Retreat the existing defence line; (e.g. Manage Retreat).

Schlacher and Thompson (2007) argued that ideally, management would entail natural retreat, removing manmade structures to accommodate the dynamism of the shore; however, this is generally not possible. In such cases, coastal authorities intervene more actively using either ‘soft’ engineering solutions (nourishment) or ‘hard’ armouring of the shoreline”.

National Research Council (2007) of the United States, documented available mitigation options against coastal erosion for sheltered coasts (which include bays). In the document, the Council summarized mitigation options against coastal erosion into four categories which are listed and defined below:

1. Land-use management entails a community-level (either local or nation-wide) approach to coastal erosion mitigation which includes: (i) community and land use planning; (ii) regulations such as imposition of set-backs, and construction standards; (iii) incentives which include taxation and transfer of development

rights; and (iv) acquisition which includes purchase of land to implement conservation and rolling easements.

2. Vegetation, on the other hand, involves the use of bio-engineering techniques to stabilize banks or bluffs, and to control groundwater seepage and surface runoffs. In other literature, vegetation techniques, along with beach nourishment/fills, are characterized as soft protection strategies. Various species of marshes or sea grass may be used in this option.
3. The hardening option involves the use of stone, wood, concrete and other local materials to protect the coast from wave attack and other erosive forces. This includes structures such as bulkheads, seawalls, and revetments.
4. Adding and trapping of sand includes projects such as beach nourishment, groins, and breakwaters.

According to Pilkey *et al.* (2004) three response alternatives are available to “solve” the erosion problem; these are construction of seawalls and other engineering structures, beach nourishment and relocation or abandonment of buildings. No matter what path is chosen, response to the erosion problem is costly (Pilkey *et al.*, 2004).

2.42 Hard Engineering Techniques

Hard engineering techniques simply involve the use of structures to prevent the full force of the sea from reaching the backshore. Traditional forms of coastal defence and the ones still most commonly applied consist of structures designed to resist natural processes such as wave action and sediment movement which are generally known as "hard engineering.

According to Wong (2003) hard engineering structures such as seawalls, groins and breakwaters are the most common responses to beach erosion, an observation the author agrees with completely. In Ghana, it is common for owners of beach-front hotels and tourist facilities to use some form of hard engineering technique to attempt to protect their properties as soon as they realize erosional activities in their area. Common hard engineering options include (Lees & Duncan, 1997):

- vertical sea walls (formed of concrete, rock, sheet piling or timber)

- revetments (sloping ramps of concrete or rock)
- flood embankments (formed of metal, concrete, rock, timber, rubble or turf)
- rock armouring (the most common 'hard' defence; designed walls and revetments constructed of boulders of a uniform size, typically many tonnes in weight (similar structures may, exceptionally, be formed from precast concrete blocks);
- rip-rap is a general term covering less tightly specified dumped or placed rock structures)
- gabions (wire baskets filled with stone, stacked vertically or stepped; often sloped to form gabion mattresses)
- dumping (piles of rock, hard core or other waste material tipped over the coastal edge)
- groynes (fences or walls generally perpendicular to the coastline, designed to intercept sand and gravel movement along the beach; constructed from timber, sheet piling, concrete or boulders.

2.43 Soft Engineering Measures

Carter (1991) observed that it is unlikely that conventional engineering techniques will suffice, and it may be essential to encourage a more dynamic environment, unfettered by economic demands, if dunes are to fulfil their full potential as natural, front-rank coastal defences. Hence, adopting a type of coastal defence with a high conservation value may be appropriate. These are what is called "soft engineering" and are designed to emulate, harness or manipulate natural processes (Lees & Duncan, 1997). Lees and Duncan (1997) enumerated the following as examples of soft engineering techniques;

- Mega-nourishments

  A surplus of sand is put into the natural system and expected to be re-distributed alongshore and into the dunes, through the continuous natural action of waves, tides and wind. In this way mega-nourishments gradually induce dune formation along a larger stretch of coastline over a period of one or more decades, thus contributing to the preservation or increase of safety against flooding over a longer period. Aarninkhof *et al.* (2010) noted that "before being fully dissipated into the coastal system, the surplus sand volume temporarily creates added value for nature and recreation; amongst others by providing shoals as rest areas for sea mammals, wide beaches for daily tourism and challenging surf conditions for the local surf community".

- Beach renourishment or recharge (addition of sand or gravel to a beach to restore former levels)
- Dune recontouring (modification of a dune profile, usually mechanically, to increase its width or make it more stable)
- Wave barrier fencing (erection of fences on the upper foreshore to reduce wave scour and promote sand deposition)
- Sand fencing (erection of fences to trap and accumulate wind-blown sand)
- Dune grass planting (stabilisation of bare sand dune surfaces with appropriate grasses which will also trap wind-blown sand).
- Nearshore renourishment (addition of sand or gravel to a beach around or below low water mark in order that waves drive it ashore)
- Sediment bypassing (transport of beach sediment, usually by lorry, from the updrift side of an obstruction, such as a pier, to the downdrift side)
- Sediment recycling (transport of beach sediment, usually by lorry, from the downdrift end of a beach back to its updrift end)
- Beach drainage or dewatering schemes (burial of a permeable pipeline below a sandy beach which, when connected to a pump, draws sea water from swashing waves downwards through the beach surface reducing backwash and promoting sand deposition)
- Set back (removal of coastal defence inland to permit natural evolution of a shoreline and, if the coastline is eroding, generation of a supply of beach sediment)
- Managed retreat (analogous to set back but generally applied to the relocation or removal of flood embankments from claimed land which was formerly saltmarsh; this encourages restoration of the saltmarsh which then acts as a form of natural coastal defence for areas inland).

2.44 Impacts of Coastal Mitigation Measures

According to Morton *et al.* (2004) attempts to stabilize the shore can also greatly influence the rates of shoreline change. Activities such as beach nourishment or emplacement of shoreline stabilization structures tend to alter coastal processes, sediment transport, and shoreline position. For example, beach nourishment artificially causes rapid, temporary shoreline accretion. Depending on the frequency of beach nourishment, the placement of large volumes of sand on the beach will bias the rates of observed shoreline change toward accretion or stability, even though the natural beach, in the absence of nourishment, would be eroding.

Several studies suggest that the ecological consequences of engineering activities on beaches can be substantial at local scales, and include the loss of biodiversity, productivity, and critical habitats as well as modifications of the subtidal zone which is an important recruitment zone for many sandy beach animals (Peterson & Bishop, 2005; Dugan & Hubbard, 2006; Peterson *et al.*, 2006; Speybroeck *et al.*, 2006; Schlacher and Thompson, 2007). Carter (1991) also noted that dunes which have been 'fixed' by ecological and engineering techniques may, at first, be less vulnerable to sea level rise. Erosion will be limited although eventually steep cliffs will form and perhaps fail as semi-cohesive materials (Carter 1980).

Nordstrom (2000) was of the opinion that part of the failure of hard structures has been the preoccupation with their discrete function and design without sufficiently considering their wider geomorphological, ecological and even recreational values. This is especially evident when structures, not properly maintained, fall into disrepair and create a negative effect on the value of shoreline (Wong, 2003).

Sanjaume and Pardo-Pascual (2005) contended that traditional sea defence works have a high rate of failure due to a lack of understanding of the physical processes occurring at the site and within the regional context. Traditionally, engineers have been more concerned with the stability of the structures than their effects on the shoreline morphology (Thomalla & Vincent, 2004).

Lees & Duncan (1997) argues that "few forms of coastal defences have a benign effect upon the environment, as all are designed to counter the natural evolution of the coastline. Any form of defence which reduces or prevents sediment loss from a previously eroding coastline reduces sediment supply to the beach and in so doing may contribute to increased erosion elsewhere". Thus, sediment starvation in one area will be countered by sediment accumulation in another (Carter 1991) and vice versa.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was carried out at three adjoining communities; Elmina, Cape Coast and Moree in the Central Region of Ghana. Elmina (Latitude 05°07′50.0″N and Longitude 001°38′20.0″W) and Moree (Latitude 05°13′91.2″N and Longitude 001°19′07.4″W) represents the western and eastern limits of the coastline that was used for this study with a total coastline length of about 25km.

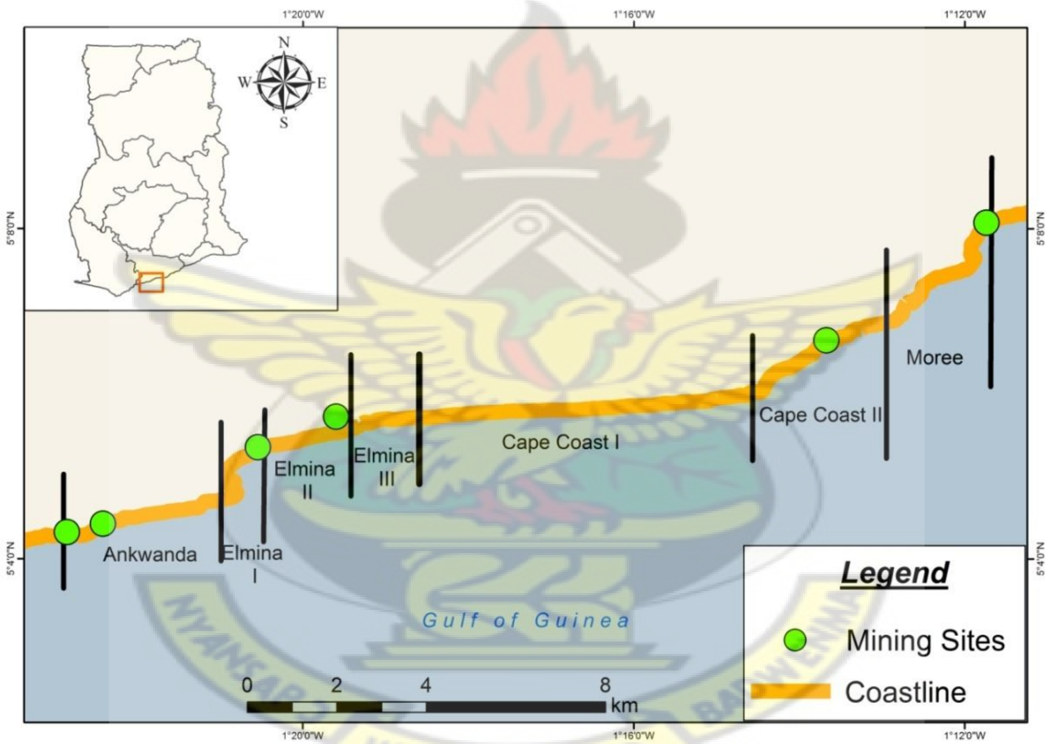

Figure 3.1 Map of Ghana indicating the Study Area with coastline segments and sand mining locations

3.2 Physical Characteristics of the Study Area

The physical and climatic information of the study area are presented below:

3.2.1 Relief & Drainage

The area is generally undulating with batholiths as a dominant feature. The slopes of the hills are steep in many areas and tend to affect physical mobility. In between the hills are valleys of various shapes, some occupied by rivers and streams including the Kakum – the major stream in the study area. Many of the minor streams end up in wetlands, with the largest draining into the Fosu Lagoon at Bakaano. The wetlands are liable to flooding and, for many of them; the water table is high, averaging just 1.2 metres below the surface (CCMA, 2010). During heavy rains, these wetlands become unusable as farmlands.

3.2.2 Climate

Elmina, Cape Coast and Moree are located in the littoral anomalous zone of Ghana, and experience high temperatures throughout the year with the warmest months being February and March, just before the main rainy season, while the coolest months are between June and August. The variability in climate in the area is influenced more by rainfall than temperature. The study area has a double maximal rainfall, with annual rainfall total between 750 and 1,000 mm. The highest rainfall ever recorded was 1719 mm in 1979 and the lowest 372 mm in 1983. The minor rainy season is between November and January (CCMA, 2010).

3.2.3 Geology

The rock type of the study area is of the Birrimian formation and consists of schist and introduced granites and pegmatite. The hills are generally overlain by sandy and clayey silts while the valleys are overlain by clayey gravel with lateritic soils exposed in a number of areas. The hilly nature of the place has greatly affected building and road construction. It also promotes erosion especially along slopes, and sedimentation/siltation and flooding at low-lying areas (CCMA, 2010).

3.3 Beach Segments

For the purpose of the ease of analysis of the historical shoreline data, the study area was divided into seven study segments based on the type of beach and location. The segments (from the western end to the eastern end of the study area) are described as follows:

3.3.1 Ankwanda

This shoreline segment starts from the western end of the study area ends at the western side of the Elmina Castle. This segment has three beach front hotels dotted along its western end, Elmina Bay Resort, Stumble Inn and Coconut Grove hotel, as well as a community that stretches from adjacent Coconut Grove hotel to the eastern boundary. Along the stretch used by the community, part is used for porting canoes, while another strip of beach is used mainly as a refuse dump.

3.3.2 Elmina I

This shoreline segment starts from the eastern end of the Elmina Castle through the beach stretch adjoining the main Elmina township to the beach adjacent the Akotobinsin community in Elmina. The western end to the front of the Elmina Castle has rocky projections on the coast that protects the facility from the force of the sea from that direction, but has a small sandy beach on the eastern side. Just adjacent the castle is the Elmina fishing port built on the Benya Lagoon. A jetty was built to protect the fishing port and stretches about 100m into the sea. The adjoining beach is used to harbor canoes and is also used as a fish market. The remaining half a kilometer or so of this shoreline segment is protected by a sea wall, built to ward of the sea from the road leading into the township.

3.3.3 Elmina II

This stretch of shoreline is about 2.5 km in length and begins at the small sandy beach to the west of the Elmina Beach Resort to the bridge on the Cape Coast-Takoradi highway. The entire coastline stretch is rocky with only about 3 pockets of sandy beaches with average length of about 100m. This segment has the Elmina Beach Resort and some houses interspersed along it. The small sandy beach in front of the Elmina Beach Resort has been protected using boulders.

3.3.4 Elmina III

This coastline stretch extends about 1.6km from the Elmina Bridge towards Cape Coast. Beneath this bridge is the estuary where the Kakum River meets the sea. About 1.3km of this stretch has been protected with a sea defence wall made up of large rock boulders, obviously to protect the highway just on the back of the shore from the action of the sea. Waves break on this stone revetment during high tides. The remainder of the segment that is unprotected is fronted in the low tide area by rocky projections.

3.3.5 Cape Coast I

This shoreline stretch is bounded on the west by the Elmina III segment and is bounded on the east by the Cape Coast Castle. This segment is made up of a stretch of continuous open ocean beach and is the longest stretch of sandy beach in the study area (extends about 7.5km). This stretch of shoreline extends along the main Cape Coast-Elmina road. The sandy stretch is only intercepted by rocky projection at Bakaano and extends for about 300m before it is intercepted again by a rocky projection just before the beach adjoining the Cape Coast Castle where the segment ends. At the Wilson Sey School beach, which is located between Bakaano and the Cape Coast castle beach, a groin had been used as a sea defence mechanism to protect the school from the action of the sea. The visible land use for the shoreline segment is predominantly fishing or harboring of canoes. No buildings are found on the beach berm of the segment except between Bakaano and the Cape Coast Castle where several infrastructure including a school, a housing building for the Ghana Police Service and two beach front restaurant and tourist facilities, can be located.

3.3.6 Cape Coast II

This segment stretches from the rocky western side of the Cape Coast Castle to the base of the cliff just beyond the sandy beach at Ekon. This shoreline segment is the most diverse shoreline in the study area, containing a number of beaches with both sandy and rocky projections, cliffed beaches and several beach stretches separated by cliffs. This stretch is made up of cliffed rocky beaches with a few stretches of sandy beaches which show signs of erosion. Many of the sandy beaches here are used as fish landing sites.

3.3.7 Moree

This segment starts from the cliffs of Ekon to the eastern end of the study area at Moree. The shoreline length is also made up of rocky cliffed coasts with a few sandy beach stretches. Most of the sandy beaches here are also used as fish landing sites.

3.4 Data Collection

Data relevant to the study was collected from various sources in order to achieve the objectives set for the study. These included both primary and secondary data, which are elaborated as follows:

3.4.1 Primary Data

Primary data used for the study included time series shoreline data obtained from the Geography and Regional Planning Unit of the University of Cape Coast, Ghana, for the shoreline change analysis. Additional primary data included a GPS shoreline tracing of the study area, a field survey to determine the magnitude of sand mining activities in the study area, as well as beach scarp measurements. Other sources of primary data for this study included a questionnaire administration, a focus group interview and a key informant interview held with the manager of the Elmina Bay Resort in Elmina.

3.4.2 Secondary Data

Secondary data for the study were obtained from the Central Regional office of the Environmental Protection Agency (EPA) in Cape Coast. These data included sections of EPA's 2009 annual report and second quarterly report for 2009 that pertained to the management of the coastline in their jurisdiction as well as a report of an ad-hoc committee set up to investigate beach sand mining activities in Cape Coast.

3.5 Shoreline Change Determination

In order to determine the extent of coastline erosion and their rates during the period 1974 to 2012 for the Elmina-Cape Coast-Moree area, an analysis of shoreline data for various years within the stipulated period was required.

The shorelines were analyzed using the combination of ArcGIS and Digital Shoreline Analysis System (DSAS) tools. ArcGIS is a useful tool for working with maps and geographic information produced by ESRI, while DSAS is a software extension of ArcGIS developed by the United States Geological Service (USGS). DSAS enables the calculation of rate-of-change statistics for a time series of shorelines.

Plate 1: Some equipment used for the field surveys

The quantification of the extent of shoreline change in the Elmina-Cape Coast-Moree area was done using available data, which spanned a period of thirty-eight years. These were made up of three different shoreline data including a 1974 digital topographic shoreline data and a 2005 orthophotograph, both obtained from the Department of Geography and Regional Planning of the University of Cape Coast (UCC). A GPS shoreline tracking survey was conducted in the period 8-10 May, 2012 to obtain the 2012 shoreline of the Elmina-Cape Coast-Moree area.

The 1974 shoreline derived from the 1974 topographic sheets of the area was obtained in digital formats and used in ArcGIS. The high water line (HWL) proxy was used to define shoreline positions on the other shoreline data (Section 2.10). ArcGIS enabled the acquisition of the 2005 shoreline from the orthophotograph. In ArcGIS, the HWL was identified on the orthophotograph at one end of the study area and carefully traced to obtain the shoreline for that year.

A GPS tracking survey was done over a 3 day period (8-10 May, 2012) using a Garmin 60Cx GPS receiver to obtain the shoreline data for 2012. The survey was done in the early mornings, between 6:15am and 11:00am, on each occasion which ensured consistency in the shoreline data obtained. The HWL was first identified at the starting point on the beach and carefully traced across the entire study area to capture the shoreline.

All the shorelines were projected into the same coordinate system, Ghana Metre Grid projection, along with the World Geodetic System 1984 (WGS, 1984) datum which enabled appending to be done and comparisons made.

The shorelines were compiled and appended into a single feature class in ArcGIS which enabled the calculation of change statistics using DSAS. An accuracy of ± 6m was adopted as default that encompassed the uncertainty in the 1974 data.

DSAS contains components that helps in defining a baseline, generating orthogonal transects at a user defined spacing along the coast and also calculates rates of change statistics. Because each shoreline data represents a specific position in time, each was assigned a date in the shoreline feature-class attribute table. A baseline was created onshore parallel to the time series of shorelines at a distance of 100m. The baseline closely followed the direction of the outer shoreline which enabled transects to be cast perpendicular to the general direction of the shorelines.

Transects were cast 20m apart and were 160m in length from the baseline which enabled transects to intersect with all the shoreline vectors. The points of intersection provided location and time information which were used to calculate rates of change. The distances from the baseline to each intersection point along each transect were used to compute the selected statistics.

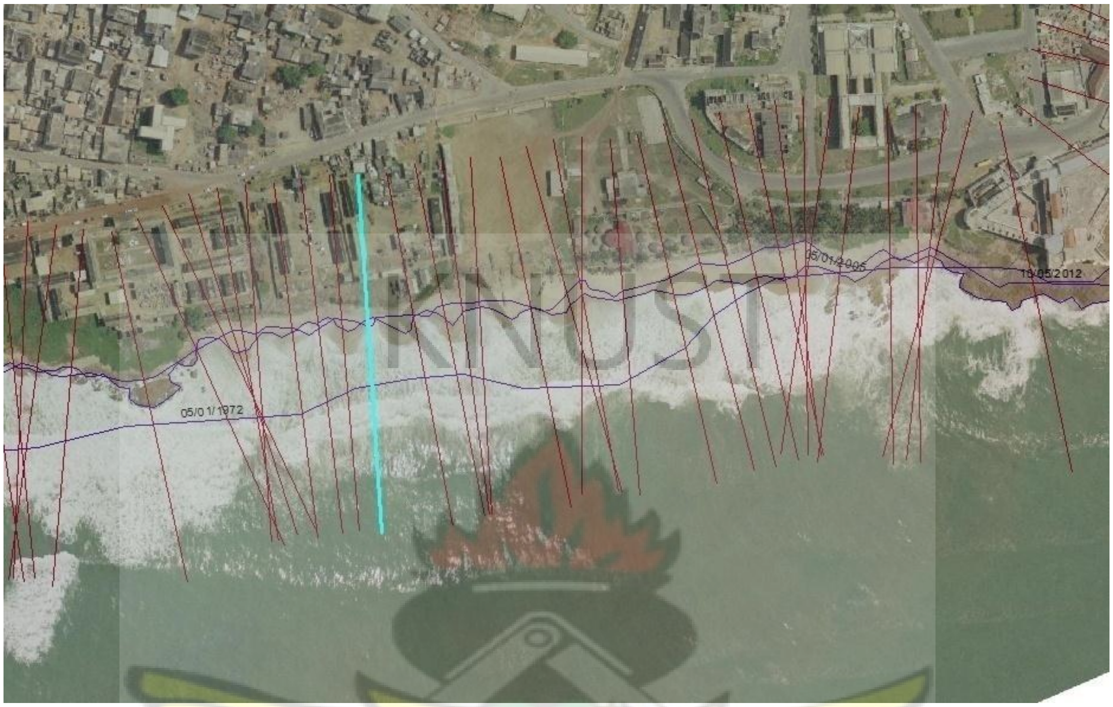

Figure 3.2 A section of the 2005 orthophotograph showing the Cape Coast Castle area with the time series shorelines and cast transects.

On the DSAS settings a default data uncertainty of ± 6m was used. This value signifies the minimum source of error within this study. This error margin was used as a result of two factors; a result of a high water line (HWL) positional error of ±6.1m, associated with photogrammetric mapping (Crowell *et al.,* 1991; Appeaning Addo *et al*,, 2008; Walkden & Mills, 2008), thus with regards to the 1974 T-sheets and an inaccuracy of ± 3m that was associated with the GPS device used to capture the 2012 shoreline. Digital Shoreline Analysis System (DSAS) then generated the shoreline change statistics using the two statistical tools used for the study, thus, net shoreline movement and end point rate (Figure 3.3).

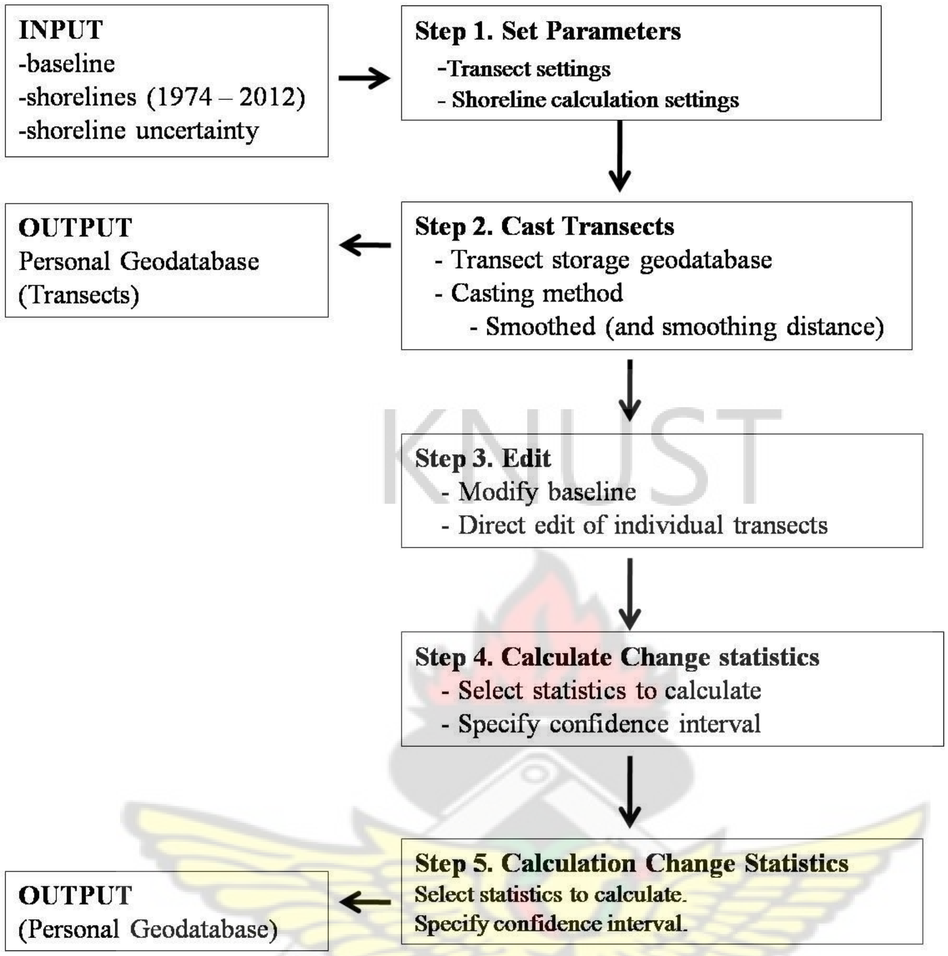

Figure 3.3: Digital Shoreline Analysis System workflow (Himmelstoss, 2009)

3.5.1 Reliability of Results

According to Morton *et al.* (2004); documented trends and calculated rates of shoreline change are only as reliable as: (1) measurement errors that determine the accuracy of each shoreline position, (2) sampling errors that account for the variability of shoreline position, and (3) statistical errors associated with compiling and comparing shoreline positions. Previous studies including Anders and Byrnes (1991), Crowell *et al.* (1991), Thieler and Danforth (1994), Moore (2000), Morton *et al.* (2004) and Hapke *et al.* (2010) provided general estimates of the typical measurement errors associated with mapping methods and materials for historical shorelines, registry of shoreline position relative to geographic coordinates, and shoreline digitizing.

This study used error (uncertainty) estimates provided by Hapke *et al.* (2010). From the methods outlined by Crowell *et al.* (1993); Hapke *et al.* (2010) identified five uncertainty terms for HWL-type shorelines: georeferencing uncertainty (U_g), digitizing uncertainty (U_d), T-sheet survey uncertainty (U_t), air photo uncertainty (U_a), and the uncertainty of the high water line at the time of survey, (also known as the proxy-datum bias uncertainty, U_{pd}). The maximum measurement errors estimates for this study are provided in Table 3.1 to show how each error contributes to uncertainty in the shoreline position and in the rates of change.

Since the 1974 shoreline data was obtained in digital format the georeferencing error and the digitizing errors were not applied. Georeferencing and digitizing errors were not applied to this study because the 1974 shoreline was obtained in digital format. Also, the T-sheet survey uncertainty was not applicable to this study since more recent shorelines are obtained from aerial photographs (Appeaning Addo, 2009) or other sources (Hapke *et al.*, 2010). The aerial photo uncertainty of ±3.0 m was applied to 2005 shoreline since it was obtained from an orthophotograph. The shoreline proxy offset was also applied to all the shoreline data, this error is due to uncertainty in HWL shorelines due to variations in water levels (Hapke *et al.*, 2010). Hapke *et al.* (2010) averaged HWL variations to be ±4.5m, which was applied to this study. The inaccuracy of ±3m associated with the GPS receiver was within the error margin estimated by Hapke *et al.* (2010), hence, Hapke *et al.* (2010) error estimate of ±4.5m was applied to the 2012 shoreline also.

The total coastline position uncertainty at each transect, U_n is thus expressed as:

$$U_n = U_a^2 + U_{pd}^2 \quad \text{...(1)}$$

Where n = coastline number (1-3)

For each coastline, a separate total error (U_n) was calculated and results presented in Table 3.1. The shoreline positional uncertainty for each period was then incorporated into an error for each transect. The value was annualized (U_F) to provide uncertainty estimation for the coastline change rate at any given transect and expressed as follows:

$$U_F = \frac{\sqrt{U_1^2 + U_2^2 + U_3^2}}{T} \text{ ....(2)}$$

Where U_1, U_2, and U_3 are the total coastline position error for the various years and T is the 38 years period of analysis. This approach carries the reasonable assumption that the component errors are normally distributed (Appeaning Addo *et al.*, 2008)

Table 3.1 Estimated Measurement Errors for the study (error estimates adapted from Hapke *et al.*, 2010)

Measurement errors (m)	1974	2005	2012
Air photo (U_a)	-	3	-
Shoreline proxy offset (U_{pd})	4.5	4.5	4.5
Total coastline error (U_n) (m)	4.5	5.41	4.5
Total coastline error at each transect (1974-2012)(m)	±8.35		
Total coastline error at each transect (1974-2005)(m)	±7.04		
Annualized transect error (m/yr)(1974-2012)	± 0.22		
Annualized transect error (1974-2005) (m/yr)	± 0.23		

The positional error for each period was then incorporated into an error for each transect. That value was annualized to provide error estimation for the shoreline change rate at any given transects (Table 3.1).

A total of 1,173 transects were generated by DSAS in the shoreline change analysis. Values for shoreline changes between adjoining transect were similar and consistent for the entire stretch of the study area, indicating the reliability of the results. The averages of shoreline changes in each shoreline segment over the period were above the maximum error computed for this study, and hence certain. Changes at specific transects that were below the error margins of ±8.35m and ±7.04m for the periods 1974-2012 and 1974-2005 respectively were considered with care.

3.6 Land Use Identification

The 2005 orthophotograph helped in visually identifying the various land uses along the coastline in the study area in the ArcGIS environment. These identified land use types were then verified on the field through observations. This land use information along the coastline helped to identify the causes of the shoreline changes in the study area.

3.7 Questionnaire Administration

A set of structured questionnaire (Appendix) were administered to residents in the Cape Coast area. Forty-four residents made up of males (36%) and females (64%) with ages ranging between 16 and 62 years were interviewed with the questionnaire. These included 24 fishermen, 7 fishmongers and 13 residents with a variety of professions.

The 4 communities used were Ekon, Amanfo, Gegeano and Ola. Residents were asked about their perception of changes that has occurred at the beach near them, the possible causes, the perceived effects of such changes on their livelihoods and the actions that they had taken to control those activities. The questionnaire served as a basis for further exploration during the focus group discussions.

3.8 Focus Group Discussion

A focus group discussion was conducted at Moree to obtain the perception of local traditional leaders and residents about various issues pertaining to shoreline changes in the area including the causes, the perceived effects and the mitigation measures if any that has been put in place.

Four people participated in the discussion, including two Chief fishermen of the two fish landing sites of Moree namely Nana Kweigya II and Nana Mensah Bonsu. The other two participants included a fisherman and a resident of the area. The participants were aged between 53 and 71 years. The focus group discussion was facilitated by the researcher who asked specific questions, controlled digressions and stopped break-away conversations during the discussions. The discussion was audio recorded which helped the researcher to easily transcribe the views expressed by the participants.

3.9 Interview

An interview was conducted with the Managing Director of the Elmina Bay Resort. Elmina Bay Resort is a beach front property situated in Elmina. The facility is located in between two well-known beach sand mining spots, which are within a half a kilometre distance in both directions. The interview was conducted on June 8 2012.

The questionnaire administration, the focus group discussion and the interview helped in addressing the objectives 2, 4 and 5 of the study which are to identify the anthropogenic activities that are responsible for the coastline changes in the Elmina-Cape Coast-Moree area, ascertain the perceptions of residents about coastal erosion in the Elmina-Cape Coast-Moree area and identify the coastal zone management issues in the Elmina-Cape Coast-Moree area.

3.10 Sand Mining Survey

Sand mining surveys were conducted during the study in order to determine the magnitude of sand that is lifted from the study area over a given period. Since a large part of the 25 km coastline of the study area is sandy, there was the challenge of surveying all the sand mining sites as part of this study. This is because most of the mining were done clandestinely and in a manner to avoid detection.

Sand miners used trucks of various capacities, but generally 8 cubic meter trucks were observed to be commonly used in the activity. Hence, truck capacity was used in the determination and extrapolation of sand lifting in the study area. Survey beaches were selected based on informal interviews and observations made by the researcher on where major sand mining occurs. Six major beaches were identified to be major sand lifting sites and were therefore used in the survey. These are;

1. Moree
2. Amoakofua (Cape Coast)
3. Elmina Bridge
4. Elmina town lagoon beach
5. Mbofra Akyinim (Elmina)

6. Ankwanda beach (Elmina)

The survey was conducted concurrently over a period of seven days from the 8th to the 14th of October 2012. Observers were placed at vantage points at all survey sites where the movement of trucks to and from the various mining sites could be seen. Daily surveys were conducted from dawn to dusk (5: 25am - 6: 20 pm). The number of times trucks visited the beach was noted and the total number of sand mining computed at the end of each day.

Initial survey at Mbofra Akyinim sighted no mining even though informal interview with residents in the area suggested that the activity took place there. The researcher later realized that the sand mining activity in that area was done at night and hence, another survey was conducted for the area. This special survey was conducted from 22 to 28 October, 2012 between 7pm and 11pm. Because of the short time frame of the survey, it is likely that the recorded sand mining in the area could be higher.

3.11 Erosion Scarp Height Measurement

The heights of erosion scarps on six sandy beaches along the coastline of the study area were taken using a surveyor's tape. The selected beaches were Moree, Amoakofua, Wilson Sey School, Bakaano, Ola and Mbofra Akyinim. Five points were selected randomly along each beach and scarp heights measured. These were then computed to determine the average scarp height at each beach.

Plate 2 Scarp height measurements along the coastline of Elmina, Cape Coast and Moree.

3.12 Desk study

Relevant secondary data were obtained from the Central Regional (CR) Environmental Protection Agency (EPA) office in Cape Coast and used as part of the data for this study. This information were obtained from sections of three official reports of the CR EPA including their 2009 Second Quarterly and Annual Reports, as well as a report submitted to the Metropolitan Chief Executive of Cape Coast Metropolitan Assembly (CCMA) about the beach sand mining activities in the Cape Coast area.

3.13 Data Analysis

Shoreline changes in the study area were analyzed using ArcGIS and DSAS. Trends from the rate statistics were generated using ArcGIS and Microsoft Excel. Results from the questionnaire administration were analyzed using Microsoft Excel and descriptive charts generated. The focus group interview and the key informant interview were also descriptively analyzed.

CHAPTER FOUR

RESULTS

4.1 Coastline Changes in Elmina-Cape Coast-Moree

The Elmina, Cape Coast and Moree coastlines experienced general erosional trends in all the three (3) epochs analyzed. A summary of the rates and net changes along these coastlines in the 3 periods are presented below;

4.1.1 Shoreline Changes Between 1974 and 2012

Figure 4.1 below indicate that the Cape Coast I segment experienced the most consistent shoreline changes with the Ankwanda, Elmina I, Elmina II, Elmina III, Cape Coast II and Moree segments recording fluctuating or more dynamic changes during the period 1972 to 2012.

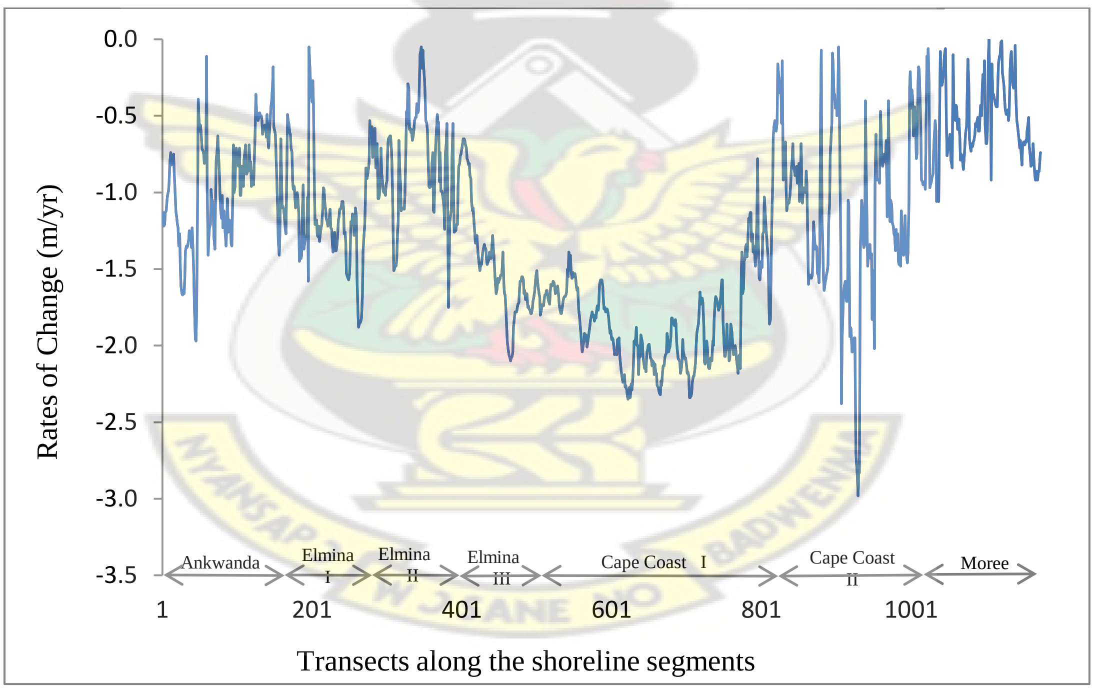

Figure 4.1 Historic end point rate trends in the Elmina-Cape Coast-Moree area from 1974-2012

The Ankwanda segment experienced a change in shoreline length ranging from a high of -79.59 m to a low of -4.31 m. End Point Rates also ranged from -1.97 m/yr ±0.16 m to -0.11 m/yr ±0.16 m within the segment. Trends in results indicated that shoreline changes were highest around the three beach front tourist facilities with an average end point rate of about -1.13 m/yr ±0.22 and NSM average of -49.88 m, whilst the remainder of the shoreline segment had an average end point rate of -0.88 m/yr ±0.16 m and NSM average of -36.05 m (Table 4.1).

Within the Elmina I segment, the shoreline surrounding the Elmina Castle experienced the highest change in coastline extent, with the loss of about -61.96m of land and an end point rate of -1.37 m/yr ±0.16 m. The next five transects immediately beyond the Benya lagoon recorded the lowest changes over the 38 year period; recording an average NSM of -9.41 m and average EPR of -0.23 m/yr ±0.16 m (Table 4.1).

The Elmina II segment also recorded general land loss trends during 1974-2012. The greatest shoreline changes were recorded at the westernmost end where the average of 6 successive transects produced an NSM of -74.26 m and an EPR of -1.84 m/yr ±0.16 m (Table 4.1). Shoreline changes were lowest at the central portion of the segment especially in areas with rocky projections.

Table 4.1 Net shoreline movement and End Point Rate for the study area during 1974-2012

Shoreline Segment	End Point Rate (m/yr)	Net shoreline Movement (m)
Ankwanda	-0.97	-39.21
Elmina I	-1.14	-46.07
Elmina II	-0.85	-34.28
Elmina III	-1.26	-51.1
Cape Coast I	-1.81	-73.06
Cape Coast II	-0.93	-37.68
Moree	-0.54	-21.88

The Elmina III segment experienced the greatest NSM of -70.62 m and EPR of -1.75 m/yr ±0.16 m at the westernmost end where the coast type was sandy (Table 4.1).

Shoreline changes ranged from an EPR of -0.55 m/yr ±0.16 m to -2.03 m/yr ± 0.16m and NSM of -22.35 m to -82.02 m at specific transects.

The greatest and most consistent shoreline changes (erosion) during this period occurred within the Cape Coast I segment. The segment experienced the greatest shoreline changes in two areas; on the beach just across the street from the Cape Coast District Hospital where 5 successive transects recorded an average NSM of -93.46 m and an EPR of -2.31 m/yr ± 0.16m and the other on the beach across the street from the Ola community and about half a kilometre to the east of the UCC west gate where 3 successive transects recorded an average NSM of -94.34 m and EPR of -2.34 m/yr ±0.16 m. The lowest shoreline changes occurred at the easternmost end of the segment, thus, at the Cape Coast Castle beach, where 9 successive transects produced an average NSM of -21.50m and with a corresponding EPR of -0.53 m/yr ±0.16 m.

At the Cape Coast II shoreline, trends indicated that net shoreline changes were smaller at cliffed rocky areas especially where the cliffs serves as the separating feature between two beaches; such as the rocky area around the Cape Coast Castle, the two cliffs along the Amanful community, the four successive cliffs along the Amoakofua shoreline stretch and the two cliffs at the Ekon. These areas averaged an NSM of -2.47 m and an EPR of -0.07 m/yr ±0.16 m over the 38 year period as compared to the average NSM of -46.33 m and EPR of -1.15 m ±0.16 m computed for the entire shoreline segment. There were areas within the Cape Coast II segment that recorded a net gain of beach area, such as the NSM of 19.23 m at one of the rocky cliffs at Amanful. The Amoakofua beach recorded the highest change in beach extent in the entire study area recording an NSM of -120.50 m and EPR of -2.98 m/yr ±0.16 m at a particular transect.

The Moree segment produced the lowest shoreline changes in the study area during this period. Shoreline changes were lowest at cliffed rocky areas in this shoreline also with 6 transects at cliffed areas producing an NSM of -7.98m and an EPR of -0.20 m/yr ±0.16m over the period (Table 4.1). Shoreline changes for the area varied from an NSM of 0.06m to -42.90 m whilst the EPR ranged from 0.00 (no change) to -1.06 m/yr ±0.22 m.

Average historic shoreline change (recessional) rate for the Elmina-Cape Coast-Moree area based on 1974-2012 data was found to be -1.22 m/yr ±0.16 m (Figure 4.1) with an average change in beach extent of -44.61 m.

4.1.2 Total Shoreline Changes Between 1974 and 2005

From Figure 4.2, it is indicative that greater parts of the entire coastline of Elmina-Cape Coast-Moree experienced recession, with a few areas showing stability or accretion. Within this period there was an average EPR of -1.32 m/yr±0.17 m and an NSM average of -39.45 m.

From 1974 to 2005, the Ankwanda segment had recorded an NSM range of -0.78m to -61.45m and an EPR range of -0.02 m/yr ±0.17 m to -1.86 m/yr ±0.17 m. The shoreline length around the three beach front hotels indicated the highest erosional trend with an average end point rate of -1.13m/yr ±0.17m and NSM of -37.20 m, whilst the remainder of the shoreline length experienced an average EPR of -0.95m/yr ±0.17m and NSM of -32.45m (Table 4.2).

Net shoreline movement and EPR at the Elmina I segment ranged from 0.97 m and 0.03 m/yr ±0.17 m to -57.14 m and -1.73 m/yr ±0.17 m respectively in the period. Average EPR for this section in 1974 to 2005 was relatively higher, -1.36 m/yr ±0.23 m, compared with that obtained for the period 1972-2012, -1.14 m/yr ±0.22 m.

Within this period, the Elmina II segment experienced the greatest shoreline changes at the western most end with NSM of -57.36 m and EPR of -1.74 m/yr ±0.23 m. The central portion especially areas with rocks recorded the lowest shoreline change trends within the period; with an average NSM of -17.18 m and EPR of -0.44 m/yr ±0.23 m.

At the Elmina III segment NSM ranged from -21.62 m to -82.02 m with erosion rates (EPR) also ranging from -0.88 m/yr ±0.17m to -2.49m/yr ±0.17 m at specific transects. Table 4.2 presents averages of NSM and EPR for the segment within the 1974 -2005 period.

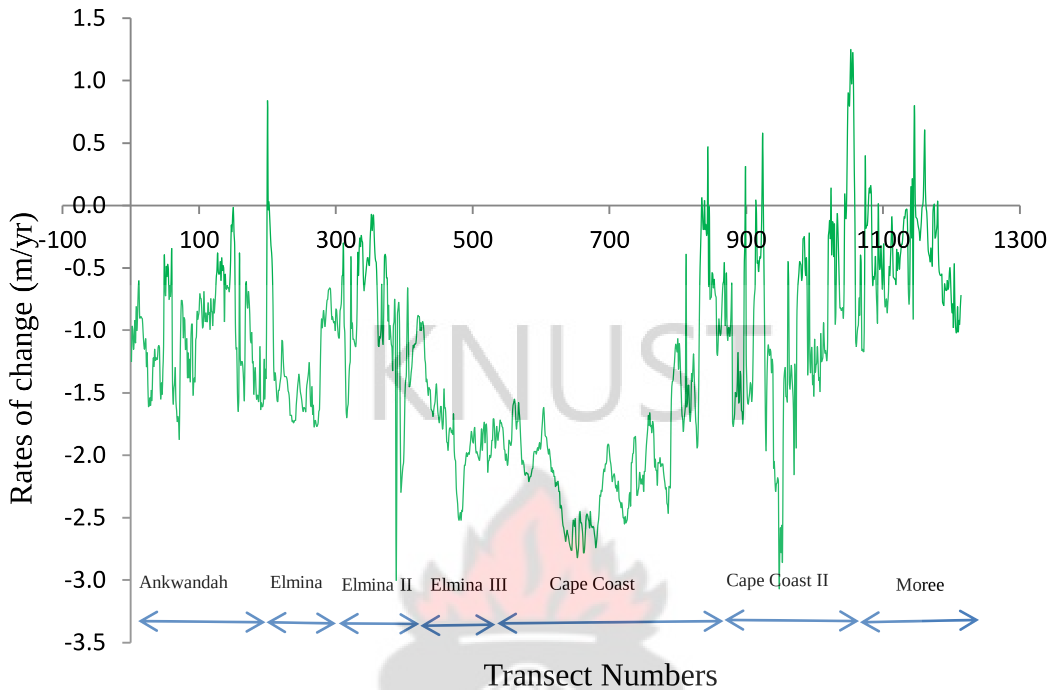

Figure 4.2 End Point Rate trends at the Elmina-Cape Coast-Moree area over the period 1974-2005.

Table 4.2 Net shoreline movement and End Point Rates for the Elmina-Cape Coast-Moree area during 1974-2005

Shoreline Segment	End Point Rate (m/yr)	Net shoreline Movement (m)
Ankwanda	-1.02	-33.72
Elmina I	-1.33	-43.96
Elmina II	-0.87	-28.78
Elmina III	-1.5	-49.6
Cape Coast I	-2.03	-66.93
Cape Coast II	-0.98	-32.20
Moree	-0.51	-16.82

The Cape Coast I shoreline segment recorded the greatest shoreline changes in the study area in this period. The segment recorded an NSM range of -2.05 m to -92.95 m and EPR range of -0.06 m/yr ±0.17 m to -2.82m/yr ±0.17 m (Table 4.2).

Net change in beach extent within the Cape Coast II segment ranged from 19.23 m (accretion) at the cliffs at Amanful to -100.74 m (land loss) at Amoakofua. End point rate also ranged from 0.58 m/yr ±0.17 m to -3.05 m/yr ±0.17 m in the same area (Table 4.2).

The Moree segment had an average NSM and EPR of -15.09 m and -0.46 m/yr ±0.17 m respectively. Shoreline changes in the segment ranged from a net gain of 4.56 m of land (EPR of 0.14 m) to a net loss of -38.67 m of coastline area (EPR of -1.17 m/yr ±0.17 m).

4.1.3 Total Shoreline Changes Between 2005 and 2012

Trends in the results for this period and indicated that a greater part of the coastline experienced erosion with few areas indicating accretion. Fewer areas experienced no shoreline change or stability over the 7 year period of analysis (Figure 4.3). There were an average EPR of -0.85 m/yr ±0.77 m and an NSM average of -6.28 m over the period.

The Ankwanda segment recorded the highest shoreline change at an individual transect in the study area during this period with the beach close to the Coconut Grove Hotel recording an NSM of -32.34 m and an EPR of -4.35m/yr ±0.77 m (Figure 4.3). Shoreline changes were relatively higher at the beaches close to the three beach front hotels; recording an average end point rate of -1.40 m/yr ±0.77 m, compared with the remaining stretch having an EPR average of -0.75 m/yr ±0.77 m (Table 4.3).

Shoreline change result for the Elmina I segment showed both net accretion and erosion over the period (Figure 4.3). This segment recorded the lowest shoreline changes in the study area within the period (Table 4.3).

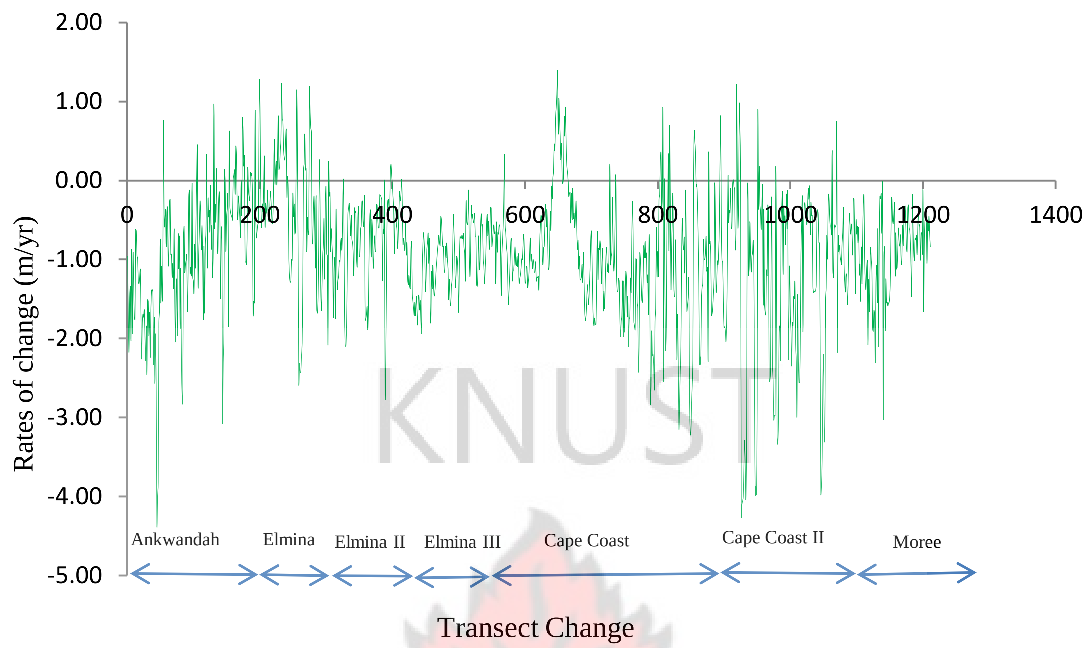

Figure 4.3 End Point Rate trends at the Elmina-Cape Coast-Moree area in the period 2005-2012.

The Elmina II segment produced the second lowest shoreline changes during this period in the study area (Table 4.3).

Within the Elmina III segment the greatest erosion occurred at the estuary beneath the Elmina Highway Bridge where there was a net loss of -20.20 m of land at an individual transect (Plate 3). End Point Rates ranged from -0.05 m/yr ±0.77 m to -2.72 m/yr ±0.77 m at specific transects (Table 4.3).

In contrast with shoreline change results that were obtained in the other epochs at the Cape Coast I segment where there were only recession, this period recorded some accretion at some areas on the beach opposite the Ola community. Net shoreline movement within this period varied from 5.06 m to -23.32 m whilst EPR also varied from 0.68 m/yr ±0.77 m to -3.14 m/yr ±0.77 m (Table 4.1).

The Cape Coast II segment experienced the greatest change in shoreline position at Amoakofua with an NSM of -31.57m and EPR of -4.25 m/yr±0.77 m. The segment also recorded a net accretion of 8.94 m and EPR of 1.20m/yr ±0.77 m at the cliff to the west of Amoakofua beach during this period (Table 4.3). Figure 4.3 shows the trends in EPR for the segment.

Table 4.3 Net shoreline movement and End Point Rates for the study area during 2005-2012.

Shoreline Segment	End Point Rate (m/yr)	Net shoreline Movement (m)
Ankwanda	-0.96	-7.15
Elmina I	-0.14	-1.04
Elmina II	-0.82	-6.11
Elmina III	-0.92	-6.82
Cape Coast I	-0.93	-6.88
Cape Coast II	-1.29	-9.56
Moree	-0.86	-6.39

Plate 3 Loss of land at the Elmina Bridge; Plate 3A is a section of the 2005 orthophotograph; Plate 3B is a section of a 2011 satellite image. Source: Department of Geography and Regional Planning, University of Cape Coast

The Moree segment also experienced an average EPR of -0.86m/yr ±0.77 m which is almost double that of the period 1974 to 2005.

4.1.4 End Point Rates Trend Comparison

A comparison of EPR averages amongst the various shoreline segments during the different epochs indicated that the 1974-2005 epoch recorded higher erosion rates in all the segments, except at the Cape Coast II and Moree segment where the 2005-2012 epoch recorded the highest trends. The 1974 to 2012 epoch recorded EPR trends which were always lower than the 1974-2005 values but higher than values recorded for 2005-2012 period (Figure 4.4).

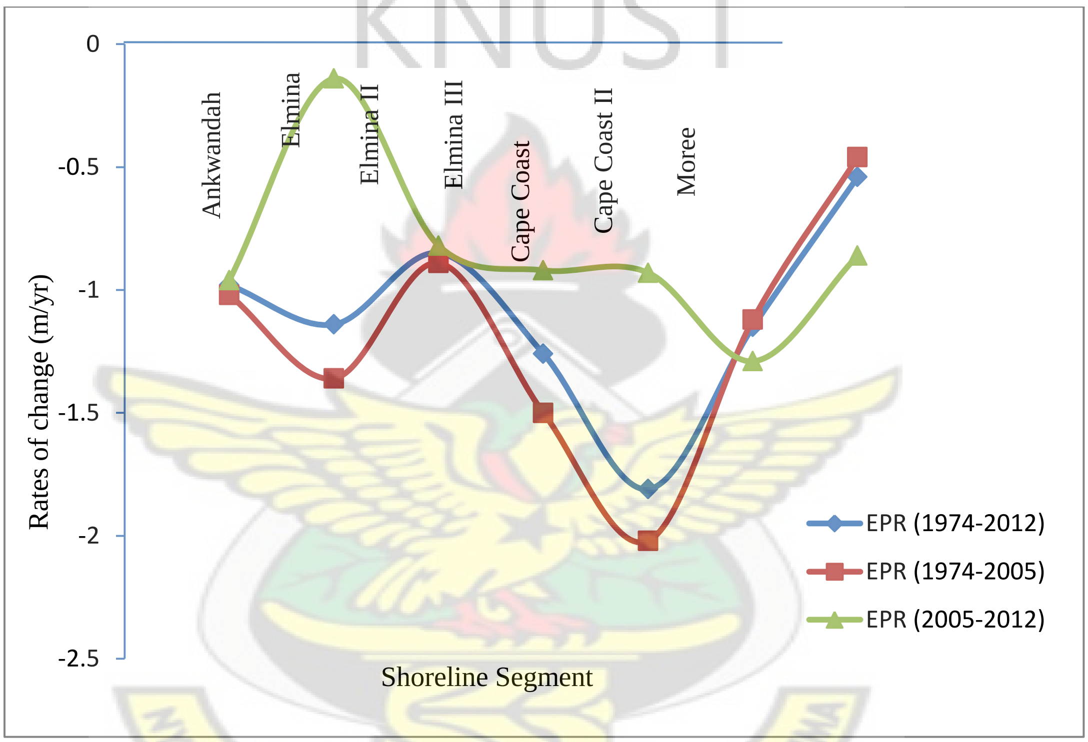

Figure 4.4 End Point Rate trend comparison amongst the three epochs used in the Elmina-Cape Coast-Moree area

4.2 Anthropogenic Causes of Coastal Erosion

The human activities identified and residents' perception of human causes of coastal erosion in the study area is presented below;

4.2.1 Coastal Land Use in the Study Area

The land use activities identified along the coastline of Elmina-Cape Coast-Moree are presented in Table 4.4.

Table 4.4 Coastal land use identified along the Elmina-Cape Coast- Moree area

Land Use Class	Identified types
Fisheries	Fishing
	Porting of canoes
	Building and repair of canoes
	Fish Processing
Coastal infrastructure	Waste disposal
Recreation and leisure	Picnicking,
	Football
	Beach front hotels
Residential	Community dwellings
Mineral extraction	Sand, pebble and rock mining
	Alluvial gold mining at Elmina
Coastal defences	Seawall
	Jetty
	Wire mesh revetment
	Sea defence (rock revetment)
	Groynes
	Seawall (revetments)

4.2.2 Perception of Coastline Changes

All 44 respondents perceived that the shoreline had moved closer to the land. According to individual respondents, there had been a coastal land loss of between 20 m to 100 m at specific areas along the Cape Coast stretch of shoreline.

Participants in the focus group discussion were also of the view that there had been a change in the shoreline position between 1974 and 2012. They estimated the loss of beach land of between 40 m to 60 m within the period at Moree. They agreed also that changes and the degradation along the shoreline became noticeable during the early 1990s when sand mining activities became popular in the area.

Forty respondents (91%) observed that sand mining takes place in their area and attributed the changes in the shoreline positions and the general degradation of the coastline in the area to this activity, whilst four respondents (9%) could not provide any reason for the changes along the shoreline.

4.3 Beach Sand Mining in the Elmina, Cape Coast and Moree Area

This section of the results presents findings of sand mining field surveys conducted during the study.

4.3.1 Beach Sand Mining Classification

Field surveys carried out during the course of the study culminated in the classification of the various types of beach sand mining activities in the area into seven groups (Table 4.5).

Table 4.5 Sand and stone mining types along the coastline of Elmina, Cape Coast and Moree

Category	Nature	Sub-category	Description
1. Beach sand mining	Commercial, in small to large scale	Tipper truck-based	This includes sand transported by tipper trucks
		Non-tipper truck-based	This includes those transported by low capacity trucks e.g. pick-ups, Kia trucks, etc.
		Manually transported	This is made up of all the forms of sand mining activities where sand is manually transported without the use of mechanized transport including the use of carts, wheelbarrows, basins, buckets, etc.
2. Beach gravel mining	Commercial, in small to large scale		Sand and pebbles are gathered from the beach or sifted from in-coming waves by using cane baskets, graded to sizes and transported by tipper trucks and other large capacity trucks
3. Coastal stone quarry	Commercial, in small to large scale		Rocks are broken off rocky and cliffed areas and crushed for the construction industry

Plate 4 Some types of coastal sand and stone mining identified in the study area. *(A) shows tipper-truck based beach sand mining activity at Amoakofua in Cape Coast*, *(B) peddles awaiting collection by trucks at Amoakofua in Cape Coast, (C) beach sand used to mould cement blocks at Bakaano in Cape Coast and (D) youths transporting beach sand in sacks using a push truck at Gegeano in Cape Coast.* Source: Fieldwork

The sand mining survey conducted on 6 beach locations in the study area produced the results presented in Table 4.6.

4.3.2 Tipper Truck-based Beach Sand Mining Estimate

The field study indicated that an average of 98 truckloads of sand (784m^3) is mined daily from beaches along the coastline of Elmina-Cape Coast-Moree. Moree recorded the highest sand lifting with a daily average of 46 truckloads or 368m^3 whilst the Elmina Bridge area recorded the lowest sand lifting of 5 truckloads or 40m^3 of sand each day. An annual lifting of 35,672 truckloads of sand or a volume of 285,376m^3 is estimated to be lifted from the Elmina-Cape Coast-Moree coastline through the field survey (Table 4.7).

Table 4.6 Estimates of volume of sand mined (m^3) along the Elmina, Cape Coast and Moree coastline based on tipper truck load.

	Moree	Amoakofua	Elmina Bridge	Akotobinsin	Mbofra Akyinim	Ankwanda	Total
Day 1	416	32	32	64	72	248	
Day 2	376	48	64	48	88	272	
Day 3	392	24	48	48	56	264	
Day 4	336	40	48	56	72	232	
Day 5	368	48	40	48	112	288	
Day 6	312	32	56	48	48	216	
Day 7	368	0	0	24	56	40	
Daily averages	368	32	40	48	72	224	784
Weekly averages	2,576	224	280	336	504	1,568	5,488
Annual Estimation	133,952	11,648	14,560	17,472	26,208	81,536	285,376

(Field study: 8th – 14th October 2012).

4.3.3 Erosion Scarp Heights in the Elmina, Cape Coast and Moree Area

Beach scarp heights along the study area indicated that Amoakofua beach had the highest average erosion scarp of 3.98 m whilst Wilson Sey School beach in Cape Coast had the lowest average erosion scarp of 0.26 m (Table 4.7).

4.4 Perception of Residents on Coastal Erosion Issues in the Elmina-Cape Coast-Moree Area

A summary of the views expressed by residents during the study are presented below:

4.4.1 Residents Knowledge and Perception of Sand Mining Activities

Responses from the questionnaire indicated that push trucks are the most frequently used medium for transporting sand from the beach (53% of respondents), with basins (30%) and tipper trucks (17%) (Figure 4.5).

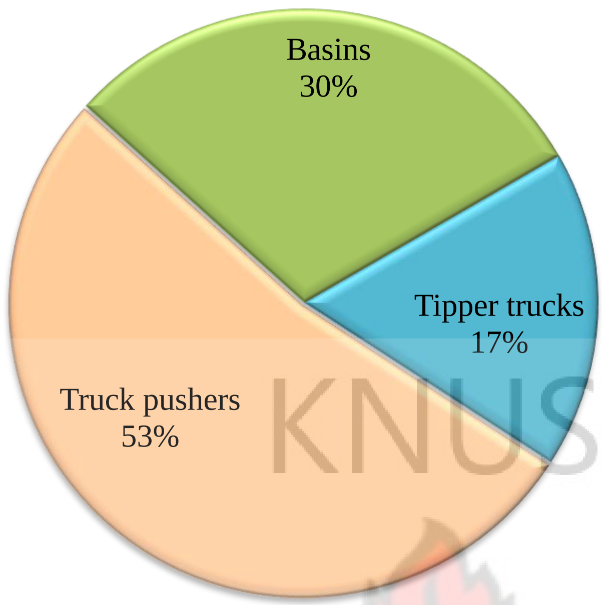

Figure 4.5 Means by which mined sand are conveyed from the beach.

Table 4.7: Average erosion scarp heights along the coast of Elmina, Cape Coast and Moree (m)

Beach	Scarp Height 1	Scarp Height 2	Scarp Height 3	Scarp Height 4	Scarp Height 5	Average Height
Moree	0.18	0	0.53	0.92	0.72	0.47
Amoakofua	3.2	4.7	4.37	3.94	3.71	3.98
Wilson Sey School	0.16	0	0.27	0.64	0.21	0.26
Bakaano	0	0.81	1.02	1.21	1.38	0.88
Ola	1.13	1.18	0.99	0.86	1.32	1.10
Mbofra Akyinim	0.88	0.93	1.47	1.67	1.24	1.24

(Field study: October 2012)

Ninety-one percent had used beach sand for various constructional activities while 9% of respondents mentioned that they had never used beach sand. Fifty-two percent of respondents had used beach sand mainly for minor renovation purposes, 38% had used beach sand to construct full structures while the remaining 10% of respondents had used beach sand for major renovations and improvements of existing buildings (Figure 4.6).

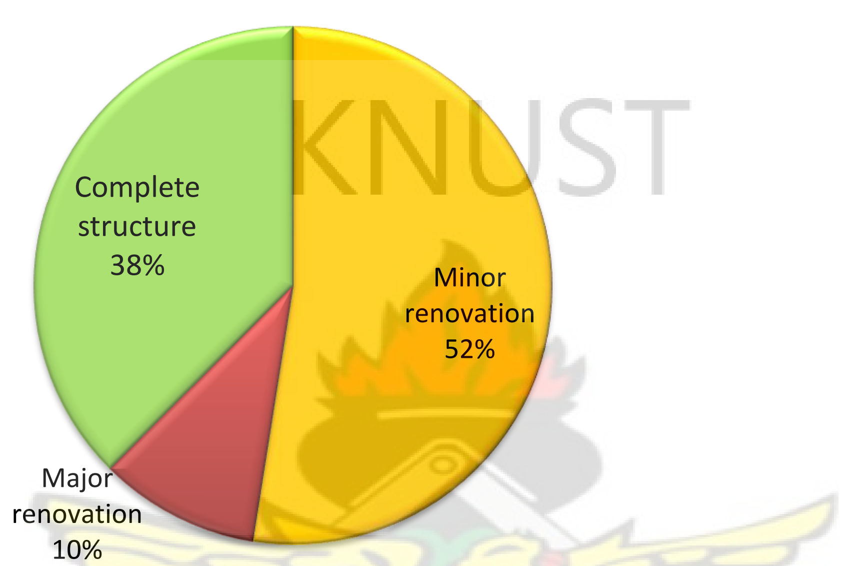

Figure 4.6 Uses to which respondents put beach sand

Plate 5: Waves affecting structures at Gegeano in Cape Coast

In the focus group discussion, participants agreed that the community members do take part in sand mining activities and also use beach sand for their constructions, renovations and other purposes. They stated that some young men within the community sometimes take contracts from people who live beyond the community to supply them with cement block. They undertake these contracts on the beach after which the blocks are transported to the owners.

4.4.2 Perception of Environmental and Social Threats Posed by Coastal Erosion

All 44 respondents to the questionnaire stated that they feel unsafe living and working along the seashore. Some respondents stated that they had lost some properties including sheds and homes situated along the shoreline to the sea. Others also stated that their buildings had caved in or fallen over due to a vertical change in the shoreline.

During the questionnaire administration, some fishermen stated that they found it difficult launching their canoes onto the sea and to land their canoes after going to sea, since there were rocky exposures on the beach face in some areas. These fears were also reiterated by the participants of the focus group discussion who were in agreement that exposed rocks at fishing landing beaches had made their fishing trade difficult and scary.

Plate 6: Beach face rock exposure at Moree

The manager of Elmina Bay Resort stated that since 2008 they had constructed 4 sea defence structures, all of which had been ineffective against the waves since parts of the main facility was still battered by the waves during high tides and storms (Plate 7) and at the time of the interview were constructing the fifth sea defence wall. He estimated that they had spent over GH 200,000 cedis (US$100,000) on these sea defence projects. He mentioned that his business had stalled as a result of these ventures he had had to undertake to protect his facility.

Plate 7 Remnants of various sea defence structures put up to protect the Elmina Bay Resort against sea waves. Source: Fieldwork: June 8, 2012.

According to the Hotel manager; his observations indicated that sand lifting at Mbofra Akyinim and Ankwanda increased from the 20-30 trucks a day to about 40-50 trucks a day in 2010, a situation he described as traumatic to the beach front environment which eventually led to an escalation in beach erosion and the consequent collapse of sea defence infrastructures (Plate 7).

Plate 8 Hollow beach left by sand miners at Mbofra Akyinim after night lifting.

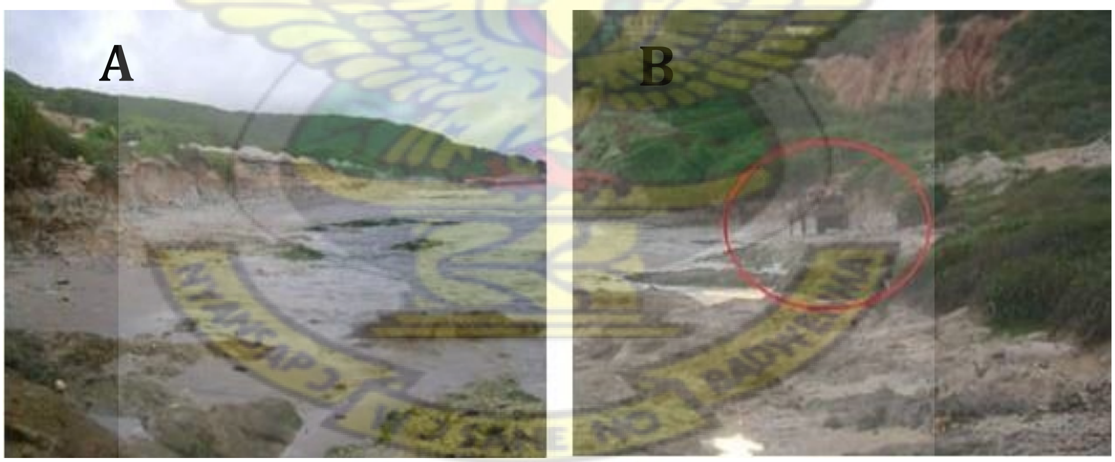

Plate 9 Beach degradation and sand mining at Amoakofua beach. Plate A shows rocky exposure at the beach. Plate B shows a tipper truck lifting sand at the area showed in Plate A (B taken 4 hours after A was taken). Source: Fieldwork November 3, 2010.

About 95% of respondents mentioned that they had observed some environmental degradation along the beaches in their area, whilst only about 5% had not observed any change to the beach environment (Figure 4.7).

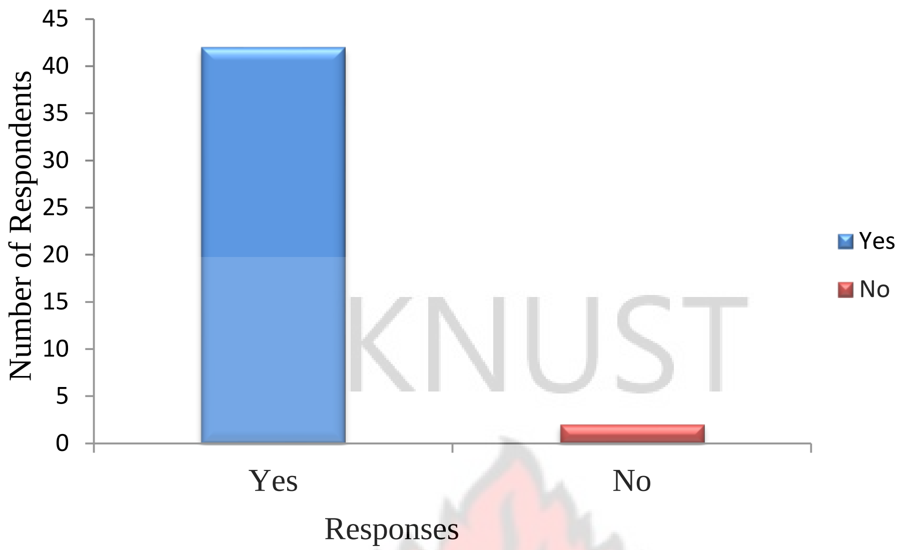

Figure 4.7 Have respondents noticed any environmental degradation at the beach that they can attribute to sand mining?

4.4.3 Monetary Benefit of Beach Sand Mining

About 36% of respondents mentioned that they were aware of some monetary benefits that had been gained by some individuals within the community, but these benefits did not flow to the entire community. Some respondents mentioned assembly members and some local chiefs as being direct beneficiaries of the beach sand mining activities. However, 32% of respondents had no idea of these benefits, whilst the remaining 32% mentioned that they had heard rumours circulating within the community about some benefits of the activity especially to certain individuals but they could not verify them (Figure 4.8).

The focus group participants were of the view that no benefit had ever come directly to the community from the sand mining activities, but rather to some key individuals in the community. The participants mentioned the names of some young men who they knew were actively involved in the activity, but mentioned that they were unaware of any traditional leader or community elder who was involved in these activities.

Plate 10: Evolution of physical changes at a section of Amoakofua beach in Cape Coast. *A: January, 2008 photograph showing erosion scarp and early signs of underground rock exposure. B: November 2010 photograph showing exposed upper layers of underground rocks at the beach. C and D: April and November 2012 photographs showing pronounced rock exposures and strong waves hitting the backshore (erosion scarp).* Source: Fieldwork.

Personal interviews conducted by the researcher with some sand miners indicated that sand contractors pay between GH5 cedis to GH15 cedis to sand scoopers per each trip of sand lifted at the beach (scoopers usually number from two to eight). Sand contractors in turn sell each truck of sand at a price ranging from GH100 cedis to GH200 cedis.

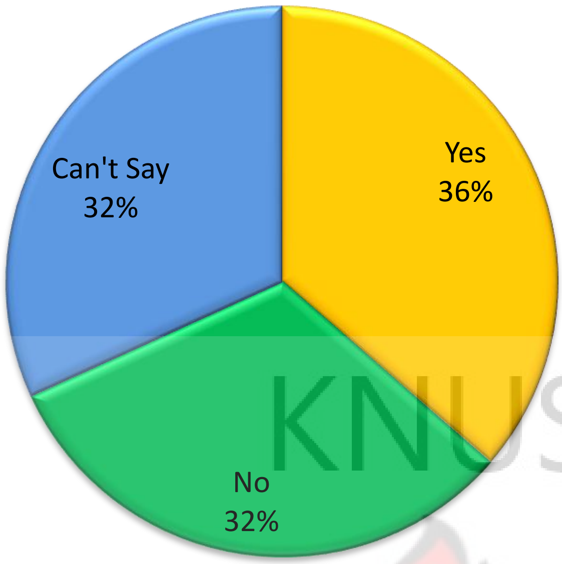

Figure 4.8 Respondents views on the monetary benefits from beach sand mining

4.4.4 Initiatives to Curb Beach Sand Mining

About 68% of respondents mentioned that they had taken part in some form of action aimed at putting a stop to sand mining activities along their community beaches. Some of these actions they had taken included:

- Physically chasing sand miners from the beach
- Marching to and voicing their displeasure to the local chiefs and assembly members about the need to take action on the activity
- Persuading young people to find alternative livelihoods.

On the part of the participants of the focus group discussion, they all agreed that there had been several mechanisms, bye-laws, bans and other actions that had been put in place to curb beach sand mining especially those done on commercial basis, *yet all* of these had failed to yield results. All participants agreed that this was due to lack of enforcement.

4.5 Coastal Resources Management Issues in the Elmina, Cape Coast and Moree Area

The following were summarized from the documents obtained from the relevant state institutions:

- The Environmental Protection Agency (EPA) is the lead government organization responsible for managing the coastal environment with the support of the Ghana Police Service who provides security and also arrest offenders. The District, Municipal or Metropolitan Assemblies are the lead sectors organizations in environmental management at the local level.
- The EPA identified that institutional capacity and legal framework for integrated coastal zone management in the Central region was poor with the action plans in the 1991 National Environmental Policy hardly implemented in the area. They also identified that district bye-laws on coastal zone management in the area were either ineffective or outmoded.
- The EPA, the Ghana Police Service and the Cape Coast Metropolitan Assembly (CCMA) are aware of the beach sand mining activities in the Elmina, Cape Coast and Moree area; with the CCMA being aware of all the beach sand mining sites under their jurisdiction.

CHAPTER FIVE

DISCUSSION

5.1 Coastline Changes in Elmina-Cape Coast-Moree

The natural tendency of a coastline is to change shape constantly in response to changing weather patterns, waves, tides and sand supply. The coastline of Elmina-Cape Coast-Moree has a series of different coast types and morphology which respond to these factors uniquely. This study identified that the entire coastline of Elmina-Cape Coast-Moree had exhibited erosion trends in the period 1974-2012, in agreement with earlier studies, such as Dei (1972) and Nail *et al.* (1993) that suggested that the entire coastline of Ghana was eroding.

This study found that the average medium-term coastline erosion rate for Elmina-Cape Coast-Moree, based on 1974-2012 data is -1.22m/yr ±0.16m similar to the average long-term coastline rate of erosion of -1.13 m/yr ±0.17m found for the Accra coastline by Appeaning Addo (2009). This similarity in erosion rates in these two areas could possibly be due to these two areas experiencing similar wave and tidal conditions as well as similar pressures from anthropogenic activities. Land uses such as beach sand mining, sea defense wall construction and touristic activities were identified by Oteng-Ababio *et al.* (2011) for the Accra coastline as were identified along the Elmina-Cape Coast-Moree coastline during this study.

Factors that control coastal erosion include shape and location of the beach (Alonso *et al.*, 2002; Oteng-Ababio *et al.*, 2011), relative sea-level change, wave energy, sediment supply (Pilkey and Thieler, 1992; Alonso *et al.*, 2002) and net longshore drift. Boateng (2006a) reported that the net longshore drift for the Elmina-Cape Coast-Moree coastline is from west to east. These could explain why though the entire coastline length of Elmina-Cape Coast-Moree is continuous and under similar conditions of influence, the medium-term (1974-2012) coastline change extent is greatest at the Cape Coast I segment (Tables 4.1-2 and Figure 4.4) which has a straighter configuration and most likely facilitates alongshore sediments movement out of the segment in the easterly direction. Erosion in the Cape Coast I segment may have also been compounded by its continuous stretch of sandy beaches, compared to the other segments which have both sandy and rocky beaches in various alternating lengths. Sandy beaches are less compact and easily influenced by currents, tides and waves. Hence, it is probably easier for sediments to have moved about and outside of the Cape Coast I segment under these influences as compared with the other segments where rocky or cliffed areas could resist these similar natural influences and also reduce the flow of sediments out of the segment.

The Elmina I segment had an average recession rate of -1.14m/yr±0.16m in the same medium-term period, even though it is also predominantly made up of sandy beaches. The lower erosion rate in this segment could be attributed to several factors. Firstly, the characteristic dome orientation of that coastline possibly protects the area from the longshore currents hindering sediment loss the segment. Coupled with the jetty built to protect the Elmina fishing harbour on the Benya lagoon, sediments are likely trapped and re-circulated within the segment. Also the Elmina I segment has a stretch with a seawall towards the eastern end that most likely protects the segment from further land retreat. Moreover, it is likely that since the Elmina I segment is adjacent to the Elmina II segment which is composed of rocky shores, the former likely benefits from the latter protecting it from the full impacts of longshore currents and sediments transport.

The other coastline segments experienced comparatively lower coastline changes and rates probably because of their composition. The Moree coastline segment, which has the longest rocky and cliffed coast stretch, experienced the lowest changes in the in both medium-term periods. The rocky and cliffed portions of Ankwanda, Elmina II, Elmina III, Cape Coast II and Moree segments may have protected the segments from the full force of the waves and rip currents while also trapping sediments for recirculation within each segment. The average erosion values obtained in these coastline segments were likely due to the sandy portions of these segments producing consistently higher trends even though rocky or cliffed areas produced consistently lower rates. The higher erosion rates at these sandy areas could largely be attributed to the anthropogenic activities that are undertaken in those areas.

The characteristic objective of a cliff and a rocky coast to protect coasts from the sea waves and currents were also observed in the shoreline change analysis results, where these areas produced lower coastline change extents. These were observed at Cape Coast II and Moree segments for both medium-term periods (Sections 4.1.1 and 4.1.2) where cliffed areas produced consistently lower coastline changes. In short, results indicated that medium-term coastline changes were lower in rocky or cliffed areas compared to higher trends at sandy beaches. These trends agree with Carter (1991) observation that sediments are constantly exchanged with adjacent environments as energy conditions fluctuate on sandy beaches. Thus, sandy beaches easily become eroded through natural forces, whereas rocky or cliffed coasts resist these same natural forces.

Results indicated that the average medium-term coastline change rates (1974-2012 and 1974-2005) were higher than the short-term (2005-2012) coastline change rate in all the coastline segments except at the Cape Coast II and Moree segments where the short-term rates were higher (Figure 4.4). This is however, not indicative of a stabilizing coastline, but rather that the study area may be eroding in different ways.

A critical study of the 2005 orthophotograph used in the analysis showed that by 2005, most parts of the study area's coastline had the 'shoreline' very close to the base of the erosion scarps or vegetation line on sandy beaches, whilst waves broke on rocky exposures on the coastlines or at the base of cliffs. This therefore could explain the lowered rates of coastline changes in the period 2005 - 2012. In the Cape Coast II and Moree coastlines where the change rates were higher in the short-term, there were areas with wider sandy beaches in 2005 which had eroded by 2012 due to factors which are clearly not natural.

The current trend of short-term coastline changes at most locations in the study area relates more to vertical beach scarp changes and lowering of beaches with a reduced rate of land recession. Waves now break at the base of erosion scarps or vegetation line at almost all the sandy beaches along the entire stretch, wearing away the base of the scarp before it falls over. Residents in the Cape Coast I area observed that in previous decades the area possessed wide gentle sloping beaches, however these have now evolved into a narrow and steep reflective beach. Other areas such as Moree and Ankwanda still have areas with gentle sloping beaches but are generally under threat of change.

5.2 Anthropogenic Causes of Coastal Erosion

The natural factors that may be in play along the coastline of Elmina-Cape Coast-Moree may include sea level rise and the actions of waves, alongshore currents, rip currents, undertow and overwash; since all these affects all coastlines the world over. These factors usually combine to cause a short-term loss or gain in beach sand volume (Özhan, 2002), which is a normal occurrence of any beach that is in equilibrium with it environment.

Though world sea level has been known to be rising slowly for at least the last 150 years (Carter, 1991; Cai *et al.*, 2009) and consequently causing coastline recession (Ghana's EPA, 2000; Pfeffer *et al.*, 2008; Vaughan, 2008), a rapidly receding coastline may primarily be due to an aggravation of the natural factors through human interference as was noted by Wong (2003). Hence, the recorded coastline recession and coastal deterioration recorded and observed along the Elmina, Cape Coast and Moree area may very well be explained by the several identified coastal land uses (Table 4.4).

According to Defeo *et al.* (2009) intense coastal development, which is the inevitable consequence of economic development has resulted in widespread modification of sandy beach ecosystems. Thus, many governments, organizations and individuals fail to adhere to environmental regulations, especially those that relate to the coastal zone. Unconstrained, beaches are resilient, changing shape and extent naturally in response to storms and variations in wave climate and currents (Schlacher & Thompson, 2007), however, anthropogenic activities tend to attempt to control these natural processes which rather intensifies the destruction of the coastal environment. Regardless of the cause of coastal erosion, its intensity and development depend to a high degree on the equilibrium state of coastal dynamics and beach stability (Cai *et al.*, 2009), thus, with regards to the sediment budget of the coast.

According to Esteves *et al.* (2000) human activities, such as urbanization in the active dune areas, shore armouring, sand mining, and construction of jetties have impacted negatively on the Brazilian coastline. Since these coastal land uses activities were identified in the Elmina-Cape Coast-Moree area, it is reasonable to relate them to the coastal land recession and degradation in the area. According to Esteves *et al.* (2002)

these anthropogenic activities might affect local sand balance in a way that intensifies natural shoreline changes.

It is understandable that when sediments input exceed sediments output, beaches will accrete or widen. However, Carter and Stone (1989) observed that when there is a negative budget, a dissected dune system characterised by erosional landforms (blowouts, deflation hollows and plains, reactivation dunes, scarping) may be formed. Since the shoreline change analysis showed a general erosional trend in the study area and also because several erosional landforms such as scarps and deflation hollows were identified in the study area, it could most likely mean that there is a negative sediment budget in the study area and thus agreeing with the observation of Carter and Stone (1989). Hence, the identified coastal land uses in the study area (Section 4.2.1) that interfere with the natural sediment budget could most likely be the anthropogenic factors that are responsible for coastal erosion in the study area. This assertion is confirmed by Thieler *et al.* (2001) who noted that human interference with shoreline sediment sources and transport patterns can significantly impact the trend of shoreline movement.

Rivers are important sources of sediments inputs to the coastal zone (Pilkey *et al.*, 2004; Sanjaume & Pardo-Pascual, 2005; Boateng, 2006a). In the Elmina, Cape Coast and Moree area several rivers, streams and lagoons have had their course altered or have been tampered with, leading to extinction of some, while others supply very little water and thereby sediment to the coastal zone. These can be observed at Elmina, Amoakofua, Ekon and Moree. According to Cai *et al.* (2009) river diversion or decrease in sediment discharge may lead to long-term erosion, which is usually not clearly visible since its effects are gradual.

At Elmina several rivers meet at the Benya lagoon before discharging into the sea near the Elmina Castle. The mouth of the lagoon used to be an estuary that has been developed, by dredging and by the construction of a jetty, to the current state which is slow moving. The dredging expanded the volume of the lagoon which also allows for easy movement of boats on the lagoon. However, this activity prevented the natural movement of inland sediments to the coast, disrupting the natural coastal dynamics of the area. Combined with the construction of the jetty, the entire coastal dynamics of that area has been affected thereby causing coastal erosion and the observed decline in coastline quality.

Several other riverine sediment sources have also been affected due to urbanization and the expansion of social infrastructure in the study area. At Amoakofua, a stream that discharged into the sea has also shrunk to extinction due to the expansion of a road network through the community to the beach. At Ekon, streams that feed the lagoon have mostly dried up due to an increase in constructions upstream and has blocked the path of the water or been abstracted for usage. Several lagoons in the study area including the Fosu lagoon, Ekon lagoon and the lagoon at Moree are naturally cut off from discharging into the sea almost all year round by a barrier of sand. It is usually in June; during the peak of the wet season that due to storms and wave actions the lagoons become linked with the sea. During these events these lagoons discharge different kinds of materials into the coastal environments including nutrients, sediments and waste materials, some of which are essential to the coastal zone. This event emphasizes the importance of the interaction of a coast with the adjacent environments including riverine systems that provide the essential basis of a stable coastline, through the regular exchange of nutrients and minerals (Carter, 1991).

The importance of riverine sediment supply to the coast is much more conspicuous on the eastern coast of Ghana, where the erosional issues have been associated to the hydroelectric dam that was constructed on the Volta River in 1964 by several authors including Ly (1980) and Boateng (2006a). The dam obstructed the flow of the river leading to new dynamic environments and low sediment inputs into estuaries and deltas that eventually drove severe coastal erosion in the area. These conditions typify the Keta and Ada coastline of Ghana which has led to the sea defence projects in those areas. Though the rivers in the Elmina-Cape Coast-Moree area are not as large as the Volta River, their importance to the sediment budget of the area's coastal zone cannot be underestimated.

It is normal for people to attempt to defend their lives and investments when these become threatened by external forces. Such is the case along coastlines the world over, since communities and property owners usually use some form of coastal erosion mitigation measure to attempt to protect their community or investment from being washed away by the sea (Sections 2.20-2.22). In the case of the Elmina-Cape Coast-Moree area, several sea defence mechanisms have been used in the past to protect various sections of the coastline albeit with varying degrees of successes. Because shoreline retreat brings beaches into conflict with human infrastructure, the mere threat of coastal erosion is enough to elicit a management response (Schlacher & Thompson, 2007).

In large communities that become threatened by sea waves, there exists a political pressure on the government to put up sea defences as a management tool to protect these areas, such communities include Keta, Nkotompo and now the 60 million Euro Ada sea defence project. Beach front facility owners also tend to construct smaller sea defences around their facility with the aim of protecting their investment from the sea's destructive force. Several forms of coastal mitigation measures exist; however, the use of hard structures such as seawalls, groynes and breakwaters are the most commonly used (Wong, 2003). Some of these hard engineering methods of sea defence have been constructed at different sections of the Elmina-Cape Coast-Moree coastline by either facility owners or the central government to protect these areas.

According to Morton *et al.* (2004) attempts to stabilize the shore can also greatly influence the rates of shoreline change, since hard engineering methods resist the natural evolution of the coastline (Lees & Duncan, 1997), alter coastal processes, sediment transport and shoreline position. In most cases, hard structures initially protect the facility or the area it is intended to protect (Carter, 1991), but eventually the quality of the structure deteriorates and fails to serve it purpose. Since, the coastline is retreating generally, when it catches up with the wall, the slope of the beach steepens in front of the wall. This happens because the seawall which is a rigid structure does not allow the beach to take up sand stored on the beach berm, as is the natural storm response of a beach. The beach therefore is unable to dissipate the force of the incoming waves and eventually the wall falls over. This most likely explains why four sea defence structures have failed to serve it purpose at the Elmina Bay Resort and collapsed sometimes a couple of weeks after construction. Thieler *et al.*, (2001) noted that the most important causes of human-induced erosion are the interruption of sediment sources (e.g. armoring of coastal banks) and the interference with alongshore sediment transport (e.g. groynes).

In the opinion of Sanjaume and Pardo-Pascual (2005) traditional sea defence works have a high rate of failure due to a lack of understanding of the physical processes occurring at the site and within the regional context. Also, according to Thomalla & Vincent (2004) traditionally, engineers have always been more concerned with the stability of the structures rather than their effects on the shoreline morphology. Nordstrom (2000) was also of a similar opinion, he stated that part of the failure of hard structures has been the preoccupation with their discrete function and design without sufficiently considering their wider geomorphological, ecological and even recreational values. The above assertions could possibly be true, since during the interview with the Elmina Bay Resort Manager, he stated that upon observing the threat of the sea on his facility he consulted engineers who advised him on engineering approaches to adopt with the assurance that those methods would be appropriate in protecting his facility in the long-term. Eventually, these structures including rip raps, gabions, rock revetment and a concrete seawall all collapsed. These occurred because the issue was not really about protecting the facility from the sea but rather that the facility had interfered with the dynamics of the coast in that area.

According to Boateng (2006b), these engineering measures are simply ad-hoc measures that tend to stabilize the shoreline at the protected section in the short-term and aggravate the problem elsewhere along the coastline as a result of knock-on effects. This observation has also been confirmed by earlier studies including studies by the Ghana EPA (1991). Garrison (2007) also observed that on the New Jersey coast in the United States of America, seawalls placed on beaches, initially to keep them from being taken by the sea, have actually expedited the erosion process, often causing waves to hit the shore where not protected by a sea wall, with more energy after bouncing off the rigid structure. Garrison (2007)'s observation could very well be the reason for the loss of land around the Elmina highway bridge in the Elmina III segment of the study area (Plate 3), since this area is just adjacent a seawall.

Other sea defence measures such as groynes and jetties also interfere with the sediment budget of the coastal area they are built. Jetties and groynes are aimed at trapping sediments that are being transported by alongshore drift, with jetties having the specific purpose of protecting inlets such as the Elmina fishing harbour. In a documentary titled "the beaches are moving", Pilkey and Sheehan (1990) observed that in addition to trapping sand on the upstream side, long jetties actually channel sand so far offshore that it is lost to the beach system; causing a dramatic erosion downstream. This observation by Pilkey and Sheehan (1990) may very well explain the coastal erosion pattern downstream of the Elmina fishing harbour. Sanjaume and Pardo-Pascual (2007) noted that the littoral transport and dune system is an important factor in maintaining the sedimentary equilibrium of beaches; if these are modified or completely stopped the created imbalance will lead to increased beach erosion. According to the Ghana Environmental Protection Agency (1991) the success of protection works along the coast has been limited, and therefore engineering options cannot provide long-term solutions to coastal erosion. Their observations indicated that the longshore drift mechanism was such that action in one section of the coast may trigger erosion in adjoining sections.

Allen (2009) concluded that through experimental models and natural examples, it is apparent that man-made structures to prevent the complete erosion of coasts and beaches are not as beneficial as once thought and that the implementation of rigid structures such as seawalls only serves to worsen the destruction over time by exposing underlying rock.

5.3 Beach Sand Mining in the Elmina-Cape Coast- Moree Area

Presently about 285,376m^3 of beach sand is mined annually by commercial sand miners who only use tipper trucks for their operations in Cape Coast. This value may have been higher in previous years, since earlier surveys (from November 2010 to May 2011) conducted at two of the sites surveyed for this study, Amoakofua and Mbofra Akyinim recorded higher lifting. Average at Amoakofua during that period was 48 truck/day or 384m^3/day whilst a 4 hour survey of the Mbofra Akyinim in February 2011 recorded 22 truck lifting or about 176m^3 of sand lifted from that area. A hotel manager in the area also indicated that between 2008 and 2011, sand mining activity at both Mbofra Akyinim and Ankwanda exceeded 50 trucks/day respectively. The current reduction in the level of the activity at Mbofra Akyinim and Ankwanda may possibly be attributed to an operation led by the National Security Council in November 2011 boulders were placed on the path used by sand miners to prevent them from gaining access to the beaches. This action most likely explains why sand miners in those two areas now prefer to undertake their activities at night. Others may have also resorted to undertaking their activities at other locations. Moreover, several of the preffered sand mining beaches such as Amoakofua has developed high erosion scarps and exposed underlying rocks making it difficult for most trucks to access the beach leading to the low recorded mining outputs during the survey.

Furthermore, since the survey was conducted during the minor rainy season, there may be variations in sand mining activities recorded in other periods of the year since sand mining activities are driven by demand by the construction industry; hence a higher demand during the dry season when construction activities are at their peak and a lower demand during the major rainy season when construction activities are reduced.

The projected annual sand lifting volume of 285,376m^3 obtained in this study is just a fraction of the total volume of sand that is mined from the Cape Coast area. The other identified six types of sand mining activities account for the rest of the volume of sand lost to the littoral zone due to sand mining.

According to Mensah (1997) the construction sector in the coastal areas of Ghana relies heavily on coastal sand and pebbles in the building of houses, bridges and roads. Mensah (1997) also noted that the contribution of sand mining to Ghana's industrial output increased from 17.4% in 1986 to 20.8% in 1993 giving impetus to contractors to undertake these activities along the coasts and emphasizing the intensity of the activity and its importance to the coastal economy. Clearly, the level of the practice of coastal sand and mining may be the single most important coastal erosion factor along the coastline of Elmina, Cape Coast and Moree. Mensah (1997) observed that this activity eventually accelerated the degradation of the coastal environment at alarming rates in many areas across the country's coastline. Boateng (2006a) concluded that the widespread unregulated practice of beach sand mining or "winning" for building purposes is one of the reasons that have led to starvation of beach sediments and consequent retreat of Ghana's coastline.

According to Biney *et al.* (1993) the coastal erosion problems in the Accra Metropolitan Area with rates exceeding 2m/yr in areas such as Labadi was caused by the removal of sand and pebbles from beaches for construction purposes. Oteng-Ababio *et al.* (2011) also noted that sand mining activities have also reduced the sediment supply to the littoral zone and has resulted in an imbalance in the sediment budget in the Faana coastline of Accra. Sand mining removes sand directly from the coastal system and thus directly affecting the sediment budget of the area. Unlike the other types of sediment outputs (Figure 2.2), sand mining does not make sand available to the coastal system by storing it in other areas or forms. Since, the coastal area is a dynamic system that needs to maintain a sedimentary equilibrium; it usually uses actions such as longshore drift, waves, tides and other sediment input mechanisms to offset the affected area. The success of the coast balancing itself out naturally and returning to equilibrium may depend largely on the intensity of the sand mining activities and the magnitude of sediments input. According to Pilkey *et al.* (2004) sand mining activities take the form of a truck load here, a wagon load there, and even wheelbarrow loads of sand which, when totaled can amount to a large loss of sand to the beaches.

Along the Elmina-Cape Coast-Moree coastline sand mining takes place in various forms with varying intensity. As much as 91% of coastal residents in the study area have used coastal sand and stones for their personal construction (Section 4.4.1), with large scale commercial sand mining activities taking a projected volume of 285,376m^3 of sand annually from the area. If the natural inputs are unable to balance this loss of sand from the area, coastal erosion will occur (Carter, 1991). By sheer magnitude and intensity, sand mining activities undoubtedly is the major cause of the recorded coastal erosion and the observed coastline degradation in the area.

The pronounced beach scarp that is characteristic of almost all the sandy beaches in the study area possibly has a direct relation to sand mining activities, since notable sand mining sites recorded high erosion scarp height values (Table 4.8). Prior to the commencement of this study, the author's observations indicated that sand mining activities in the Elmina-Cape Coast-Moree area was highest at Amoakofua beach in Cape Coast, with over 50 trucks visiting the beach on a daily basis, resulting in the formation of very steep beach scarps in the area while exposing underlying rocks. The shoreline change analysis also indicated that the Amoakofua beach experienced the highest beach erosion in the study area in the period 2005-2012, a phenomenon which is clearly due to the level of beach sand mining that has gone on in the area within that period. The Wilson Sey School beach where no sand mining activity was observed recorded the lowest erosion scarp height values in the study area, confirming the theory that sand mining activities has a direct relation on the formation of beach scarps. This assertion is confirmed by Mensah (1997), who observed that the sandy beaches that existed in the eastern coast of the Ahanta West District of the Western Region had degraded into denuded beaches sitting about 2.5m below an "artificial" cliff as a result of beach sand mining.

Sand mining activities, especially the commercial types (Table 4.5), create large hollows on the beach (Plate 4.7). Eventually, the beach is lowered allowing higher energy waves to reach the backshore to interact with the vegetation line. The vegetation line usually has plants which trap or hold sediments and initially resist the waves. However, prolonged exposure to high energy waves gradually wears the sediments from under the vegetation, in order to balance out other areas of the coastal system and also the beginning of the formation of the erosion scarp. The lack of sediment to support the vegetation causes them to hang for sometime before falling over eventually. Thus, the continual action of the sea waves shapes the coastline by the formation of the beach scarps.

Rock exposures along the coastline of the study area can also be related to sand mining activities interfering with the sediment budget of the coast. In some parts of the Western Region of Ghana Mensah (1997) observed that beach sand mining had led to exposure of rocks which pose danger to landing canoes and had also reduced the scenic beauty of the beach which used to attract visitors and tourists. Such rock exposures were also identified in parts of the Elmina-Cape Coast-Moree coastline. Pronounced rock exposures were identified at Moree, Amoakofua and Amanful, where sand and pebble mining are prevalent.

The high coastal erosion trends experienced at the easternmost end of the Ankwanda coastline segment especially around the Elmina Bay Resort could have been exacerbated by the intense sand mining activities in the area. Due to knock-on effects the effects of the sand mining activities could have been transmitted to the area around the hotel. Also, due to longshore currents (west to east), sediments could have been rapidly transported from in front of the Resort towards Mbofra Akyinim to balance the sand that were usually lifted in the area. These reasons combined with the seawalls that were eventually constructed to protect the facility, could have acted together to accelerate coastal erosion in the area.

Most residents in the study area believe that sand mining is the major cause of the coastal erosion and beach degradation, with as many as 91% of interviewed residents identifying beach sand mining as the sole cause of coastal erosion. Though the activity is illegal, its widespread nature and intensity can only be due to the responsible agencies not adequately performing their tasks. A personal discussion with a programmes officer of the EPA indicated that they are aware of these activities in the study area but due to lack of institutional capacity and lack of support from the Ghana Police Service, they had been unable to sustain their efforts to curtail this activity.

Mensah (1997) argues that coastal sand needs to be exploited to satisfy human demands but this requires efficient and effective resource management to ensure sustainable development. Sustainable development calls for the use of resources in a manner that will benefit the present generation as well as posterity without negatively affecting the environment. Hence, without an appropriate management approach these resources should not be exploited.

Beach sand mining as a trade accrues a significant amount of resources for those involved. Coastal sand is considered by contractors as premium quality, especially for building constructions due it cohesiveness and other properties. From the annual sand lifting projections, an estimated GH 7,134,400 Cedis or about 3.5 million dollars is accrued from only tipper-truck based sand mining in the Elmina-Cape Coast-Moree area. The other types of beach sand mining may also produce significant revenues in the study area, thus, making the venture very lucrative for those involved. The revenue obtained from this activity may very well be the most important motivating factor for sand miners in persisting in the activity.

Due to the illegality of the practice and the clandestine nature under which the activity is undertaken, the central government is unable to collect her share of the revenue especially by way of taxes. Moreover, residents in the study area have no knowledge of any direct benefit of beach sand mining to the study area by way of social improvement or infrastructure thus questioning why the venture should be allowed since the repercussions is usually borne by all.

Some argue that sand mining is a venture that creates jobs for youth in the community such as those who undertake the scooping and loading of the sand into the trucks. This may be true, albeit temporarily, until the area becomes degraded and the sand contractors move to other locations. Individuals in the community who obtain the most direct benefit from the activities are perceived to be key influential people in the community. The allegation made by the Hotel Manager that the local Chief may be involved in allowing the sand miners in the area may be true, since a Programmes Officer of the EPA mentioned during a personal interaction that certain traditional leaders had been trying to force them to provide permits for sand miners at Ankwanda. A Daily Graphic report of 10 November 2011 also made mention of claims by sand miners at Ankwanda that they had the support of leaders of the Elmina Traditional Council to undertake the beach sand mining venture in the area.

The arguments of Mensah (1997) that it is quite futile for governments to spend huge sums of monies to protect the interest of coastal communities while allowing sand mining activities to still persist seems logical here. The only plausible outcome of beach sand mining is coastal erosion and degradation, which leaves low lying communities vulnerable to coastal flooding (Boateng 2006a). The level at which the Hotel Manager has pursued the sand mining issue in the area and the apparent lack of interest from authorities both local and national suggests some high level complicity in the activity. It does not make economic sense for the government to spend huge sums of money to build sea defences, such as the 60 million Euros Ada sea defence project, and not be interested in removing the human factors that brings the need to build sea defences in the first place.

The Elmina-Cape Coast-Moree areas are well noted among the best tourist destinations in the country, possessing several historical monuments such as castles and forts within eyesight of the coasts. With this knowledge many investors have put up hotels and tourist facilities within a walking distance of the coast. An unsightly and degraded coastline does not auger well for the tourism business which creates a lot of jobs for locals as well as boost the local economies. It is important to note that many tourists and holidaymakers go to the coasts to enjoy the sea breeze and the supposed scenic environment that the area naturally possesses. Currently these intrinsic values of the coastline are on the verge of being lost, a situation that would create problems for the local economy. Mensah (1997) observed that in the workings of the sand miners, they create paths and steps onto the beach by carving through cliffs to enable them carry their products which has reduced the scenic beauty of the beach which used to attract visitors and tourists.

The security of these beach front facilities in the area may yet not be known. Regardless whether facilities were built too close to the sea or that the sea is advancing at much faster rates, it points out to the fact that coastal management in Ghana has been grossly inadequate. Almost all the tourist facilities in the study area, including hotels and restaurants, have some form of coastal defence constructed in front of it. Most of the measures have failed and only worsened the plight of facility owners whilst becoming a financial burden.

The cost to other sectors such as the local fishery may also be enormous. An eventual outcome of beach sand mining and coastal erosion is the exposure of beachrocks (Cooper 1991; Wong, 2003). Mensah (1997) noted that the activities of sand miners had led to exposure of rocks which pose a danger to landing canoes. Several beaches along the Elmina-Cape Coast-Moree area have developed rock exposures and have caused a loss of vital landing and fishing sites. A major fear expressed by many fishermen during the study had to do with these rock exposures both on beaches and in certain shallow areas of the sea, which poses a grave threat to canoes and nets, which easily get caught up and damaged. A decline or the loss of the fishery sector may cause a series of social problems since a large number of people depend on the sector for their livelihood.

Mensah (1997) argues that policy makers and the local people have the enormous task of protecting the environment, which requires intersectoral co-operation and community participation in management of the coastal environment. Result from this study suggests that some residents in Elmina-Cape Coast Moree are prepared to support coastal management activities with some having already taken initiatives to curb the practice of beach sand mining and to draw the attention of authorities to the damage being inflicted upon the coast. However, residents without lawful authority cannot do much to stop the sand mining activity. The membership of the ad-hoc committee setup by the MCE of Cape Coast in 2011 clearly demonstrates that relevant state institutions as well as the local assemblies are aware of the activities of beach sand miners and also know the actions that need to be undertaken. The failure of these state agencies to act probably accounts for the high rate of beach sand mining activities in the study area.

Ad-hoc measures to counter sand mining activities may not suffice; since these are often not sustainable. This could easily be seen in the much publicized operation of the BNI and other state agencies to stop sand mining at Ankwanda on the 9th of November 2011. A few weeks after this operation, sand miners returned to the area to restart their work and have met with little opposition since. Similar unsustained operations and ad-hoc measures have been taken in other parts of the country. Mensah (1997) mentioned that on 5th June 1993, the Western Regional Administration organized a task force and impounded nine tipper trucks carrying sand from Funkoe beach; after that day, the tipper trucks continued their activities as usual. Mensah (1997) also noted a publication in the local newspapers in 1993 that suggested that the Ga South District Assembly had sold tickets to sand miners as a means of generating revenue and providing employment.

It is quite clear that if the issues of coastal degradation are to be appreciated and properly addressed by all, there has to be a proper coastal management policy that will hold certain institutions accountable for activities in the coastal zone.

Earlier research (McNeely and Miller, 1984; Western & Wright, 1994; McNeely *et al.*, 1994) suggested that human activities need not necessarily be incompatible with nature and that local people need to derive benefits from protected areas if they are to be expected to support conservation efforts, Mensah (1997) argued that beach sand mining need not completely be banned; instead, only local communities should be allowed to utilize sand to build houses until such time as the coast has been assessed and to have regained healthy environmental conditions. At this point, Mensah (1997) suggests that sand mining should be re-activated on commercial basis, with licences or permits given only to contractors who are able to prepare Environmental Impact Assessments (EIA) or proposals to demonstrate their competence and technological know-how with access to equipment to deal with coastal environmental damage.

This study disagrees with the argument and suggestions of Mensah (1997). It is argued here that sand, pebble and rock mining should be completely prohibited across the country's coastline as was suggested by Biney *et al.* (1993). If beach sand mining is to be made the preserve of local communities, the tendency for abuse is palpable, as was highlighted in the focus group discussion undertaken by this study. Furthermore, data on key coastal variables are limited in Ghana (Boateng, 2006a) and therefore the guarantee of a properly informed and executed EIA may not be assured. It has also been proven in earlier sections of this study that coastal sand mining degrades the coastline and hence should not be encouraged. Coastal damage control is expensive and the outcomes not easy to predict. It is injudicious and short-sighted to sacrifice the ecosystem for short-term financial and economic objectives (McNeely & Ness, 1996).

5.4 Perception Of Residents On Coastal Erosion Issues In The Elmina-Cape Coast-Moree Area

Results indicated that majority of residents in the study area have noticed the coastline retreating and coastal erosion and think it is a threat to coastal inhabitants. Most residents believe that coastal erosion in the area has been caused primarily by sand mining. However, sand miners seem unconcerned about the implications of their actions. A personal interview with several sand miners during the study indicated that most think that their actions do not affect the coastal area. They argued that the sea will ultimately bring in fresh sand to cover what they had taken. This assertion comes from the fact that the hollows they create usually become filled with sand after the next high tide causing them to believe that the sea has unlimited amount of sand in storage. It is only until the beach becomes completely damaged that the implications of their actions become clear to them.

It is often sad to observe that only after disasters do authorities in Ghana act to attempt to salvage an already uncontrollable situation, when the issue could have been curtailed by being proactive. The reason for the failure of the initiatives undertaken by residents to stop sand mining activities and thereby control the rates of coastal erosion simply has to do with the lack of support and apathy from the institutions tasked by law to undertake these actions. The ban on sand mining by local traditional leaders in Moree, the confrontational approach adopted by some residents in Cape Coast and the official appeals by the Hotel manager had always been doomed for failure without the full backing of the EPA and the Ghana Police service.

The general lack of enforcements of the environmental laws, as were identified by most residents in the study area, may be the plausible explanation why sand miners operate on the country's coastline without fear.

5.5 Coastal Resources Management Issues in the Elmina, Cape Coast and Moree Area

Since, government has the ultimate right for all coastal resources found along Ghana's coast; it is responsible for the management and protection of these areas as has been stated in various sections of the constitution.

According to Mather & Chapman (1995) resource management is concerned with the physical or biological functioning of part of the environment but also with the allocation of resource products within the framework of a particular legal and cultural setting. This means that coastal and marine space administration tries to ensure that the uses of coastal and marine resources are physically possible, economically viable, culturally acceptable and sustainable (Boateng, 2006b).

The basic objective of resource management (administration) as was identified by Mather & Chapman (1995) is to ensure that present levels of exploitation are consistent with the replacement of stocks to ensure long-term sustainability. Boateng (2006b) further argues that any management approach (Sectoral, Integrated and Collaborative management) can be adopted in the administration of coastal and marine space provided it does not conflict with the basic objectives of resource management.

Aarninkhof *et al.* (2010) observed that coastal areas are naturally dynamic zones that are vulnerable to anthropogenic interventions; hence, the increased pressure for developing these areas means that interventions need to be tuned to the natural situation and dynamics. Accelerated erosion, disappearing beaches, increased frequency of flooding, degraded ecosystems, etc, are all symptoms of an inability to provide competent coastal land management (Charlier & De Meyer, 2000). With the findings from this study, the above observations make it exceedingly obvious that the coastal management regime in Ghana, if any, has been grossly inadequate, given the global perspective of climate change and associated sea-level rise (Boateng, 2006a).

Boateng (2006a) noted that there is no holistic policy and integrated plan for the management of coastal erosion and flooding in Ghana. Boateng (2006a) reported that management remains traditional, reactive, site specific, and dominated by hard engineering approaches, which are also fraught with their peculiar problems to the environment (as has been outlined in Section 5.4). The adoption of a national coastal management policy with clearly delineated uses, rules for usage of the coastal area with assigned management responsibilities may be the most appropriate solution to the coastal problems of Ghana.

EPA (2010) suggested that the degradation of the region's coastline was a result of the ineffective management of the coastal zone due to outmoded and ineffective local level bye-laws, lack of enforcement of relevant legislature and the weak implementation of sectoral policies for the protection, development and management of coastal resources. Results from this study indicated that there is a lack of coordination between the EPA and the Ghana Police Service with regards to the management of the coastal area, with several media organizations suggesting the complicity of some Police personnel in the sand mining activity in the area. Thus, explaining why the local level (the Metropolitan and District level) management of the area has failed in the past.

A National Coastal Management Policy can establish the requisite management responses based on scientific findings at the coastal zone, thereby preventing the various ad hoc and site erosion controls adopted by property owners as well as ensure the sustainable use of the zone.

Chapter Six

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The coastal zone is known for its dynamic nature and is intensely used and populated by humans. The area is prized as a national asset as it provides a range of essential services and products. The intervention of humans in the coastal zone has a direct impact on the natural response of the zone. This study concluded that;

1. The medium-term shoreline erosion rate for the Elmina-Cape Coast-Moree area based on 1974-2012 data is 1.10m/yr ±0.16m with an average land recession of 44.61m. Medium-term coastal erosion rates in the area are in conformity with long-term coastal erosion rates along the Accra coastline according to studies conducted by Appeaning Addo (2009). Open ocean sandy beaches experienced higher coastal erosion compared to rocky or cliffed areas. In the medium-term (1974-2012 and 1974-2005) erosion were generally higher than the short-term (2005-2012) erosion, since during the short-term period there was the pronounced formation of erosion scarps that resisted rapid coastline retreat.
2. The extent and rates of coastline retreat along the Elmina-Cape Coast-Moree coastline has been exacerbated by anthropogenic activities that has interfered with the sediment budget in the coastal area. The identified anthropogenic activities responsible for this are;
    a. Urbanization that interacts with fluvial sediments supply to the coast.
    b. Sea defence construction that disrupts the natural pattern of sediment movement through the interception of alongshore currents as well as knock-on effects accelerating coastal erosion elsewhere.
    c. Beach sand mining that takes sand directly from the coastal zone creating a huge deficit in the sediment budget of the area.
3. Beach sand mining is widespread across the Elmina-Cape Coast-Moree coastline and takes place in several forms, with the amount of sand lifted dependent on the mode of transport. The magnitude of sand taken from the beach is dependent on

the transportation medium and the purpose to which sand is to be put. Most coastal residents have at some point in time used sand for their construction or renovation works.

4. Residents along the Elmina-Cape Coast-Moree coastline mostly perceive coastal erosion as being caused by anthropogenic activities such as sand mining, with some taking initiatives to curb this activity in their area. Residents mostly perceive coastal erosion as a threat to their safety and livelihoods as it has destroyed vital facilities along the coastline.
5. The coastal management regime in the Elmina-Cape Coast-Moree area is ineffective. Relevant agencies are unable to address the coastal management challenges in the area due to lack of inter-institutional cooperation. No distinct management approach exists for the management of the local and national coastline, making management interventions ad-hoc and unintegrated.

6.2 Recommendations

1. An undisturbed and ecologically balanced coastline has a positive economic implication for the community and hence, such should be the target of any coastal community. This study has provided valuable and comprehensive baseline information on the state of the coastline in the Elmina-Cape Coast-Moree area which can serve as a guide for coastal environmental managers and policy makers in Ghana. However, due to the sparse nature of coastal research in Ghana, there should be a coordinated national inter-discipline research approach aimed at filling gaps in available coastal information.
2. This study supports the recommendations made by the CCMA 'ad hoc' committee on sand mining in 2011 (Section 4.5.3) and recommends that these recommendations be immediately implemented.
3. The environmental awareness of residents in the Elmina-Cape Coast-Moree area is quite low and can easily be observed by the way wastes are disposed off onto the coastal areas. Relevant agencies including the EPA and the Information Service Department of the local assemblies should step up efforts to educate residents on coastal environmental sanitation and general management.

4. The Environmental Protection Agency and the Ghana Police Service who have in the past failed to enforce the coastal environmental regulations, should as a matter of national interest take up a more proactive posture in dealing with coastal sand mining issues.
5. The National Environmental Policy (1995) has become outdated and the sections dedicated to the coastal zone are irrelevant due to new research data and trends in administration. The time is right for a concerted national policy dedicated to only the coastal zone that takes into consideration the multiplicity of use of the zone and adopts an integrated management approach to managing the area.
6. A Construction Setback approach should also be adopted for seafront facilities to allow for the natural dynamism of the coast. Thus, there should be a defined limit to which facilities could be put up in the coastal zone allowing natural coastal processes to perpetuate whilst also controlling the usually ad hoc methods of sea defence put up by facility owners to protect their investments.
7. The legal alternative to coastal sand mining is inland sand mining. Institutional bottlenecks and corruption should be ceased to ensure a smooth and genuine licensing process in order to encourage beach sand miners to undertake those legal ventures.

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APPENDIX

Questionnaire for Residents

Coastal Erosion in Ghana; the Case of the Elmina-Cape Coast-Moree Coastline

All information provided will strictly be treated as confidential and for academic purposes only.

Age: Occupation:

1. How long have you stayed in the area?
2. Would you say the sea has moved closer or away from the land? [ ] Away [ ] Closer
3. About what distance would you say the sea has moved closer to or away from the land?
4. Do you sometimes feel threatened that the sea might destroy your business or homes? [ ] Yes [ ] No
5. Does sand winning take place on the beach in your area? [ ] Yes [ ] No
6. On what scale does sand winning take place in your here? [ ] Heavy trucks [ ] packed in sacks and transported by truck pushers [ ] Basins
7. Does this activity affect your business? [ ] Yes [ ] No
8. Have you taken any step to put a stop to these activities?
   [ ] Yes [ ] No
9. If yes what steps did you take?
10. Have you observed any environmental effect of sand winning in your area?
    [ ] Yes [ ] No
11. If yes what have you observed?
12. Do you think the practice should be encouraged? [ ] Yes [ ] No
13. Have you used beach sand for your personal work before? [ ] Yes [ ] No
14. If yes on what scale did you use it? [ ] Minor renovation [ ] Major renovation [ ] For putting up a full building
15. About how much did you spend on this?
16. About how many push trucks of sand did you use for your work?
17. Do you know that it is illegal to take sand from the beach? [ ] Yes [ ] No
18. Does your area obtain any monetary benefit or development as a result of the sand winning activity in your area? ? [ ] Yes [ ] No [ ] Can't say
19. Have you observed or heard about any programme put in place by the Metropolitan assembly or local assembly aimed at stopping sand winning in your area? [ ] Yes [ ] No