UNIVERSITY OF GHANA, LEGON

SHORELINE CHANGE ANALYSIS OF THE COASTLINE OF TESHIE IN ACCRA.

BY

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DECLARATION

This thesis has no material that has been accepted for the award of any other degree or diploma in any university or other institution. To the best of my knowledge, this thesis has no material published or written by another person, except where due reference is made in the text. This thesis results from a research work undertaken by David Augustus Otoo in the Department of Geography and Resource Development of the University of Ghana.

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DEDICATION

I dedicate this work to Ernestina Torto who has played a pivotal role in my academic pursuits.

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ABSTRACT

Coastal areas around the world are being shaped by natural and anthropogenic activities. These factors include ocean level rise, tides, geomorphology of the coastline, sand mining and coastal population increase. This study assessed the rate and extent of coastal erosion from 1986 to 2016 of the Teshie coastline; the socio-economic and cultural patterns (causes and effects) and the adaptive strategies undertaken by the locals of Teshie. Analyses of the shoreline change were computed using four historic years (1986, 1991, 2003 and 2016) of Landsat imageries over a 30-year period. The Digital Shoreline Analysis Systems based on formulae of the End Point Rate, Net Shoreline Movement and Linear Regression Rates were used. In addition, questionnaires and interviews were used to get first-hand information from the local inhabitants and concerned stakeholders. The results of the study showed 40.67% of the coastline to be eroding with 59.33% to be stable or accreting. The average erosion rate for the study is -0.41 m/yr and 0.52 m/yr for average accretion rate. The study had a range of shoreline change of -2.51 m/yr and 2.85 m/yr. The rate of erosion on the Teshie coastline has affected socio-economic and cultural livelihoods (including low fish catch, loss of landing sites and low beach turn-out). Unemployment and poverty were the main effects of socio-economic activities caused by coastal erosion. Effective coping strategies adopted include piling of sandbags and beach nourishment. The findings of the results showed that geomorphology and tidal waves have influenced shoreline change at Teshie. The study recommends regular and continuous study of the shoreline, to understand and predict shoreline changes.

Keywords: Coastal erosion, Coastal accretion, DSAS, Geographic Information System

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LIST OF ACRONYMS AND ABBREVIATIONS

DSAS - Digital Shoreline Analysis System

ENVI – Environment for Visualizing Images

EPA – Environmental Protection Agency

EPR - End Point Rates

GIS - Geographic Information System

IPCC - Intergovernmental Panel on Climate Change

Km^2 - Square Kilometre(s)

LANDSAT ETM – Landsat Enhanced Thematic Mapper

LANDSAT TM – Landsat Thematic Mapper

LRR - Linear Regression Rate

M - Metre(s)

M/S - Metre(s) per second

M/Yr - Metre(s) per year

NSM - Net Shoreline Movement

RS – Remote Sensing

SCE - Shoreline Change Envelope

SPSS – Statistical Package for Social Sciences

UTM - Universal Transverse Mercator

WGS - World Geodetic System

CHAPTER ONE

STUDY BACKGROUND

1.0 Introduction

The coastlines of the world react to change (erosion or accretion). In contrast to accretion, the rates at which the coastlines are eroding pose danger to man and the environment. Efforts to control retreating coastlines are a burden on the monetary budgets of coastal nations. Marchand *et al*. (2011), in an assessment, found that France disbursed €20 million to control coastal erosion; the Netherlands used €41 million on sustaining the coast and Portugal spent €500 million on coastal recovery, which involved constructing dunes and other hard guard engineering works.

Ghana’s coastline has changed over the earlier decades (Ly, 1980). The changes (which include but are not limited to anthropogenic exercises, climate change and the geomorphology of the coastlines) traverse over spatial and temporal periods. The combination of the activities have increased the risks of coastal erosion (Dovie, 2015). The coastal zone, marked by socio-economic and cultural structures, induce coastal erosion (Leichenko & O’Brien, 2008). The risk of the coastal zone has raised concerns due to harsh natural conditions; making the sustenance of enhanced coastal management tough as impacts from natural causes can only be curbed (IPCC, 2007). In a quest to attain equilibrium, the coastline experiences changes, threatening socio-economic activities along these areas (Anim *et al*., 2013).

Despite the nature of the coastal zone, man's activities have increased in these areas over the past decades (Crowell *et al*., 2010). Reports from studies conducted show that 70% of the world's population is affected by climate change resulting in coastal erosion and denudation (Nicholls & Cazenave, 2010). According to McGranahan *et al*. (2007), coastal urban centres accommodate 25% of the world's organisations. Despite the worsening state of coastlines, it harbours a large proportion (60%) of the human populace and increases over time (Small & Nicholls, 2003).

Ghana's coastal zone has been inhabited by various communities for over a century (Oteng-Ababio *et al*., 2011). Coastal communities (of Nzemas, Fantes, Gas and Ewes) are susceptible to a potential number of risks associated with coastal erosion and its effects on socio-economic activities (Adger *et al*., 2005). Thus, the issues surrounding coastal erosion in past years, influenced by urbanisation and climate change, show a relationship (Jonah, 2015).

Studies conducted show the entire Ghanaian coastline to be retreating (Nail *et al*., 1993; Armah, 1991). The intensity of coastal erosion increases from east to west (Ly, 1980). Aside the natural (such as sea level rise and tidal waves) and human (including coastal engineering and sand mining) factors, have influenced Ghana's coastline (Appeaning

Addo, 2013). These factors deny the coastline of the sediment influx it needs to sustain equilibrium. This has affected the geomorphic features of the coastline and the effects of coastal erosion on life and property (Ricketts, 1986).

1.1 Problem statement

The landscape of Ghana's coastline, stretching over 550 kilometres (km) is low-lying and 30 metres (m) above sea level (Boateng, 2010). Along the coast, the total land cover of 7%, accommodates 80% of the country's enterprises and organisations (Appeaning Addo & Lamptey, 2013; Armah & Amlalo, 1998).

According to Ly (1980), Ghana's coastal zone can be categorised into three main geomorphic sections: the Western, the Central and the Eastern coasts. The Western section spans 95 km of the coastline from the Côte d'Ivoire-Ghana border to the estuary of the Ankobra River. The Central Coast, from the Ankobra River estuary to Ningo-Prampram covers 321 km; the Eastern section stretches 149 km from the Laloi Lagoon (Ningo-Prampram) to the Ghana-Togo border (Boateng, 2006). Studies conducted over the earlier decades sought to find the remote causes and patterns of coastal erosion. Appeaning Addo *et al*. (2011), examined the shoreline change at Keta, using reliability of medium resolution satellite imagery for mapping shoreline positions and for estimating the historic rate of change. Ly (1980), examined the role of the Akosombo Dam on the Volta River in eroding the Central and Eastern coast of Ghana using aerial photographs and maps before and after the dam construction. Nail *et al*. (1993), identified twenty-four (24) hotspots, which proved the whole coast of Ghana is experiencing erosion. Kusimi and Dika (2012), assessed the impacts of sea erosion at Ada Foah and proposed mitigation measures.

In a quest to ease erosion assessments of Accra's coastline and aid in the study of shoreline change; Appeaning Addo (2009), maintained the earlier divisions of the coastline (Western, Central and Eastern). The Western coastline spans 14.3 km, from Bortianor to Jamestown and the Eastern coastline extends 11.3 km from Nungua to Sakumono Lagoon; the Central coastline stretches 12.7 km from Jamestown to Teshie and includes the territories Osu and Labadi (Appeaning Addo, 2010). The study, which spanned from 1904 to 2002, pegged erosion rate at -1.13 metres per year (m/yr) ± 0.17 m/yr. This result indicated 18% of the coastline to be steady or accumulating with 82% receding (Appeaning Addo, 2009). The erosion rate for the Central part of the Accra coastline was -0.40 m/yr ± 0.17 m/yr (Appeaning Addo, 2010).

Regarding the aim of this research, the examined coastline by Appeaning Addo (2009), was on an extensive scale. Therefore, this research focused on Teshie (which falls within the Central coastline); that is on a smaller scale as compared to Appeaning Addo's (2009) study area, to provide a better knowledge of the differing rates of coastal erosion. Thus, this research localised the coastline assessment within a short-term. As regards a short-term analysis of coastline change, Anfuso *et al*. (2007), proposed a 10-year period for coastal assessment. In this research, a 30-year period was adopted to show the changes in the Teshie coastline within a short-term.

Hitherto, most studies on coastline change have used quantitative techniques because they sought to present facts and precise rates of erosion. Appeaning Addo (2009), assessed coastal erosion in Accra, which gave insight into the rates of erosion. Other studies focused on its associated impacts on the life of people. For instance, Oteng-Ababio *et al*. (2011), gave an insight into the potential hazards and coastal resource degradation at Faana-Bortianor.

With the background given, the studies mentioned gave relevance to the assessment of coastal erosion and its associated impacts (Oteng-Ababio *et al*., 2011; Appeaning Addo, 2009). It can be justified that none of the studies assessed the shoreline change and the socio-economic and cultural patterns (causes and effects) regarding space and time, which pertain to Teshie.

This study, therefore, sought to assess the rate and extent of shoreline change from 1986 to 2016 along the Teshie coastline, (which showed the rates and distance of shoreline change against time); the socio-economic and cultural patterns (causes and effects) of coastal erosion at Teshie and the adaptive strategies undertaken by the local inhabitants. This will be addressed with triangulated methods to show the different aspects of the problem.

1.2 Research questions

This research made enquiries in line with the introduction and problem statement. The issues highlighted in the introduction and problem statement served as a guide to finding out the relevant information of the study to the objectives of the study.

1. What is the average rate of shoreline change at Teshie from 1986 to 2016?
2. Which segments are the "hotspots" on the Teshie coastline?
3. What are the views of the local people on the socio-economic and the cultural causes and effects of coastal erosion?
4. What are the coping strategies undertaken by the local people?

1.3 Aim

The research assessed the shoreline change at Teshie; the socio-economic and cultural patterns (causes and effects) and the coping strategies adopted.

1.4 Objectives

1. Analyse the extent and rate of shoreline change at Teshie from 1986 to 2016.
2. Identify the "hotspots" along the Teshie coastline.
3. Determine the views of the local people on the socio-economic and the cultural causes and effects of coastal erosion at Teshie.

4. Assess the coping strategies of the local people and management measures by the government.

1.5 Proposition

Shoreline change has affected socio-economic and cultural activities of coastal residents of Teshie.

1.6 Justification

The issues on coastal erosion are vital, based on the effects it has had on man and the environment. The intended outcome of this study was to assess coastal erosion at Teshie while asking questions on the perception, socio-economic causes and effects and the coping strategies. The research gives information on the challenges of the Teshie coastline, which will aid policy frameworks and exemplify the mixed research method.

The Teshie coastline is inhabited by an indigenous population with more than a century stay (Oteng-Ababio *et al.,* 2011). Beyond the socio-economic and cultural challenges, this area faces the threat of coastal erosion (Appeanning-Addo, 2009). Hence, a scientific study (both qualitative and quantitative) of the rates of erosion at Teshie in the Ledzokuku/Krowor district; this will give an appraisal of the coastline and awareness on the socio-economic patterns (causes and effects) and coping strategies from the locals. Earlier studies conducted pegged the rate of erosion between 1.5 m/yr and 10 m/yr

(Appeaning Addo, 2009; Norley, 2006; Nail *et al.*, 1993; Armah, 1991). These rates, which stem from the past studies of Ghana's coastline, show more than half of the coastline to be eroding (Appeaning Addo, 2010; Armah, 1991).

This study provides first-hand information on the challenges of the Teshie coastline; the appraisal of the rates of change; the perceptions on erosion; the socio-economic and cultural patterns (causes and effects) and coping strategies. Thus, the study's analysis of identifiable issues along the Teshie coastline will aid in replicating workable strategies in other coastal areas experiencing similar rates of shoreline change.

The study used a mixed research method, thus, influencing other studies. This is because, most studies have gaps on the perceptions, socio-economic causes and effects and coping strategies, hence, the need for a triangulated approach.

1.9 Outline of the thesis

The study is in six chapters. The first chapter provided a general introduction to the study background, problem statement, research questions, aim and objectives, proposition and justification of the study.

The second chapter discussed the related literature on specific themes including understanding coastal erosion in its global context; the causes of coastal erosion; the effects of coastal erosion and the geometric representation of coastlines in Geographic

Information System (GIS). This chapter concluded with the theory of risk perception adopted from Bradford *et al*. (2012) and the conceptual framework modified from Cai *et al*. (2009).

Further, the third chapter addressed the Study Area and Methodology. For the Study Area, it entailed the location, geology, climate and socio-economic characteristics of Teshie. Regarding the Methodology, the chapter dwelt on the philosophical underpinnings, data collection methods, sample size and distribution, as well as, data analysis.

The fourth chapter delved into the analysis of the rate of erosion and hotspot identification. The chapter includes analysed rates of erosion for the various years under review and assesses eroding hotspot zones.

The fifth chapter delved into the analysis of the socio-economic effects of coastal erosion and coping strategies adopted. The chapter examined the respondents' perception, socio-economic causes and effects of coastal erosion and the coping strategies adopted. The final chapter presents the summary of key findings, conclusions and recommendations.

1.10 Chapter summary

This chapter comprises seven sections. The first section is the introduction, which gives a general background to the study. The second section addresses the problem statement.

The focus of the third, fourth and fifth sections were the research questions, the aim and objectives and the proposition of the study. The sixth section addresses the justification of the study. The final section looks at the outline of the thesis. The next chapter addresses the related literature, theoretical and conceptual frameworks of the study.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.0 Introduction

This chapter (in two sections) reviewed the related literature and the conceptual and theoretical frameworks adopted for the study. The first section reviews the literature on several themes including coastal erosion, the causes and effects of coastal erosion and the geometric representation of the coastlines in the Geographic Information System (GIS) database. The other section focuses on conceptual and theoretical frameworks.

2.1 Coastal erosion

The shoreline or coastline accommodates the natural features and human activities (French *et al*., 2016). The coastal zone shows both sides of the "land-sea boundary", the inner part of the coastal shelf and a hinterland (Boak & Turner, 2005). The dynamic nature of the earth comes with differentials, which cause the oceans to make sudden changes to attain equilibrium (Appeaning Addo, 2009). The dynamic nature of coastlines affects both anthropogenic activities and natural processes. Accretion within a perspective brings relief as sediments add onto the beaches to beef up the pre-existing beach sand (Zhang, 2011). Coastal erosion has caused increased flooding, damage to coastal protection, loss of renewable and subsistence resources, loss of property, coastal habitats and loss of life (Anthony, 2005).

Relating to coastal erosion, much work has been conducted. These studies were toward understanding the reasons for coastal erosion, analyse the connection and association among the operators driving the occurrence and anticipate the future patterns of coastal erosion.

A study by Romine *et al*. (2013), on the coastline retreat in Hawaii, indicated ocean level rise as the main cause. The ocean level rise along the coast of Hawaii was due to change in island subsidence. Other factors found to be influencing coastal erosion in Hawaii included sediment supply, waves, anthropogenic interferences and littoral processes.

In the United Kingdom (UK), the coastlines are experiencing different erosion rates. This is because of the varying geography and geomorphic forms acting on the coastline. It is estimated that 17% of the coastlines in the UK as a whole is experiencing erosion; with 30% in England, 23% in Wales, 20% in Northern Ireland and 7% in Scotland (https://www.jrf.org.uk/file/40977/download?token=5MlPJbZE&filetype=full-report).

In Asia, coastal erosion is a major concern in China due to the socio-economic ties attached to the coastal cities. For instance, the Shandong Peninsula affected by coastal erosion was because of its low-lying nature. A coastal retreat of 300 m/yr assessed at the mouth of Luanhe River gave an erosion rate of 25 m/yr for its offshore sandbars, linked by a decline in sandbar measure. This was because of the rise in ocean levels and the negative effects caused by human exercises (Cai *et al*., 2009).

In Africa, the coastal zone is narrow and low-lying. Factors, such as ocean level rise, storm surges, increase flooding, climate change and human exercises have worsened existing physical, ecological/biological and socio-economic stresses on the coastal zone (Goussard & Ducrocq, 2014). Coastal African nations (such as Egypt, South Africa, Nigeria and Ghana) have low-lying lagoonal coasts susceptible to erosion, threatened by ocean levels because nations within the region have growing urban communities (IPCC, 2007). Results from studies on the effects of ocean level rise on the Egyptian Coast show a loss of a sizable extent of the northern piece of the Nile delta. This is attributed to inundation and erosion (Warne & Stanley, 1993). Likewise, a study by Corbella and Stretch (2012), on the Eastern Coast of South Africa, attributed the retreat of the coastline but not limited to waves, tides, ocean level rise, wind and anthropogenic activities.

In West Africa, the coastal zone is home to 31% of its population. Urban population growth in the region is increasing at an annual rate of 4% (World Bank, 1995). This is in relation to natural factors and its associated hazards along the West African Coast as reported by Allersma and Tilmans (1991). Coastal erosion rates of West African states are alarming and anticipated to range between 23 m and 30 m (Ibe & Awosika, 1991; Ibe & Quelennac, 1989). Studies conducted in connection with Ghana’s coastline have encountered changes, which have affected socio-economic activities (Appeaning Addo, 2010).

Studies by Quashigah (2011) and Ly (1980), perceived the loss of sediment because of the damming of the Volta River between 1961 and 1965. This influenced erosion in the Eastern segment and its connecting Central section. In addition, studies on the Central segment of the coastline characterised the eroding coastline to the silt blockage by coastal engineering works; they include the Densu dam, groynes, Kokrobite water irrigation scheme and geology along the central coastline (Armah, 1991). These structures have both eroded in adjoining regions and the blockage of sediments to different regions of the coastline. Due to these hard engineering structures, Boateng (2006), proposed the possibility of an integrated coastline administration approach in addressing coastal erosion issues in Ghana.

Armah (1991), in the appraisal of Ghana's coastline, assumed anthropogenic and climate change to explain coastal erosion. This attestation buttressed studies by Appeaning Addo (2009) and Boateng (2006), with the risk of increasing erosion, due to human migration to coastal areas. In addition, Jonah (2015) and Mensah (1997), upheld the dependence on coastal resources (sand and rock) for the construction industry as a reason for coastal erosion.

Olympio and Amos-Abanyie (2013), analysed the effects of coastal erosion on coastal infrastructure along Nkontompo in Western Ghana. The study recommended new legislation that will create a setback line for coastal development to be enacted to reduce losses from coastal erosion. Regarding the effects of coastal erosion, Ransom (2002), proposed a 60-year future for buildings along the coast, with the setback distance based on the position of the current coastline recession rate.

2.2 Causes of coastal erosion

The coastline depicts the boundary between water and land; it tries to achieve and keep up harmony amid many contradicting natural and human-initiated factors (Church *et al*., 2007). Coastal erosions are subjected to the adjustments in relative ocean levels, atmosphere and biological community, which have been affected by human exercises (Nicholls *et al*., 2007; Kumar *et al*., 2003). The erosion processes include movement of sand along the coastline, occurring amid storms and a solid breeze movement; this may lead to loss of sand and rocks or the impermanent redistribution of coastal sediment, in the long-term (Woodroffe, 2002). Despite the natural causes, human intervention assumed a key part in driving the extremes of the natural factors (Zhang *et al*., 2004). The natural causes discussed in this research include ocean currents, tides, the geomorphology of the coastline and ocean level rise; sand mining, coastal population, loss of wetlands, loss of mangroves, coastal defence and engineering structures addressed the human causes.

2.2.1 Ocean currents

Ocean currents are characterised as the net flow of water from a region of higher concentration to a region of lower concentration (https://oceanexplorer.noaa.gov/facts/climate.html). They portray developments of fluids (water) seen along both surface and deep waters throughout the world's oceans. Ocean currents are because of surface strain made from the sun and winds managed by gravity. An ocean current is in a continuum and acted on by the forces following up on it (Marshall & Plumb, 2016). These forces may be an immediate result of tides, winds, waves or by contrasts in temperature and saltiness (http://oceanexplorer.noaa.gov/facts/currents.html). Throughout the globe, ocean currents contrast in size, importance and magnitude (Garrison, 2015).

The world's ocean currents may be grouped into two; the uppermost currents and the undercurrents (https://earth.usc.edu/~stott/Catalina/Oceans.html). The uppermost currents make up around 10% of the total and are called surface currents while the undercurrents (or deep water currents) make up 90% of the ocean. They begin by the stress of winds blowing over a waterway, thermal expansion and contraction and by density differences in the water layers. The distinction in temperature between the tropical and polar waters (which get changing degrees of the sun's energy) brings increased water volumes of the former. Besides the fundamental components; auxiliary factors such as the Coriolis drive, friction, gravity and the condition of the ocean bowl have affected the ocean currents (https://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-32.pdf). About this study, the ocean currents (near current and longshore current) indicated how coastal areas are eroded off the shores of Teshie and Ghana as a whole.

2.2.2 Tides

The intermittent rise and fall of the sea level are described as tide. Tides are caused either by the differential forces of attraction between the earth, the moon and the sun as they revolve in their orbits. For the proximity differences of the moon-earth and the sun-earth systems, tide intensities vary. When the earth, moon and sun align (180˚), a spring tide occurs. A neap tide happens when the moon-earth and the sun-earth systems are at right angles to one another. The measure of tides experienced at any period depends on the sun and moon in relation to the earth and the morphology of the coastline (http://www.alternative-energy-tutorials.com/tidal-energy/tidal-energy.html).

Tide and wave energies have tendencies to change coasts. Depending on the force driving the source of the formation of coasts, a coast may be classified as tide dominated, wave-dominated or mixed-energy. Sedimentary coasts are defenceless to erosion and are at risk of geomorphic shapes (Masselink & Hughes, 2003). Where tides along sedimentary coasts are low, the coastline has a tendency to be strong as waves engulf coastlines. Under such conditions, the coastlines adjust to advance toward wave tops (Hayes, 1979). This information helped in understanding the dynamics of how tides affect coastal erosion at Teshie.

2.2.3 Geomorphology of the coastline

Among the many factors, geomorphology has affected coastlines (Valvo *et al*., 2006). Related bays and ocean headlands and to an extent, landforms inside the landscape, form the present state of many coastlines, including Accra's coastline (Inman *et al*., 2005). The Markovian process describes Accra's coastline, which clarifies the morphodynamics (Inman & Nordstrum, 1971).

The geomorphology serves as a column that characterises the changes of the coastline. The coastline of Accra can be categorised into three main zones, the Eastern, the Central and the Western zones (Boateng, 2006). The Western segment comprises disjointed rocks from sediments and shallow shore; the Central segment comprises the Accraian (a mixture of sandstone, shale and laterite); the Eastern segment comprises the Dahomeyan rocks (transformative cellar rocks overlain in clay and laterite) (Muff & Efa, 2006).

The prevailing rocks along Accra's coastline contrast in structure and property, hence, their doggedness and endurance from the actions of waves, which sweep the coastline (Appeaning Addo, 2009). The Accraian rocks are in three structures (Dickson & Essah, 1998). They incorporate the upper sandstone-shale, the middle sandstone-shale and the lower sandstone-shale (Muff & Efa, 2006). The middle sandstone-shale and upper sandstone-shale are likely inclined to erosion faster than the lower sandstone-shale. The bonding is grounded in the lower sandstone shale than the upper sandstone-shale and middle sandstone-shale. Besides, activities of sand and rock mining for engineering works have weakened the bonding of the layer, hence, their inability to endure the harsh conditions of the wave actions (Armah, 1993b).

2.2.4 Climate change: ocean level rise

Many analysts attribute global warming to climate change, which poses the worst form of environmental threat to the world (IPCC, 2007). Because of the concentrations of different gases such as methane and chlorofluorocarbons discharged by human practices; these have intensified the rates at which ocean levels have risen (Mallick, 2017; Titus, 1988). This may be because these gases absorb infrared radiation, which warms up the earth. Climate change has been a huge influence on ocean level rise (Hicks *et al.*, 1983). The sunlight received (reflected and retained) helps determine a planet's temperature. Based on this analogy, an evaluation shows the earth will be around 33 ˚C (60 ˚F) colder than its present state, without the impacts of greenhouse gases. The power and pattern of the centralisation of greenhouse gases started with the mechanical upheaval. For example, nitrous oxide, methane and chlorofluorocarbons are effects of practices, which included the burning of non-renewable energy sources and deforestation (Titus, 1990).

One school of thought embraced by Hansen *et al*. (2016), held the view that these gases (which include methane, chlorofluorocarbon and nitrous oxide) have the tendency to warm up the earth twice. This means snow and drifting ice will liquefy to counterbalance the measure of daylight reflected into space. Although different analysts opined distinctive appraisals of cloud cover and extent, this adds to the impacts of the greenhouse.

Ocean level rise and dissolving ice have a corresponding relationship that has resulted in global warming impacts. Melting ice caps in Greenland, Arctic and Antarctica, introduce effects of ocean level rise. Appraisals show the melting of Greenland's mountain ice sheets and thermal expansion could cause the ocean level to rise increment of 30 centimetres (cm) and 12 cm (Revelle, 1983). The assessments anticipate ocean level rise of 26 cm to 39 cm by 2025 and 91 cm to 137 cm by 2075 (Hoffman *et al*., 1983). Melting in Polar Regions cause coastal flooding, thus eroding the coastline. This perceived repercussion threatens human life and the coastal biological system.

Ghana's coastline is anticipated to retreat due to ocean level rise at 2 m/yr in 2010 and 6 m/yr in 2021 (Appeaning Addo *et al*., 2011). Other causes of coastal retreat include human activities (such as unsuitable management intervention), storms and torrential rainfall (Boateng, 2010; Allersma & Tilmans, 1993; Armah, 1991; Ly, 1980). Predicted impacts of environmental change: ocean level rise perceived by the Intergovernmental Panel on Climate Change (IPCC, 2007), include storm intensity and storm damage; the submergence of low-lying wetland and dry-land domains; the erosion of delicate coastlines by expanding offshore loss of silt; the increasing saltiness of estuaries and aquifers; raised water tables and exacerbated coastal flooding and erosion. A change in the mean level of the ocean does not show sediments on the coastal zone but the redistribution of sediments. Thus, no supply of sediments to renew the coastline will lead to the recession. As a result of the low-lying nature of Ghana's coastline, the susceptibility of the rise in ocean level and its effects have influenced coastal erosion.

2.2.5 Sand mining

The coastlines of the world contain resources (sand and stones), which provide various purposes. Over the earlier years, opencast mining of these resources has been a wellspring of material for the Ghanaian construction industry (Jonah, 2015; Schlacher *et al*., 2007). Streets, houses and bridges have depended on sand and stones from the coastal regions; these include a part of the changes in the coastal zone due to business purposes (Defeo *et al*., 2009; Pilkey *et al*., 2004). Despite the natural causes, human factors have expanded the risks on the coastline (Jonah *et al*., 2015; Lucrezi *et al*., 2009).

Indiscriminate sand mining is an illicit act that is a threat to coastal zones (Mensah, 1997). Issues of sand mining are seasonal (Boateng, 2006). During the wet season, precipitation prompts fluvial sediment to the coastline; the pinnacle period of the development business (the dry season), records the exercises of sand mining (Jonah *et al*., 2015; Jonah, 2015). Urbanisation and industrialisation have heightened the need for settlements at the coast; this has led to increasing construction outputs from 17.4% in 1980 to 20.8% in 1993 (Jonah *et al.*, 2015; Mensah, 1997), while sand off the coast of Accra has been utilised for landfill (Amatekpor, 1994). Labadi, an adjoining coastline to Teshie has encountered 2 m/yr recession of the coastline. This is because of sand and rock mining along the coast (Biney, 1991). Activities (like longshore float, waves and tides) and other silt instruments are strategies used to establish harmony, with a specific end goal to counterbalance influenced territories. As observed around La coastline, which covers a distance of 400 m, experienced exercises of excessive sand mining because of the nearness of uncovered bedrock (Muff & Efa, 2006; Armah, 1991). "A large scale of sand mining from the La coastline for development works have added to the eroding coastline. The coastal recession has been seen along this part of the coastline within the period of 1904 and 2002; the gradual addition observed within the period of 1996 and 2002 can be attributed to the supply of sediment of the uncovered rock stratum" (Appeaning Addo & Lamptey, 2013). Studies prove residue supply to littoral zones decreased and this brought the change of the coastline. This assertion supported by findings indicated a retreat of Faana coastline of Accra due to the decrease in sediment movement (Oteng-Ababio *et al*., 2011; Sanjaume & Pardo-Pascual, 2005).

Human activities have left hollows at the coastlines (Jonah *et al*., 2016). These activities, in tandem with the low-lying nature of the coastline, have permitted destructive waves to reach the vegetation line (Appeaning Addo *et al*., 2008; Boateng, 2006). The vegetation along the coast acts as a buffer zone. Losing residue and higher wave activity in the long run, uncover the roots; this leads to loss of vegetation (Anim *et al*., 2013). Mensah (1997), observed that compensation for losing sediment movement prompted specific rocks, which postured dangers to landing canoes.

2.2.7 Coastal population increase

About urbanisation and industrialisation, the coastal zone is a development post (Jonah, 2015). Land use patterns along the coast of Ghana have changed due to the influx of migrants (Anarfi *et al*., 2003). The rate of urbanisation remains at 52%; this is one of the key anthropogenic elements, which have started and intensified erosion of the coastline (Churcher, 2006; Armah, 1991). The coastal area suits around 80% of the country's enterprises and organisations (Armah & Amlalo, 1998). This is beside individuals moving from the inland to the coast in search of economic opportunities and accommodating a populace density of 3,388 people for every km^2 (Churcher, 2006). Hence, this has increased the risks in the coastal zone, since these areas house the transients and businesses (Jha *et al*., 2012). This translates into coastal assets, which incorporate wetlands, mangroves and coastal vegetation being swapped for settlement and businesses (Alvarado, 2003).

These coastal resources create buffer zones, which serve as natural windbreaks and coastal erosion guard systems. In their absence, this led to a retreat in the coastline

(Olympio & Amos-Abanyie, 2013). This supports the trends of erosion in the period between 1974 and 1996 and in the period between 1996 and 2002 (Appeaning Addo & Lamptey, 2013). There should be an altering space within the coastline to take into consideration the settlement of eroding forces and adjustments to changes (Passeri *et al*., 2015). Imprudent coastal land use development and administration carried out by both the authorities and the local populace have been because of coastal populace increment (Appeaning Addo & Lamptey, 2013). One noteworthy reason for expanding erosion in Accra is the unsuitable location of coastal infrastructures since it does not take into consideration the impact on the environment (Hens & Boon, 1999; World Bank, 1995).

2.2.6 Coastal defence structures

Coastal retreat endangers the environment and biological framework, which exist within the coastline (Charlier & De Meyer, 2000). Because of the advantages the coastal zone provides in terms of development, urbanisation along coastlines have surged (Satterthwaite, 2007). Living along the coastline pose threats to life and property (Ricketts, 1986). Due to these challenges posed by the retreat in the coastline, mechanisms, which include sea defence walls, groynes, revetments and beach nourishment have been put in place. The effects of these structures have affected the rate of erosion along the coastline (Armah, 1991).

Along the coastline of Accra, multiple assessments have shown the coastline to be eroding (Appeaning Addo, 2010; Boateng, 2006; Armah, 1993a). To deflect the outcomes of the retreat of the coastline; structures were placed along the Accra shores to curb the erosion rate but circumstances have heightened erosion along the bordering shores (Appeaning Addo, 2010; Allersma & Tilmans, 1991). A stable coastline along Jamestown in the central zone was because of piers developed in 1906. These served as cushion zones to explore entrance channels to the defunct Accra Harbour, in this way trapping littoral sediment (Appeaning Addo, 2009; Dickson, 1965). Because of the drawback float of silt, which piers hinder; erosion has altogether expanded around Osu (the regions of the Black Star Square coastline range) and adjoining areas such as La and Teshie (Appeaning Addo & Lamptey, 2013). This led to the construction of coastal guard structures containing groynes and revetments (Appeaning Addo, 2010; Armah, 1993a). The effects of accretion on a section of the coastline have eroded in the abutting region, due to the knock-on effects.

2.2.8 Construction of the Akosombo Dam and Tema harbour

In correspondence to the dynamics, which come to play in understanding the coastline, engineering works such as dams and harbour constructions have been a cause of coastal erosion (Appeaning Addo *et al*., 2012; Quashigah, 2011). The coastline of Ghana characterises many engineering works, which include the Akosombo Dam, Densu Dam, jetties and Tema Harbour. These structures have intercepted the littoral/longshore drift of sediment from west to east, leading to aggravated coastal erosion (Boateng, 2006). This phenomenon occurs when the natural flow of sediment is interrupted by human engineering. Hence, an inadequate supply of fluvial sediment amongst other coastal hazards pose adverse tendencies of altering the coastline (Andredaki *et al*., 2014).

Past studies have magnified the rates and effects of erosion on the eastern segment of Ghana's coastline (Ly, 1980). Hence, what happens in the eastern part of the coastline; an effect is evident in the central part of the coast. The Akosombo Dam has affected both the eastern and the central coastlines of Ghana (Quashigah, 2011). The dam in 1964 reduced sediment supply locally, causing an imbalance in the sediment lost to longshore drift and replenishment (World Bank, 1995). Studies by Quashigah (2011) and Ly (1980), asserted increasing rates of erosion from 4 m/yr to 8 m/yr. Total sand transported to the coast reduced by 60%, because of the drop in the overall flow velocity of the Volta River. According to Boateng *et al*. (2012), engineering works, such as the Densu dam and Takoradi harbour have contributed to the coastal processes along the Guinea Coast. Studies show that these structures have interrupted the littoral sediment transport within the central part of Ghana's coastline (Dadson *et al*., 2016). This concludes with the eroding nature of Ghana's coastline showing how engineering infrastructure has affected Teshie.

2.2.9 Loss of wetlands

The transitional zone between salt marshes and uplands exposed to harsh states of saltiness, temperature and immersion by tidal water and a vulnerable habitat describes the qualities of a wetland (Armah, 1993a). The extensive salt marshes, which cover the estuarine and deltaic environments are within mid to high latitudes (FitzGerald *et al*., 2008). Wetland relevance has often been disregarded, though recognised to be the most profitable biological communities on Earth (Titus, 1990; Nixon, 1980). For the past three centuries, marshes and swamps have been drained and filled for urbanisation, businesses, agriculture and other human needs (Titus, 1988). Wetlands provide both economic and environmental functions (Hartig *et al*., 1997). Wetlands serve as buffer zones that provide protective barriers for urbanised communities and the coastal zone at large, from intense wave action (Mitsch & Gosselink, 2000). Studies show that every 2.7 miles of wetlands lessen a tempest surge by a foot (Sheng *et al*., 2012). Wetlands vary in contour, biota, tidal action and water quality; its value dwindles when there is a loss of marsh acreage resulting in ecosystem loss (Hartig *et al*., 1997).

The uniqueness of the environment on plant and animal life is what wetlands describe (Farris, 2005). Wetlands show a continuum between terrestrial and aquatic ecosystems, demarcated by temporal or permanent water, which may be stagnant or flowing. This environment provides services, which supports fisheries and most livelihoods within the community (Morris *et al*., 2002). Wetlands flourish in sloppy environments and support a variety of life forms (Woodroffe, 1990). Many coastal dwellers will be vulnerable if not for the coastal protection of wetlands. Storm surges, breezes and precipitation have affected the wetlands (Appeaning Addo, 2013).

Ghana has designated five wetland areas as Ramsar conservation sites due to its importance. This initiative has had support from foreign institutions, such as the World Bank and the Global Environmental Facility (Ntiamoa-Baido & Gordon, 1991). These wetlands include Muni, Densu delta, Sakumono, Songor and Keta Lagoon. Wetlands act as sponges, soaking up and storing runoff before releasing it into an aquifer or nearby water bodies. The wetland size affects the protection provided. Without wetlands to store storm waters, flooding will be continuous. Wetlands react to sea level rise by either moving to a higher elevation on land or move into nearby waters if they become filled with sediment (Woodroffe *et al*., 2016).

2.2.10 Loss of mangroves

Mangroves are tropical woody forest ecosystems in the transition zone between land and ocean thriving in brackish environments, around lagoons and estuaries (Alongi, 2002). They assume noteworthy parts in the socio-cultural and economic existence of the general population in the zones (Armah & Amlalo, 1998). They have a natural estimation of supporting the biological system (FAO, 2005). Rivers and estuaries fill in as methods for transport courses and offer high profitability, managing an atypical state of sustenance creation (Wolanski *et al*., 2004). In West Africa, the total land cover of mangroves is 10,000 hectares. Most parts can be located on the West Coast between Côte d'Ivoire and Cape Three Points (Armah & Amlalo, 1998; Saenger & Bellan, 1995).

Ghana's coastline is characterised by lagoons and estuaries, associated with narrow and patchy mangrove vegetation (Armah *et al*., 1996). Ghana's mangroves can be found in tidal ponds, flanking the lower ranges of the coastline and the delta of the Volta River. Most parts of the coastal areas are occupied by secondary and tertiary growth. In abundance and dominance is the red mangrove (*Rhizophora sp*.) with an average height of 10 m. The expanding rate of urbanisation towards the coastal region has caused contamination of these water bodies, eutrophication, erosion of soil and contamination from various chemicals. The expanding populace in the coastal zones strains mangroves and their biodiversity.

The coastal woods, which include mangroves serve as bio-shields, lessening the wave energy from storm surges (Anim *et al*., 2013). Thus, decreasing the height and speed of the waves and diminishing water flow as seawater moves inland. They have a tendency to shield the coast from erosion and supported in sparing human life (Mazda *et al*., 1997). According to Thampanya *et al*. (2006), mangroves saved lives, amid the Indian Ocean tidal wave in 2004. Mangroves could likewise shield the hinterland from the salt shower; this is dominant in the semi-dry and dry district (precipitation under 0.5 m/yr) (Sackey *et al*., 1993).

Aside the many environmental preferences, mangroves situated before a coastline reduce tidal wave intensities (Verhagen & Loi, 2012). Coastal woodlands are helpful to the human populace since it traps sediment and upgrading estuarine and coastline fisheries (Manson *et al*., 2005). Despite the expected, the mangroves have reduced because of human activities (over-harvesting), which have corrupted and eroded the coastal zones. Studies have shown the effect of deforestation on estuaries is more prone in the tropics than in the temperate zones; this is because of the power of precipitation (Wolanski & Spagnol, 2000). Mangroves give preferred security over the "hard" arrangement of rocks and concrete, through noteworthy stream decrease; in this way relieving the wave action. According to Massel *et al*. (1999), mangroves have propensities to ingest water waves and shield the coast from wave erosion through the engrossing system of wave vitality through drag and idleness powers. For example, a mangrove ranch at the shore of Vietnam's Gulf of Tonkin is because of the shallow seaside rack. Hence, these shallow zones can retain tropical storm wave vitality, so the waves do not surpass one metre (Wolanski & Gereta, 2001). Wave levels are reduced by mangroves to a certain degree. In this way, the waste framework can quicken the seepage of the swash back to the sea. This reduces the span effect a surge has on the land (Fritz, 2011). Another favourable position of a mangrove belt is that it allows siltation. Because of streams lessening in the backwoods, greater silt will settle. Amid the long procedure, the higher foreland will definitely lessen wave action leading to less load on the barrier (Verhagen & Loi, 2012).

2.3 Effects of coastal erosion

The confines of the coastal regions characterise the urban and industrial infrastructure, tourism resources, industrial-scale fisheries and oil and gas development (Olympio & Amos-Abanyie, 2013). These landmarks along these coastlines are socio-economic and cultural determinants (Jonah, 2015). This is because of the foundation and administrations, which have decided the standard of living; this has caused an expansion in the populace's pattern in the coastal areas (Armah & Amlalo, 1998). Over 70% of the world's coastlines are retreating; this presents genuine risks to the assessed 60% of the human populace living in the coastal zones (Zhang, 2011). Factors, which include ocean level rise, tides, waves, flooding and global warming have had effects on the coastal areas. Studies by IPCC (2001), assessed the retreat in coastlines and flooding of low-lying territories, to be an aftereffect of environmental change.

The socio-economic effects of coastal erosion may impact a few people (reaching millions) living in coastal zones; despite the general open move towards the coasts, in the coastal locales (Nuemann *et al.*, 2015). The lifestyles of various people and groups are appended to the coast (Hugo, 2011). The socio-economic lifestyles shift from nation to nation and from site to site (Oteng-Ababio *et al.*, 2011).

In Ghana, the adjustments of the coastline position have caused destruction to the coastal environment; this has influenced the socio-economic life of the neighbourhood populace, hence, threatening cultural heritages (Appeaning Addo *et al*., 2012). Ghana's coastal zone is 7% of the total land region (Armah, 1991). The coastal zone of Ghana describes a dense populace (Ghana Statistical Service, 2010). This vulnerable nature of Ghana's coastline has eroded. The coastal zone is low-lying and 30-metres, above ocean level, making it inclined to erosion; the degree and level of which relies upon the geography and the territory concerned (Appeaning Addo, 2009).

Over the temporal and spatial scales, the coastline of Ghana throughout the years has encountered changes (Dadson *et al*., 2016). These progressions show in the life of the local people. Ghana's coastline is described by economic activities, for example, fishing, salt mining industries, seaports harbours and oil and gas exploration. Social activities include residential infrastructure. The cultural perspective incorporates prominent archaeological and historical heritage sites. The proof of the loss of land along the coastal zone is a noticeable concern. The rates at which these coastlines are eroding have prompted a measure of land loss. The waves and currents have evacuated residue along the coastline of Ghana. The removal of these silt has uncovered the bedrocks. Eroding coastline affects human life and infrastructure (Anim *et al*., 2013).

Another impact of coastal erosion is flooding. Because of the low-lying nature of Ghana's coastline, the weakness of seawater immersing the coastal zones is a usual phenomenon. Reports propose that the eastern and the central sections of Ghana's coastline are more inclined to flooding (Armah & Amlalo, 1998). Over the earlier decades, sea levels have increased; this is the main consideration in coastal erosion analysis (Appeaning Addo, 2013). These cases referred to are like the impacts experienced at Teshie.

2.4 Geometric representation of the coastlines in the GIS database

Over the past decades, methods and data on coastline assessment have experienced changes (Taguchi *et al*., 2013). One of the heuristic tools used in analysing these changes of the coastlines are the geospatial tools (Remote Sensing (RS) and Geographic Information System (GIS)). Introducing GIS in recent years has changed analyses of coastal change (Morton *et al*., 2004). Pertaining to coastal analysis, the relationship, which exists between the historic coastline changes and the variability in the coastline assumes a key part in finding out the rate of erosion (Burningham & French, 2007). This depends on the past and current positions of the coastlines, which give information on the trends on the rates of change (Boak & Turner, 2005). GIS is a tool that gives not only statistical measurements but a source of the database for these coastlines (Lin & Pussella, 2017).

The coastlines are dynamic and due to this unique nature; it makes it difficult to give standard evaluations (Manno *et al*., 2016). This has been the condition throughout the decades with various analysts frowning on the variance of appraisals (Appeaning Addo, 2010; Norley, 2006; Mensah, 1997; Armah, 1991b; Ly, 1980). Ocean level rise, tidal waves and alteration in longshore currents have affected silt development. This influences the precision in assessing the coastline and recognising the hotspots (Gornitz *et al*., 2005).

Because of the anomalies with the appraisal, terms were given; categorising two stages of identifying the coastline; the selection and definition, of a coastline indicator that acts as an intermediary for the land-water interface (Boak & Turner, 2005). But the most used method for coastline identification is the mechanical visual interpretation of aeronautical photography or on the field (http://www.fao.org/docrep/003/t0446e/t0446e04.html). Using the aeronautical photos and T-sheets; the extraction of coastline position from these information sources included georeferencing maps or elevated photos and along these lines analysing and digitising coastline positions (Morton *et al*., 2004; Komar, 1998).

The National Oceanic and Atmospheric Administration of the United States of America was the primary source that went before the use of Global Positioning System and LIDAR (Light Detection and Ranging) innovation (Hapke, 2011). Based on the cost and accuracy the analytical photogrammetry brings to bear, it makes its acquisition the best primary method for coastline mapping (Ali *et al*., 2010). Despite the frequency with which the coastlines are analysed, there is always a concern with the rates at which these coastlines are changing (Appeaning Addo, 2010). This is because of the advancement in data collection techniques, which include Global Positioning System, photogrammetric sensors and other weather and coastal sensors. This has translated into efficient and economical coastline mapping methods (Li *et al*., 2001; Merchant, 1994). The developments in RS technologies regarding air/space-borne and land-based techniques have added to the wide range of modern sources of data (Thieler *et al*., 2009). Geographic Information System (GIS) allows for archiving data sources and reproducing works either by manual digitisation or scanning (Morton *et al*., 2004).

Usually, history on the coastline gives data to assess the rates of change (erosion or deposition). This is fundamental in finding out the zones, which are confronting erosion issues (Thieler *et al*., 2009; Thieler & Danforth, 1994). According to Crowell (2006), because of headway in innovation, coastal mapping has changed in recent decades. Institutionalisation is key regarding science but the never-ending progression (the change in coastal information processes and capacity abilities) keep changing, hence, a lack of assessing coastlines (Moore, 2000). Besides, each innovative source accompanies its favourable circumstances and weaknesses. Thus, the information sources and assets availabilities rely on these elements. A summary of these information sources encourages a database of coastline positional data to show the changes and show erosion 'hotspots' (Douglas & Crowell, 2000). By determining hotspots precisely is a blend of uncertainties but based on the accessibility of information, spread over longer periods (Nguyen *et al*., 2010).

Based on the temporal scales, the dynamics could either be looked at in the short or long periods (Boak & Turner, 2005). A shroud of doubt surrounds the outcomes of coastal erosion 'hotspot' when they do not span over long periods of time (Appeaning Addo, 2009). Within a time frame of 60 to 80 years analysis, Crowell *et al*. (1993), determined coastal erosion ‘hotspots’. Appeaning Addo (2009), used a 98-year period to identify the hotspots within Accra’s coastline. Accra‘s coastline is receding between 2 m/yr and 10 m/yr (Norley, 2006; Armah, 1993a; Nail *et al*., 1993). About the coastline of Ghana, geospatial information, which include a map of Ghana delivered by CTK Aviation in 2002, bathymetric maps from Ghana Ports and Harbour Authority delivered in 1904 and topographic maps delivered by the Survey Department of Ghana in 1974 and 1996, form the database in ArcGIS for assessing the coastline of Accra (Appeaning Addo & Lamptey, 2013).

The requirement given within the GIS allows for an extension of the Digital Shoreline Analysis System (DSAS). This extension comes with statistical computations used in assessing the coastline. The statistical methods include techniques such as End Point Rates, Linear Regression Rate and Net Shoreline Movement (Doyle & Adams, 2015; Morton *et al*., 2004). Shoreline Change Envelope, Net Shoreline Movement, Linear Regression Rate and End Point Rate are the common measurable techniques utilised in the coastal investigation (Himmelstoss, 2009). Shoreline Change Envelope (SCE) calculates the distance of coastlines from the most distant and nearest to the benchmark at each transect. Net Shoreline Movement (NSM) calculates the dates of just two coastlines and reports the separation between the most distant and nearest coastlines for each transect. End Point Rate (EPR) determines coastline development when passed between the most distant and nearest coastline. The EPR is the least difficult approach utilised as a part of coastal erosion examination as it utilises just two coastline positions for the count. This may cause inaccurate coastline computations. Again, helpful data on intermediate coastline morphology is a major opportunity in the analysis (Dolan *et al.*, 1991). Linear Regression Rate (LRR) measures by fitting slightest squares relapse lines to the coastlines, which focuses on a specific transect.

Regarding the aim of this research, four historic coastlines served as bases of assessment. Appeaning Addo *et al*. (2008), referred to four historic coastlines as a typical and standard practice for coastline analysis. In determining the rate of change, the increase in the number of coastlines showed less deviation when compared with those with fewer coastline records. For example, Gibeaut (2003), executed a rate of progress of the Galveston Bay System from 1930 to 1995 utilising four coastline positions. Morton *et al*. (2004), assessed the normal rate of coastline change along the Gulf of Mexico from 1930 to 1980 utilising four informational indexes. A traverse from 1885 to 2002 saw Dickson *et al*. (2007), survey the rate of change in North Norfolk (UK) utilising four informational indexes. These helped the coastline assessment. Concerning short periods, techniques used as regards the annual variations of a period should not be under 10 years (Anfuso *et al.*, 2007). In developing countries, assessing the position and ‘hotspots’ within the coastline is a challenge, where there are no data sources (Appeaning Addo, 2009).

2.5 Theory underpinning: risk perception

To explain the findings, the study adopted risk perception as the theoretical framework. This informs the research questions. Risk perception as a theory should help one understand what informs one's perceived risk. Risk perception can consider a person's impression since a specific danger may cause death or property loss (Bradford *et al*., 2012). More formal definitions which exist in literature. For example, Slovic (2000), defined risk perception as the natural judgement of people and groups, of dangers about limited and uncertain information. Raijmakers *et al*. (2008), show this definition and characterise perception as the relationship of a particular arrangement of hazard attributes: awareness, worry and preparedness. Expanding any or a blend of these raises the view of hazard and this adds to curbing coastal erosion.

Risk perception is based on two factors, which include cognitive and situational (Tobin & Montz, 1997). These factors are related since the situational factor shows the physical location of the coastal zone whiles presenting the hazards. The cognitive elements, show the individual's psychological and behavioural traits, which account for particular emotions evoked by coastal erosion and its effects on socio-economic activities (Bradford *et al*., 2012). Therefore, what the theory shows is merged into this conceptual framework (Figure 2.1). Meaning, the causes (A) show the situational factors while the control (D) and lead to (C) shows the cognitive factors.

2.6 Conceptual framework

A conceptual framework is a heuristic tool for project management and often serves as a framework for studies. The framework provides relevance to the issues of coastal erosion. The conceptual framework by Cai *et al*. (2009), gave relevance to the natural and human factors that affect the shoreline. Based on the conceptual framework, this research further established shows four (4) sections, which conceptualises the issues in the study area. Box (A) causes, describes the natural (include but are not limited to waves, winds, tides, climatic change and nature of the coastline) and human factors (include but are not limited to sand mining, coastal infrastructure/ engineering). This box elaborates the causes of erosion of the coastline. This leads to the effects (B), which include the loss of natural resources and social infrastructure (lands, mangroves and wetlands, landing beaches, beaches, reducing sediment supply, house, communities and businesses). These effects impact the socio-economic activities (C) and this has led to migration, loss of social identity, poverty, unemployment, isolation of communities and homelessness. The control (D) entailed education, sea defence, groyne schemes, policy alleviation fund and insurance policy. The activities undertaken in boxes (D and A), effect boxes (B and C) (Figure 2.1).

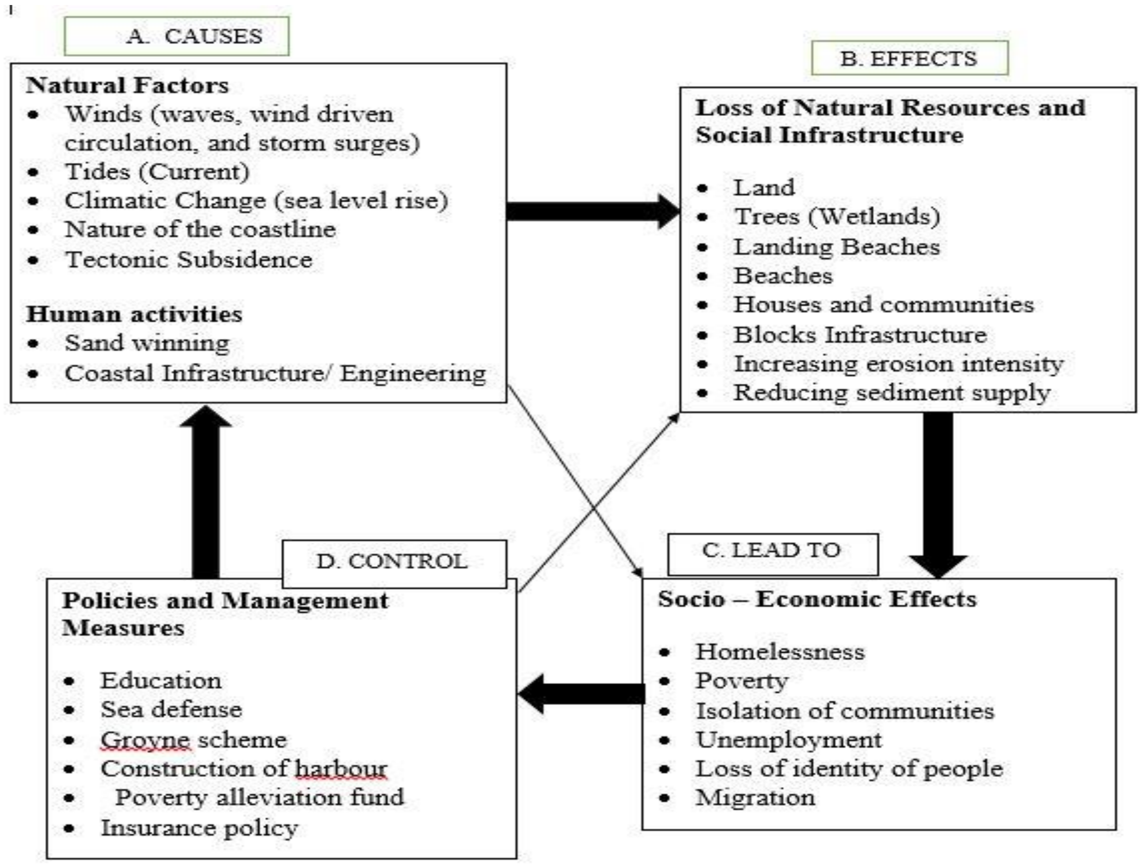


Figure 2.1 Framework showing the relationship between the causes, effects and coping strategies. (Source: Cai *et al*., 2009)

Based on the conditions of the Teshie coastline and what this research assessed; the conceptual framework will guide the results and findings of this study.

2.7 Chapter summary

The chapter reviewed the related literature and the conceptual framework adopted for the study. These were sorted out into two subsections. The first section focused on reviewing literature on several themes including coastal erosion, causes of coastal erosion, effects of coastal erosion and geometric representation of the coastlines in the GIS database.

The second section focused on the conceptual framework modified for the study. The study modified the coastal erosion framework from Cai *et al*. (2009). The framework was generally described with its causes, effects, lead to (socio-economic effects) and control and its relevance to the study.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.0 Introduction

This chapter presents literature on the study area and the methods, which guide this study. The study area presents issues on the location, geology, climatic conditions and the livelihood conditions of the people. The methods dwelt on issues of the philosophical underpinning, which gave the insight to research strategy and research design; data sources, sample size and distribution, image extraction and processing, detection of erosion hotspots and data analysis.

3.1 Study area

3.1.1 Location

Teshie is in the Ledzokuku-Krowor District in the South-Eastern part of the Greater Accra Region. The delimitation of the southern boundary of the district is between the Kpeshie Lagoon and Songor Lagoon. The eastern boundary joins the Accra-Tema road to the Nungua Police Barrier. The northern boundary connects the Ashaiman road and the Spintex Road. The western boundary connects the south-end of the Motorway and the estuary of the Kpeshie Lagoon (Figure 3.1) (Ghana Statistical service, 2010).

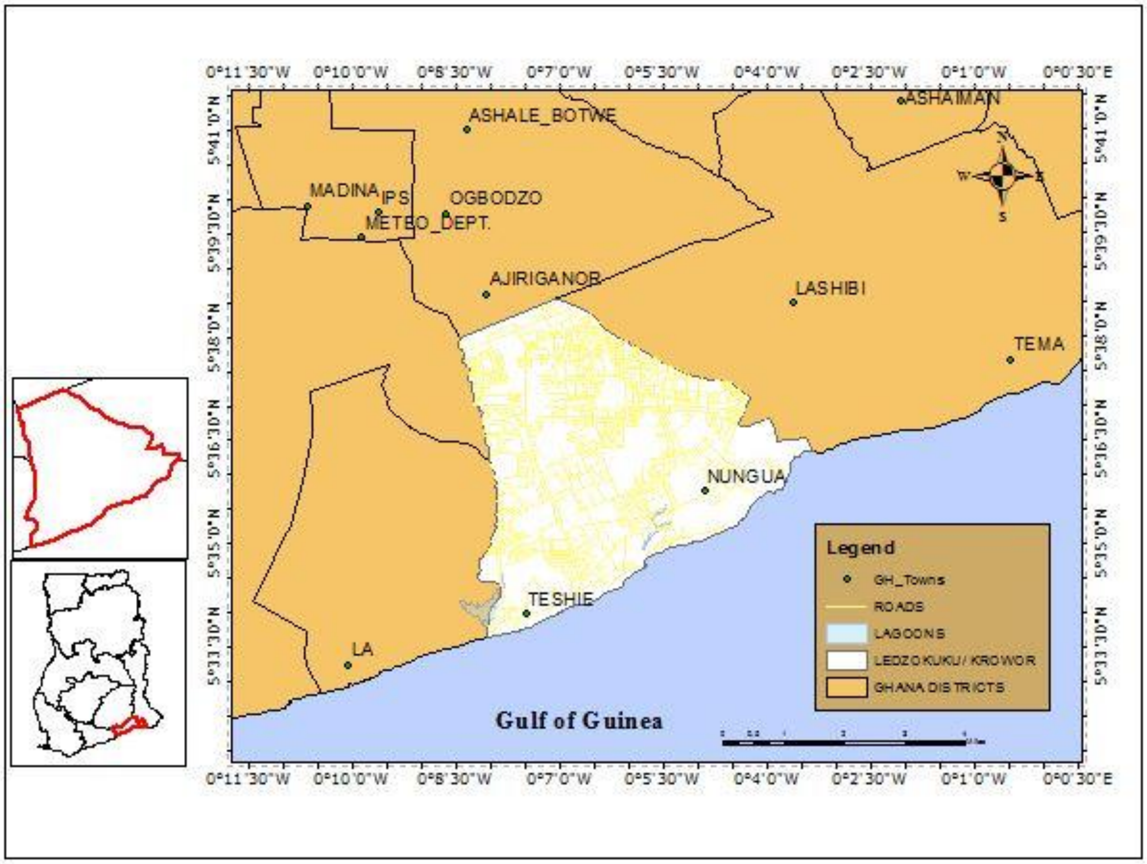


Figure 3.1 Map of the study area.

3.1.2 Geology

The geology is characterised by rocks formed within the Paleozoic era. Based on the geology, the coastline of Teshie comprises the Accraian series, which make up sandstone, shale and laterite. The prevailing rocks along Teshie's coastline differ in structure and property. This shows in their tenacity and endurance from the actions of waves, which sweep the coastline (Dickson & Benneh, 1998).

The basis for the morphological configuration of Teshie's coastline is the geology (Appeaning Addo, 2010; Ly, 1980). Associated terraces, sandy beaches and sea cliffs, landforms within the landscape, have shaped the present status of the coastline (Inman & Nordstrum, 1971). Thus, the coastal evolution may be termed as a Markovian process, which seeks to explain the morphodynamics (Appeaning Addo, 2009).

The Accraian rocks are in three (3) forms the upper sandstone-shale, the middle sandstone-shale and the lower sandstone-shale. The upper sandstone-shale is prone to erosion than the middle sandstone-shale and the lower sandstone-shale. The bonding is much stronger between the middle sandstone-shale and the lower sandstone-shale than the upper sandstone-shale and middle sandstone-shale (Appeaning Addo, 2010; Muff & Efa, 2006). The characteristics of these rocks show high variability (Dickson & Benneh, 1998). These characteristics, regarding the geology, shows the different features of the study area; thus, the differences accounting for the rate and extent of change of Teshie's shoreline.

3.1.3 Climate

The climatic conditions include wind, rainfall, currents and waves. These characteristics describe the conditions of a place and Teshie is no exception. The Teshie coastal zone has a narrow continental shelf of (50 - 65 km), with no protection of the coast from the ocean waves (Appeaning Addo, 2009). The winds which sweep the shores of the study area are the South-Westerly Monsoon with slight sea breezes between speeds of 0.5 metres per second (m/s) at night and 1.5–2 m/s at day (Allersma & Tilmans, 1991). The flow of the Guinea current offshore, within the continuity of the Equatorial current, runs from west to east (Benneh & Dickson, 1995). With a velocity between 0.5 m/s (0.7 m/s max.) during winter (dry season) and 1 m/s (1.5 m/s max.) during summer (rainy season) (Quashigah, 2011; Sorensen *et al.*, 2003; Allersma & Tilmans, 1991).

About climatic zonation, the study area is within the dry equatorial climatic zone, which shows a change in terms of the level and seasonal distribution of the precipitation (Allersma & Tilmans, 1991). The study area experiences two major winds comprising the South-Westerly Monsoon winds, which bring rains from the Gulf of Guinea; the dry and dusty North-Eastern Trade Winds take roots from the Sahara Desert to the coast. A double maxima rainfall pattern characterises the region with 700 millimetres (mm) in the first rainy season between May and June and 770 mm in the second rainy season between October and November. The average yearly temperature of the Teshie coastal territory is between 25.1 ˚C and 28.4 ˚C. (Dickson & Benneh, 1998). Two sorts of waves sweep the shores of the study area: waves framed via the frail local monsoon winds and the waves produced by storms from the southern section of the Atlantic Ocean (Wellens-Mensah *et al.*, 2002). A Global wave by Svašek Hydraulics (2006), using a directional wave float indicated that normal wave height for the territory between 1997 and 2006 is 1.39 m but could attain heights of around 3 m (Appeaning Addo, 2010). These climatic characteristics show the natural causes and how they affected the coastline and activities along the coast over the stipulated timeframe. Amidst the climatic elements, climate change and flooding, these factors have altered shorelines globally and Ghana's shoreline is no exemption; this has affected the rate and extent of change.

3.1.4 Socio-economic characteristics

With a population of 227,932, Teshie is the ninth most populous settlement in Accra (Population & Housing Census, 2010). Teshie has a land area of around 47, 57510 square kilometres (km^2). Fishing forms the main source of livelihood to inhabitants of the coast and it supports over 50% of the adult population. The other economic undertakings include petty trading, artisanal fisheries and mariculture (http://www.statsghana.gov.gh/docfiles/2010_District_Report/Greater%20Accra/LEKMA.pdf).

3.2 Philosophical underpinnings

Philosophy has become an underlining basis in many disciplines and establishes clarity of concepts, which transcends many disciplinary boundaries while asking pertinent issues that seek the truth (Haferkamp & Smelser, 1992). Philosophical assumptions are starting points for research, dependent on the research understudy (Teye, 2012). Often, beginning with abstract thought and the ordinary ideas, which life presents the researcher with, from which solutions are sought as findings (Emmett, 1964).

The perspective of any research enquires what acceptable knowledge is. It tries to gather information on the general worldview of human understanding according to the same principles, procedures (interpretivism) and ethos such as the natural science (positivism); this is based on the pragmatists' viewpoint (Meetoo & Temple, 2003).

The positivist approach is like natural science, which believes in real facts that are pieced together by an impartial scientist (Teye, 2012). The natural sciences use closure to develop scientific knowledge - impartial and value-free. The quantitative part of the work applies the DSAS and questionnaires, in finding out the scientific result. This is to give statistical rates at which the coastline is eroding and the number of people who have been affected by coastal erosion. Hence, the accuracy that comes with the scientific approach is objective. The interpretivist approach is based on the outcome of believing individuals have a shared existence through, in which identities are constructed. Thus, what is real is the product of our interpretations (Creswell, 2009). Therefore, the socio-economic impacts were addressed using interviews, showing the views of the locals. People's perceptions, experiences and accounts of the challenges they face regarding the socio-economic effects give a representation of the many vulnerable issues. Thus, this research was guided by both the positivism and interpretivism approaches.

3.2.1 Research design

The research adopted a case study approach, which sought to give a detailed and intensive analysis of the study area. This research aims to assess coastal erosion and how it has affected livelihoods socio-economically. The study emphasises the quantitative and qualitative methods. Further, the rates of erosion used a statistical procedure within the DSAS; the Statistical Package for the Social Sciences (SPSS) for questionnaires used the quantitative part of the research while qualitative research method focused on the perspectives on the effects of coastal erosion on socio-economic and cultural activities and the coping strategies. The qualitative research included experiences and perception. Based on the literature, human activities have had a substantial impact on the coastline aside the natural causes. Considering this, a mixed method which joins the prowess of both quantitative and qualitative was engaged in this study (Bazeley, 2004; Bryman, 2001).

3.2.2 Research strategy

Tashakkori and Teddlie (2010), indicated four different characteristics which established the mixed research method. They include applying both the qualitative and quantitative methods in particular research. This is based on a choice of the sequence of adopting the two research designs (Creswell, 2009), concurrent or transformative, an explicit account detailing how the qualitative and quantitative research relates, with emphasis on the triangulation method adopted.

The quantitative technique emphasises measurements for dissecting quantifiable information valuable for speculations and forecasts. Another capacity is the model determination and connections between various factors (Castro *et al.*, 2010). Despite these qualities, the quantitative research approach has a limit when it concerns clarifying behaviours and perceptions recognition (Teye, 2012). Thus, a tendency to cut off discoveries from genuine conditions (Moghaddam *et al*., 2003).

The qualitative research strategies, which involve participant observation, interviews and in-depth interviews give detailed results on discernment, feelings, convictions, conduct and encounters with the respondents (Bryman, 2001). The researcher's experience had a great influence on the research. Due to the different realities of the world, the triangulation of a mixed method was used, to give a better understanding of the issues (Sharan, 2002).

3.3 Data sources

This study collected data from two main sources. These were the primary and secondary data sources. Primary data was obtained through the administration of questionnaires and in-depth interviews. The primary data probed into the perceptions of residents on coastal erosion, the socio-economic effects on coastal erosion the residents and the coping strategies adopted and management measures by the government.

Secondary data, on the other hand, was obtained from websites, reports, books, journals and articles, newspapers, brochures, magazines and any other relevant sources. Landsat imageries were obtained from the GIS unit at the Department of Geography and Resource Development, Legon.

3.3.1 Qualitative data

Regarding the qualitative source of retrieving data; a purposive sampling method was ideal because this research intended to interview key informants who gave information on the Teshie coastline. Hence, this meant first-hand information on the challenges encountered, with residents and workers who live and ply their trade along the coast. In-depth interviews were conducted with residents with over 25 years stay using an interview guide. The reason is that a period of a 25-year window helped respondents make value judgements on the questions on the perception of erosion, the socio-economic and cultural (causes and effects) and measures put in place to discuss the issues.

3.3.2 Quantitative data

The research used GIS and RS software (ArcGIS 10.4 and ENVI 5.0) in the data analysis. Landsat images were used for this research. Four-year periods (LANDSAT TM 1986,

LANDSAT TM 1991, LANDSAT ETM 2003, LANDSAT ETM 2016), which span a 30-year frame were chosen. These year periods were chosen since it helped in the comparative analysis of the different time periods and the rates of erosion. The year differences between these satellite images are five (5), twelve (12) and thirteen (13). Calculated rates of change indicated fewer deviations influencing the use of increasing numbers of the historic coastlines (Morton *et al*., 2004). When it concerns short periods, techniques used should not be less than 10 years (Anfuso *et al*., 2007).

Five main communities were selected purposively in collecting data for the study. These were Teshie Songor (Aligaanor), Krobor, Akoblem, Gbugbla and Lenshie. These communities were selected because of their engagements in the area regarding the focus of the study. The quantitative data for the study was obtained using semi-structured questionnaires. The questionnaire was used to solicit data from respondents in the communities. The questionnaires were organised around four main areas by taking the objectives of the study into consideration. The thematic areas were the demographic and socio-economic profile of respondents, local people's perceptions of erosion, socio-economic effects of coastal erosion and the coping strategies adopted by locals and management measures by the government.

3.4 Sample size and distribution

For the qualitative perspective, 10 stakeholders were chosen for the interview. The stakeholders included the chief fisherman, fishermen, residents, inns/guesthouse administrators, Municipal Assembly, Traditional authorities and an officer from Environmental Protection Agency-Ghana (EPA). The prominent roles the stakeholders hold and their opinions on the Teshie coastline helped in this research. Interviews do not require a large sample size, rather, the emphasis is placed on the process and meaning and in-depth knowledge on the topic. Based on the language barrier, with concerns to the locals, the interviews were conducted in Ga. The simple random sampling technique was used in selecting respondents for the questionnaire survey. The simple random sampling techniques helped the researcher to accrue different views from different backgrounds (age, income, length of stay and marital status). It is distinguished as a technique for selecting sample sizes from heterogeneous populations.

Regarding the questionnaires, sample size was required. Based on the statistics of the 2010 Population and Housing Census, 227, 932 was given for the inhabitants of the Teshie coastal area. Using Yamane's (1967) formulae;

$$n = \frac{227{,}932}{1+227{,}932(10\%.)^2}$$

Where, **n** = sample size,

N = population size (227,932) and

e = level of precision or sampling error: ± 10%.

The result given as a sample size for analysis was 99. Ninety-nine (99) represents n, which denotes the number of respondents for questionnaires to be administered to. As regards quantitative studies, large sample sizes are needed for quantification and representativeness of the sample (Bazeley, 2004). This is to make sure populations are represented in the study to allow for more rigorous analyses and interpretations (Teye, 2012). In order to increase the representativeness and ease of generalisation, the researcher rounded up the sample size from 99 to 150.

The questionnaires were administered to (5) areas of Teshie. These communities selected included Teshie Songor (Aligaanor), Krobor, Akoblem, Gbugbla and Lenshie. 30 questionnaires were allocated to Teshie Songor (Aligaanor), 40 for Krobor, 20 for Akoblem, 40 for Gbugbla and 20 for Lenshie summing up to 150 questionnaires distributed to targeted respondents.

3.5 Method for image extraction and processing

The Landsat images were obtained from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov). The Landsat images are at a resolution of 30 m. The image data sets acquired include (LANDSAT TM 1986, LANDSAT TM 1991, LANDSAT ETM 2003, LANDSAT ETM 2016). The images acquired were between the months of December and February. The reason for this was because of the low cloud cover and the reduced seasonal effects. Hence, more clarity to analyse features within the study area. The images were already radiometrically and geometrically corrected and projected to World Geodetic System (WGS) 1984, Universal Transverse Mercator (UTM) zone 30 ˚N. A shapefile was created for the Teshie coastline for the various years and a geodatabase created in ArcCatalog. The coastlines were appended to a single file in the geodatabase after their attributes had been added to their respective tables. A baseline was created offshore through manual digitisation in the same coordinate system of the satellite images. The baseline constructed was maintained for the periods of analyses. Transects were cast perpendicular to the baseline. The extent and rate of change between the periods were calculated using LRR. LRR method gives the rates of regression of three coastlines or more. To ensure consistency with the statistical result, the error rate was pegged at 0.01. The EPR and NSM determined the rates of change and distance between two coastline positions; these were used in calculating the year periods of two coastlines.

3.6 Method for detection of erosion hotspots

After the coastlines were transected and rates of erosion calculated, the coastline for the years 1986, 1991, 2003 and 2016 were clipped with the transected and intersecting statistics generated. The new clipped layer was joined to the statistical rates of erosion. The symbology allowed a visual depiction of the various hotspots within the coastline.

As regards this research, the coastline was divided into 3 major sections arbitrarily based on equidistance. The justification for this division is with the view of addressing the research question on the hotspots within the coastline. This helped categorise the Teshie coastline, to know which section is eroding faster. The following formulae show how the level of the eroding segments was deduced:

$$\left(\frac{\text{the sum of eroding rates [Linear Regression Rates]}}{\text{number of transects}} \text{ x } 100\right) \text{------------ (Equation 1)}$$

$$\left(\frac{\text{the sum of eroding rates [Linear Regression Rates]}}{\text{number of eroding transects}} \text{ x } 100\right) \text{------------ (Equation 2)}$$

$$\left(\frac{\text{the sum of eroding rates } (<) -0.47 \text{ [Linear Regression Rates]}}{\text{number of eroding transects}} \text{ x } 100\right) \text{---(Equation 3)}$$

3.7 Ethical considerations

The role of ethical consideration in research cannot be undermined. It ensures credibility, validity and integrity of research. Therefore, the ethical concerns of the respondents were duly observed during this study. In the first place, respondents were informed that their consent was needed and that participation was voluntary during the administration of questionnaires and other field activities that involved the respondents. The objectives of the study were spelt out to the participants and that no monetary or material benefit is to be expected from the researcher. As a way of ensuring and protecting the anonymity of key informants, pseudonyms were used to represent the identities. Participants were assured that their responses to questions will be kept confidential.

3.8 Data analysis of social survey data

The quantitative data was coded and entered into the Statistical Package for Social Sciences (SPSS) version 23 software. Tables and graphs were generated to aid in data analysis. This helped to identify the perceptions of respondents concerning the socio-economic effects of coastal erosion on the locals and the coping strategies adopted by locals and the management measures by the government. DSAS was used to compute for the rates and ranges of the coastal erosion. These retrieved data were presented in graphs.

The qualitative data included the results of interviews, which were transcribed into word documents and categorised into various themes. The themes together with thorough readings of the transcripts supplement the quantitative data to identify the reasons people make certain choices and perception with regard to coastal erosion.

3.9 Chapter summary

Chapter three was devoted to the study area and the methodology. The discussion of the chapter looked at the study area, providing a general background of the location, geology, climate and socio-economic characteristics. The methodology discussed under the following themes includes the philosophical underpinning that guided the research design, the research strategy, data sources, quantitative and qualitative data collection methods, sampling size and distribution, ethical considerations and data analysis.

CHAPTER FOUR

ANALYSIS ON THE RATE OF COASTAL EROSION AND HOTSPOT IDENTIFICATION

4.0 Introduction

In line with the objectives, this chapter provides results on the average shoreline change rates and erosional hotspots. The position of the coastline was analysed according to the different years. Hotspots analysis complements the erosion rate, by recognising the sections of the coastline experiencing high rates of coastal erosion.

4.1 Analysis of the extent of coastal erosion at Teshie between 1986 and 2016

In the evaluation of the Teshie coastline, four (4) shorelines were extracted from the satellite images. The shoreline positions and change rates were calculated for the periods of 1986, 1991, 2003 and 2016. The results show changes along the entire coastline during the 30-year period under investigation. Five Hundred and eight (508) transects were developed at a 20 m interval. The average erosion rate for the study is 0.41 m/yr and 0.52 m/yr for accretion; the range of erosion is -2.51 m/yr and 2.85 m/yr; where negative values represent erosion and positive values represent accretion (Figure 4.1; Appendix 1). The evaluation conducted between 1986 and 2016 revealed that 40.67% of the entire coast was experiencing erosion with 59.33% accreting or stable.

Table 4.1 Teshie shoreline average rates of (End Point Rate (EPR) & Net Shoreline Movement (NSM)) from 1986 to 2016.

Time Frame of Shoreline Change	Period of Analyses	Average End Point Rate (EPR) (m/yr)		Average Net Shoreline Movement (NSM) (m/yr)	
		Erosion	Accretion	Erosion	Accretion
1986 - 1991	5	-2.42	4.18	9.89	17.07
1986 - 2003	17	-0.55	0.89	8.87	14.31
1991 - 2003	12	-1.17	0.81	14.16	9.74
1991 - 2016	25	-0.64	0.54	15.92	13.55

2003 - 2016	13	-0.93	0.85	11.94	11.05

Source: Author, 2018

The period between 1986 and 1991, showed that the change rates (EPR) ranged between -8.52 m/yr to 32.81 m/yr. The period experienced an average erosion rate (EPR) of -2.42 m/yr and an average accretion rate of 4.18 m/yr. The change rates (NSM) ranged between -34.78 m and 133.95 m. The period experienced an average erosion (NSM) of 9.89 m and an average accretion (NSM) of 17.07 m.

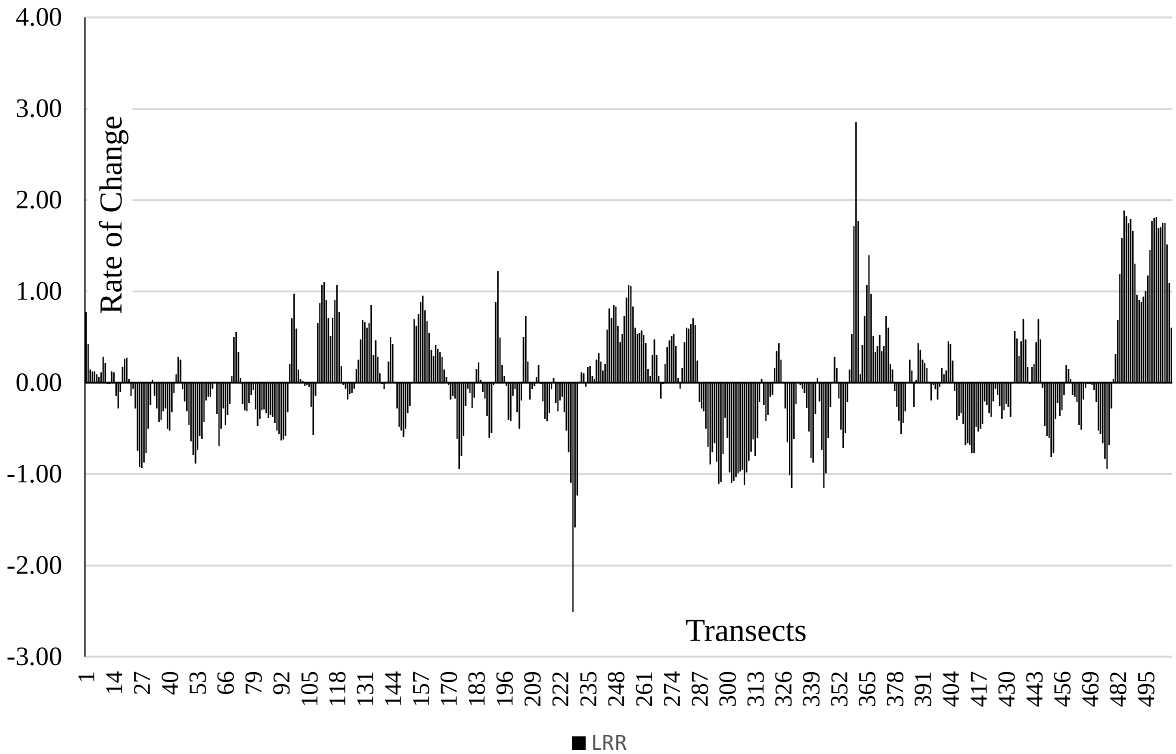
The period between 1986 and 2003, showed that the change rates (EPR) ranged between -2.10 m/yr and 4.43 m/yr. The period experienced an average erosion rate (EPR) of -0.55 m/yr and an average accretion rate of 0.89 m/yr. The change rates (NSM) ranged between -33.96 m and 71.70 m. The period experienced an average erosion (NSM) of 8.87 m and an average accretion (NSM) of 14.31 m.

Between 1991 and 2003, showed that the change rates (EPR) ranged between -9.29 m/yr and 2.49 m/yr. The period experienced an average erosion rate (EPR) of -1.17 m/yr and an average accretion rate of 0.81 m/yr. The change rates (NSM) ranged between -112.29 m to 30.07 m. The period experienced an average erosion (NSM) of 14.16 m and an average accretion (NSM) of 9.74 m.

This period between 1991 and 2016, showed that the change rates (EPR) ranged between -4.86 m/yr and 3.83 m/yr. The period experienced an average erosion rate (EPR) of -0.64 m/yr and an average accretion rate of 0.54 m/yr. The change rates (NSM) ranged between -121.53 m and 95.72 m. The period experienced an average erosion (NSM) of 15.92 m and an average accretion (NSM) of 13.55 m.

This period between 2003 and 2016, showed that the change rates (EPR) ranged between -4.80 m/yr and 7.66 m/yr. The period experienced an average erosion rate (EPR) of -0.93 m/yr and an average accretion rate (EPR) of 0.85 m/yr. The change rates (NSM) ranged between -61.95 m and 98.90 m. The period experienced an average erosion (NSM) of 11.94 m and an average accretion (NSM) of 11.05 m.

In summary, the periods between 1986 - 1991, 1991 - 2003 and 1991 - 2003 experienced more of accretion than erosion while the periods between 1991 - 2016 and 2003 - 2016 experienced more erosion than accretion. Thus, the period in review shows the accretion to be more than erosion.



4.2.1 Coastline change between 1986 and 2016

Figure 4.1 shows the historic trend between 1986 and 2016. This is a 30-year period showing the changes the coastline experienced within the time frame.

Figure 4.1 Linear Rate of Regression graph of 1986-2016.

4.2.2 Coastline change between 1986 and 1991

Figures 4.2 and 4.3 depict a historic trend between 1986 and 1991. This is a five (5) year period showing the changes the coastline experienced within the time frame. This period showed that accretion dominated the entire shoreline with 59.41% of the cast transects recording accretion while erosion was 40.59%. The change rates (EPR) ranged from -8.52 m/yr to 32.81 m/yr. The accretion rates (EPR) ranged between 0.01 m/yr and 32.81 m/yr. The erosion rates (EPR) ranged between -0.05 m/yr and -8.52 m/yr. The change rates (NSM) ranged from -34.78 m and 133.95 m. The accretion rates (NSM) ranged between 0.03 m and 133.95 m. The erosion rates (NSM) ranged between -0.22 m and -34.78 m. Erosion was rife between transects 331 – 467 and transects 5 – 12. Accretion occurred on the most part of the coastline, with most transects exceeding 5 m/yr. Transect 231 experienced the highest rate of accretion.

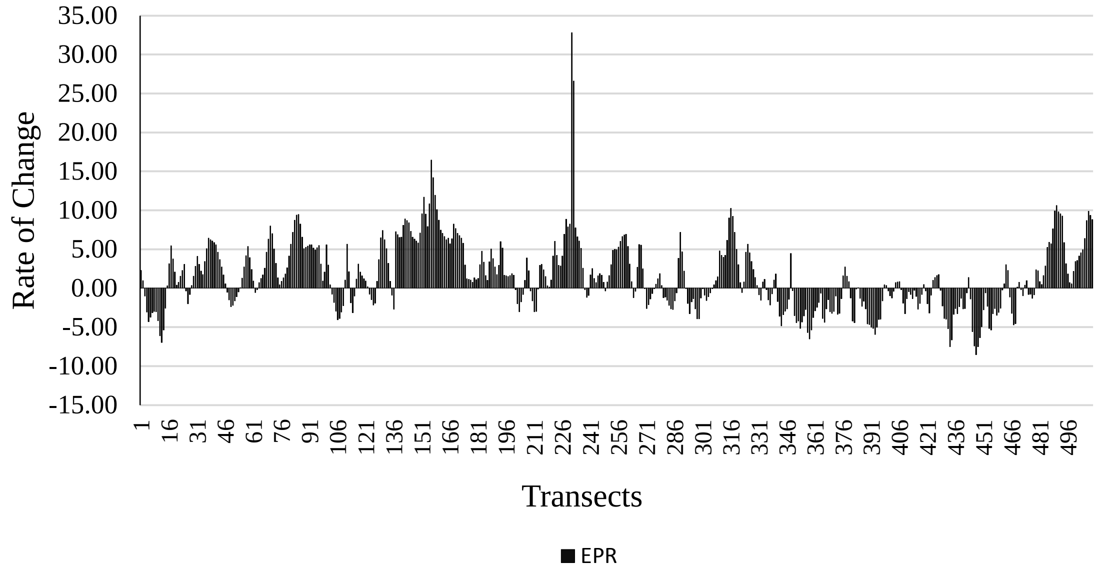


Figure 4.2 End Point Rate graph of 1986-1991.

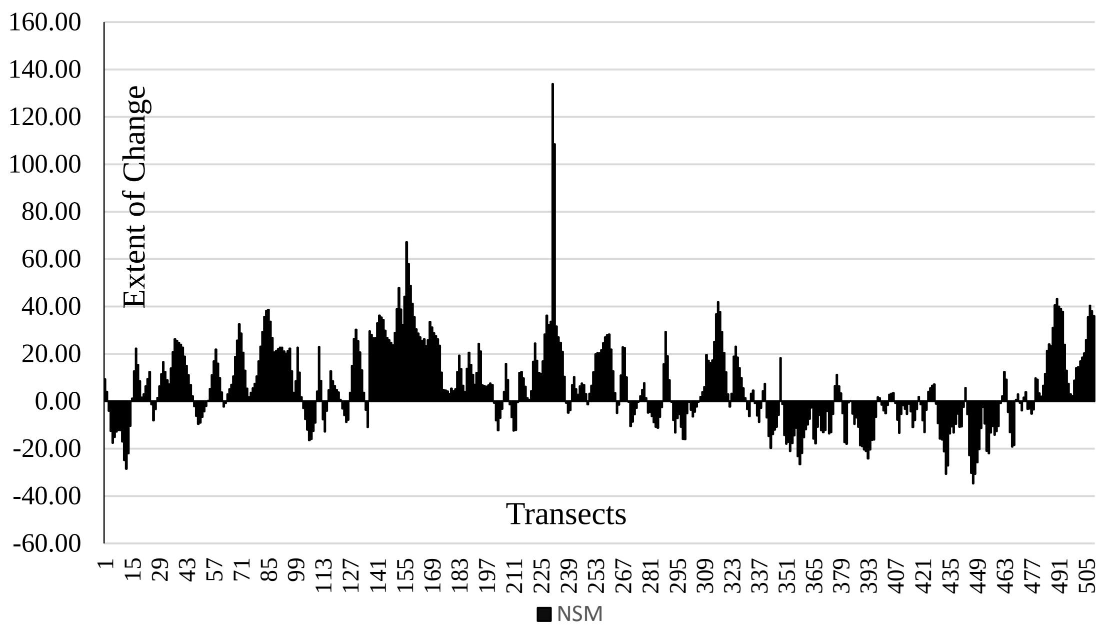


Figure 4.3 Net Shoreline Movement graph of 1986-1991.

4.2.3 Coastline change between 1986 and 2003

Figures 4.4 and 4.5 depict a historic trend between 1986 and 2003. This is a seventeen (17) year period showing the changes the coastline experienced within the time frame. This period showed that accretion dominated the entire shoreline with 56.69% of the cast transects recording accretion while erosion was 43.31%. The change rates (EPR) ranged from -2.10 m/yr and 4.43 m/yr. The accretion rates (EPR) ranged between 0.01 m/yr and 4.43 m/yr. The erosion rates (EPR) ranged between -0.01 m/yr and -2.10 m/yr. The change rates (NSM) ranged from -33.96 m to 71.70 m. The accretion rates (NSM) ranged between 0.09 m and 71.70 m. The erosion rates (NSM) ranged between -0.10 m and -33.96 m. Erosion was rife on the different sections of the coastline. Many parts of the transects, regarding erosion were found at -0.5 m/yr. Transect 189 experienced the highest rate of erosion. Based on the percentage of transects, accretion occurred in the most part of the coastline. Accretion was clustered in particular sections of the coastline. This is evident between transects 109 – 118, 136 – 166, 224 – 286 and 482 – 502. Transect 154 experienced the highest rate of accretion.

Figure 4.4 End Point Rate graph of 1986-2003.

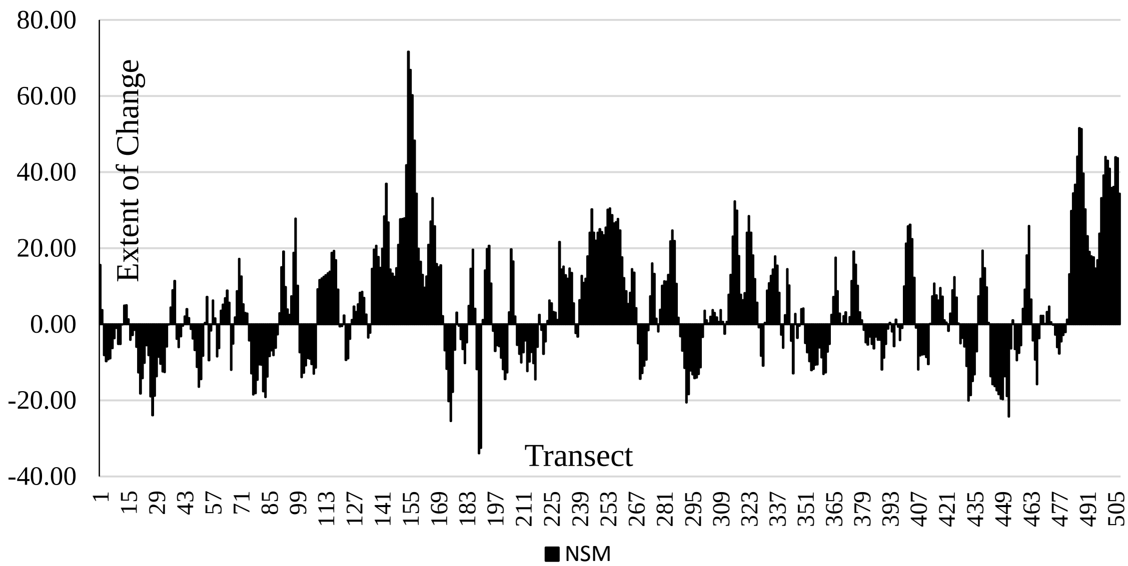


Figure 4.5 Net Shoreline Movement graph of 1986-2003.

4.2.4 Coastline change between 1991 and 2003

Figures 4.6 and 4.7 depict a historic trend between 1991 and 2003. This is a twelve (12) year period showing the changes the coastline experienced within the time frame. This period showed that accretion dominated the entire shoreline with 51.38% of the cast transects recording accretion while erosion was 48.62%. The change rates (EPR) ranged from -9.29 m/yr and 2.49 m/yr. The accretion rates (EPR) ranged between 0.01 m/yr and 2.49 m/yr. The erosion rates (EPR) ranged between -0.01 m/yr and -9.29 m/yr. The change rates (NSM) ranged from -112.29 m to 30.07 m. The accretion rates (NSM) ranged between 0.02 m and 30.07 m. The erosion rates (NSM) ranged between -0.07 m and -112.29 m. Erosion was dominant on the different sections of the coastline. The coastline showed most part of the Western section to be eroding while most parts of the Central and Eastern sections were accreting. The calculated average rate of erosion is -1.17. Transect 229 experienced the highest rate of erosion. Despite the high rates for the eroding transects, the percentage of the number of accreting transects was more.

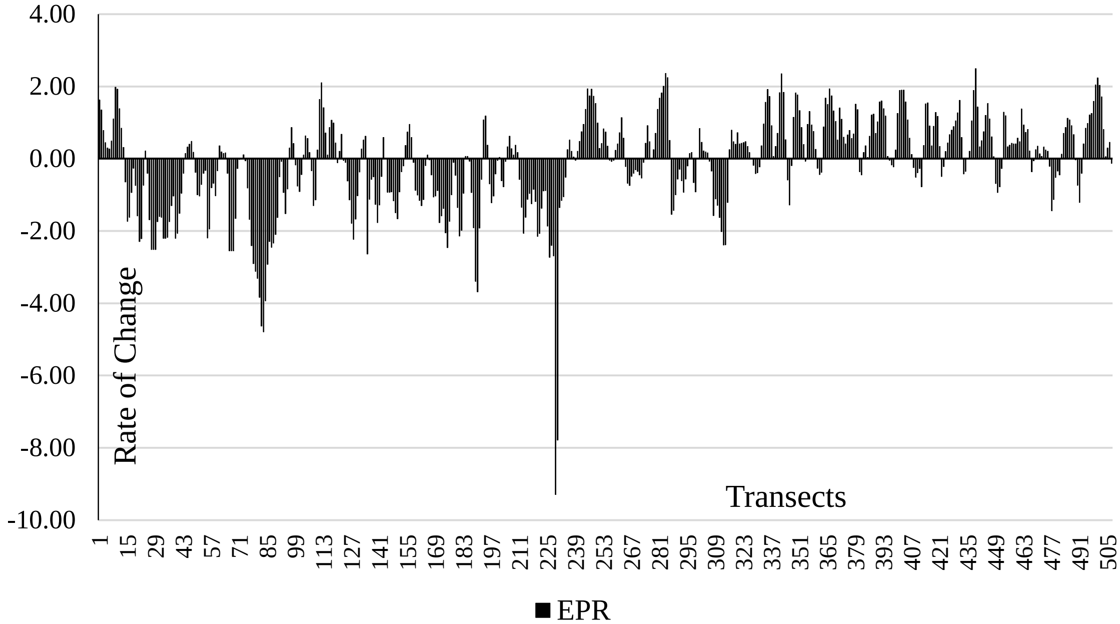


Figure 4.6 End Point Rate graph of 1991-2003.

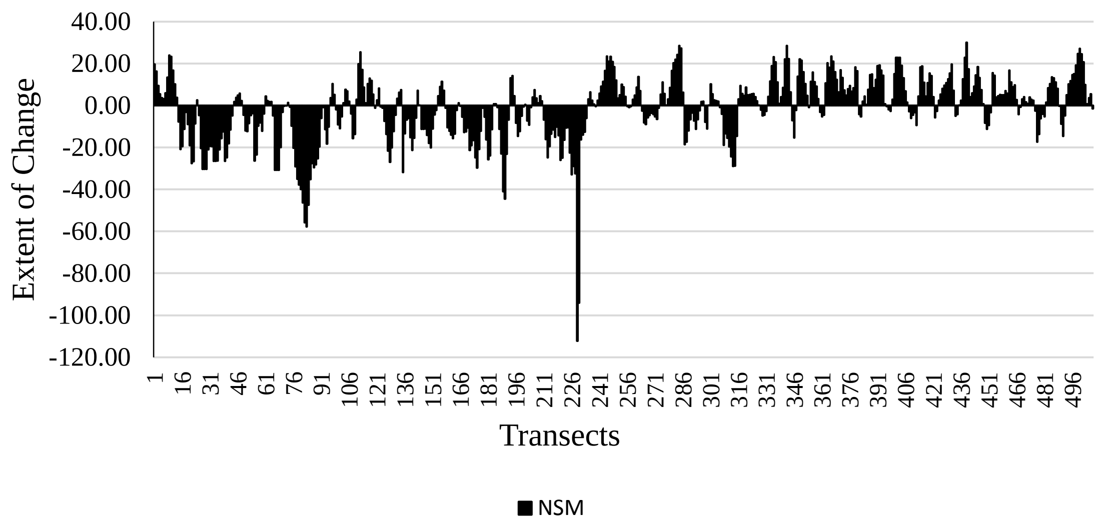


Figure 4.7 Net Shoreline Movement graph of 1991-2003.

4.2.5 Coastline change between 1991 and 2016

Figures 4.8 and 4.9 depict a historic trend between 1991 and 2016. This is a twenty-five (25) year period showing the changes the coastline experienced within the time frame. This period showed that erosion dominated the entire shoreline with 57.28% of the cast transects recording erosion while the accretion was 42.72%. The change rates (EPR) ranged from -4.86 m/yr to 3.83 m/yr. The accretion rates (EPR) ranged between 0.01 m/yr and 3.83 m/yr. The erosion rates (EPR) ranged between -0.01 m/yr and -4.86 m/yr. The change rates (NSM) ranged from -121.53 m to 95.72 m. The accretion rates (NSM) ranged between 0.12 m and 95.72 m. The erosion rates (NSM) ranged between -0.02 m and -121.53 m. Most parts of the coastline experienced erosion and this is affirmed by the percentage of the number of eroding transects. The coastline showed most part of the Central and Western sections to be eroding. Transect 229 experienced the highest rate of erosion. Erosion is clustered at sections of the coastline. This is evident between transects 15 – 94, 137 – 230, 286 – 345 and 404 – 424. Transect 360 experienced the highest rate of accretion. The period shows accretion between transects 481 – 502 and 97 – 134.

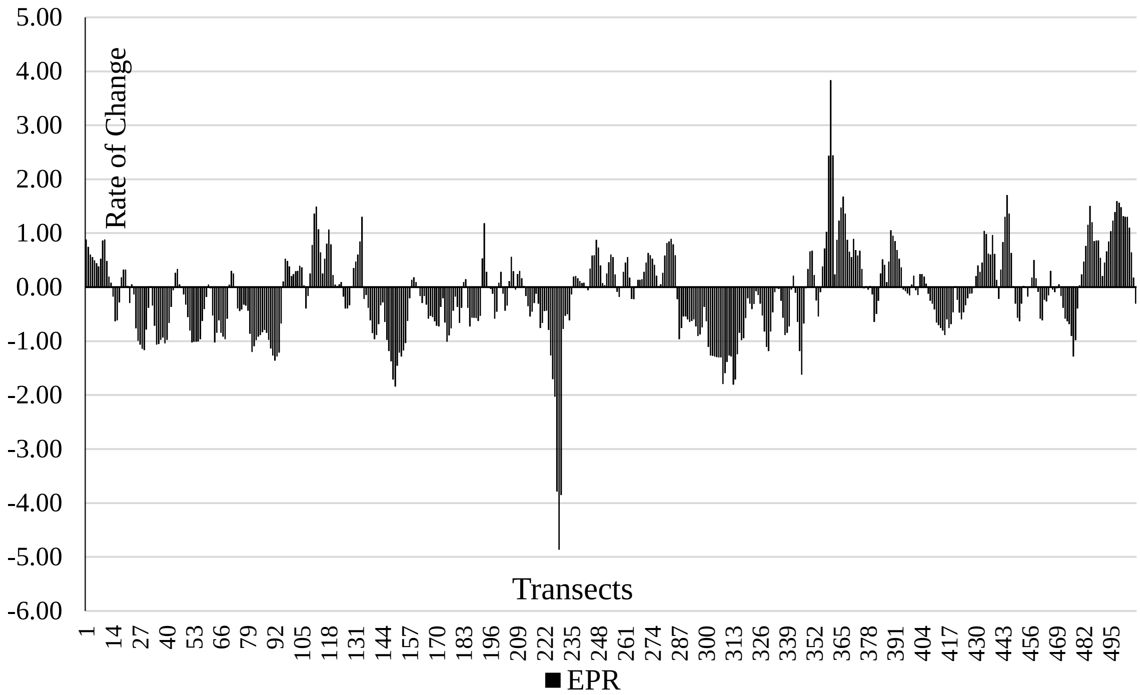


Figure 4.8 End Point Rate graph of 1991-2016.

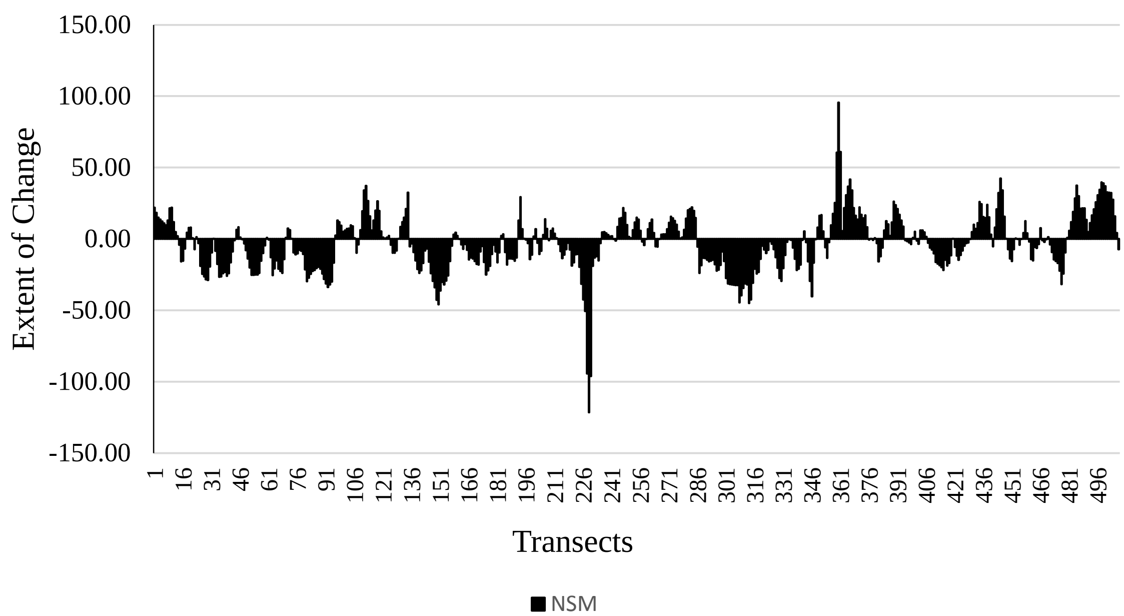


Figure 4.9 Net Shoreline Movement graph of 1991-2016.

4.2.6 Coastline change between 2003 and 2016

Figure 4.10 and 4.11 depict a historic trend between 2003 and 2016. This is a thirteen (13) year period showing the changes the coastline experienced within the time frame. This period showed that erosion dominated the entire shoreline with 54.33% of the cast transects recording erosion while the accretion was 45.67%. The change rates (EPR) ranged from -4.80 m/yr to 7.66 m/yr. The accretion rates (EPR) ranged between 0.02 m/yr and 7.66 m/yr. The erosion rates (EPR) ranged between -0.02 m/yr and -4.80 m/yr. The change rates (NSM) between -61.95 m and 98.90 m. The accretion rates (NSM) ranged between 0.03 m and 98.90 m. The erosion rates (NSM) ranged between -0.01 m and -61.95 m. Most parts of the coastline experienced erosion and this is affirmed by the percentage of the number of eroding transects. Transect 229 experienced the highest rate of erosion. Erosion was clustered in particular sections of the coastline. This is evident between transects 14 – 94, 135 – 234, 286 – 354, 407 – 424 and 449 – 479. Transect 360 experienced the highest rate of accretion. Accretion was experienced between transects 349 – 394, 430 - 446 and 96 – 131.

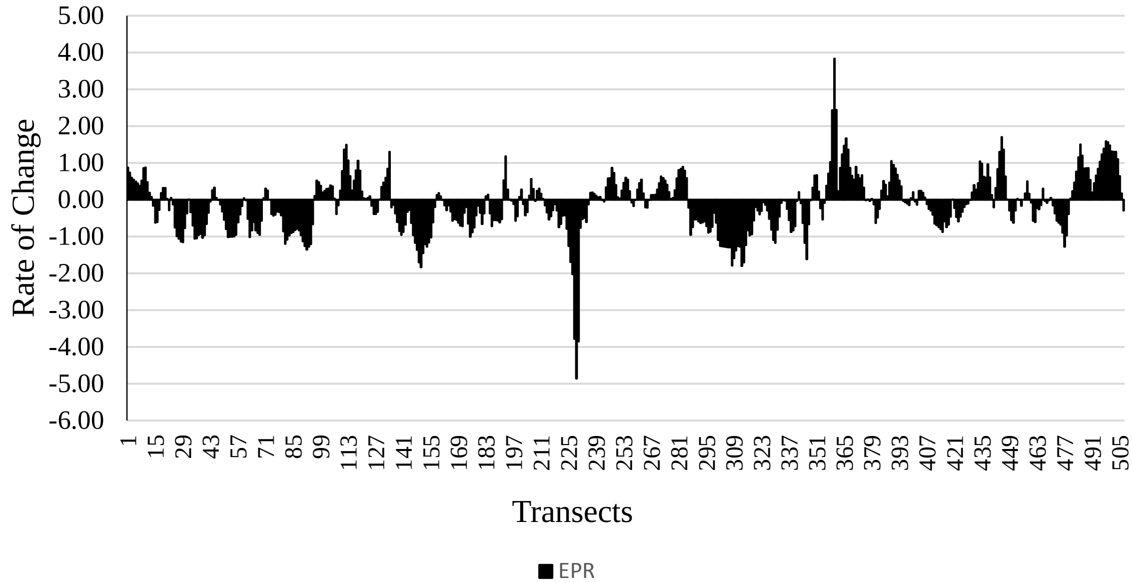


Figure 4.10 End Point Rate graph of 2003-2016.

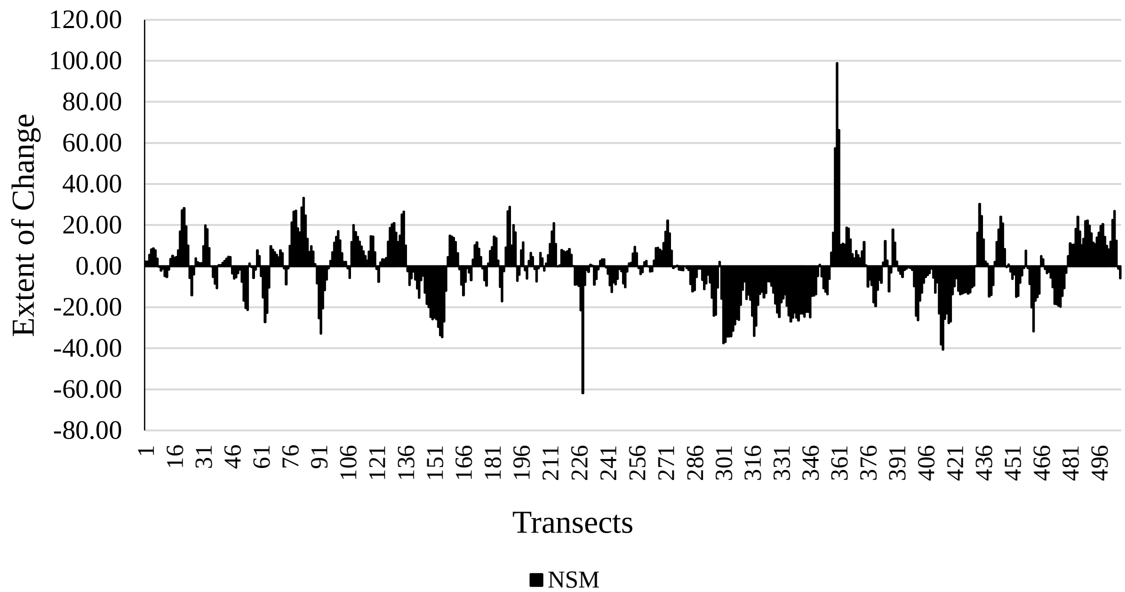


Figure 4.11 Net Shoreline Movement graph of 2003–2016.

4.3 Causes of coastal erosion

Considering natural factors (such as waves, weather, tides and sediment movement), the Teshie coast has succumbed to changes. This is because of the geomorphology of the area. The study area based on the researcher's fieldwork showed that some sections of coastline experiencing retreat. The geomorphology, which makes up beaches, soft rocks interwoven with hard rocks and lagoons is a contributory factor which had caused the current state of Teshie's coastline. The results from the study show that the majority of the Teshie coastline is accreting and this can be attributed to the rocky nature of the coastline which traps sediment displaced from longshore drift and other natural activities.

Regarding what is depicted in the graph, the axis (transect points) showed both erosion and accretion. Regarding the geomorphology of the coastline which characterises both soft and hard rocks, gave an insight on the shoreline change. Thus, a relationship between the graph and the geomorphology provided the analogy that areas on the graph which show erosion characterise soft rocks while the areas which show accretion characterise hard rocks. The sandy shores (soft rocks) are low-lying; this defenceless part influences erosion by longshore waves and tidal action, making this zone more liable to intermittent floods. Based on the statistics, 98.7% of the respondents indicated that they knew of the coastal erosion in the areas (Figure 4.12). Residents of Teshie know of the changing coastline. Interviewed residents were of the view that coastline erosion was imperceptible and this was due to the geomorphology of the area but acceded that certain portions of the coastline were experiencing a high rate of erosion.

> *"Due to the extensive rocky nature of the Teshie coastline, the coastline has experienced none perceptible retreat. This does not include sandy areas of the coastline which are facing the harsh conditions of the tidal waves,"* (Response by a resident).

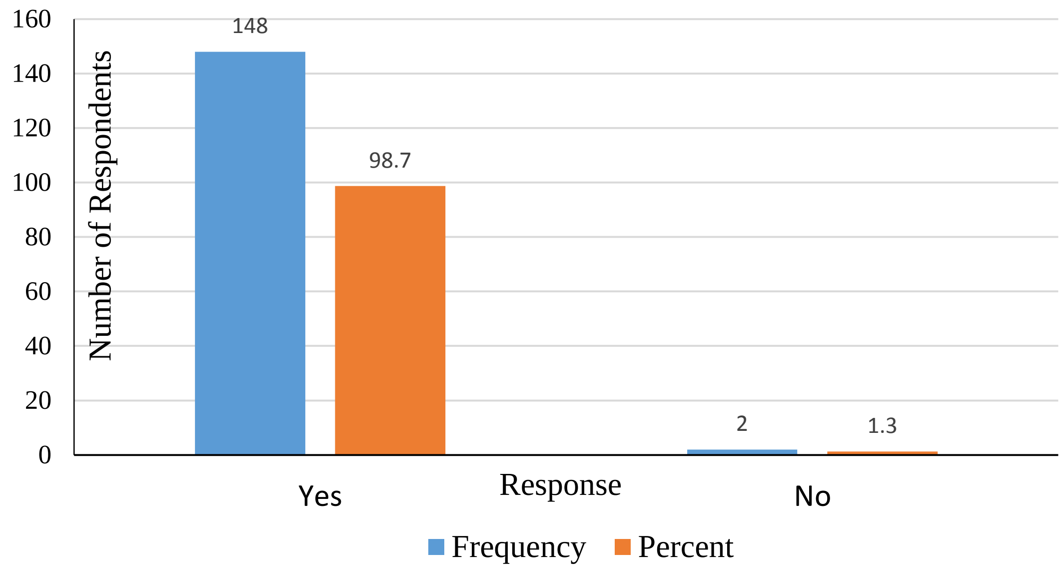


Figure 4.12 Awareness of coastal erosion.

Other elements aside the geomorphology, which was attributed to coastal erosion include both natural (climate change, longshore drift, tidal waves and ocean level rise) and human factors (sand mining, coastal engineering and pollution of the Songor and Kpeshie Lagoons). These activities within the study area have impacted the rates of erosion as regards the different years assessed. Figure 4.13 shows the responses of respondents regarding the causes of coastal change. A majority (57%) indicated that coastal change was because of both Natural and Human causes; 16% stated the cause to be Human whiles 27% attributed it to Natural causes. Both human and natural factors have caused the current state of the coastline. The natural elements include tidal waves, ocean level rise, geomorphology of the coastline and low littoral transport. While the human components include coastal engineering, sand mining, contamination of tidal ponds (Songor and Kpeshie) and urbanisation. Interviewees indicated natural factors to be the fundamental driver of erosion as these causes have been exacerbated by the human components.

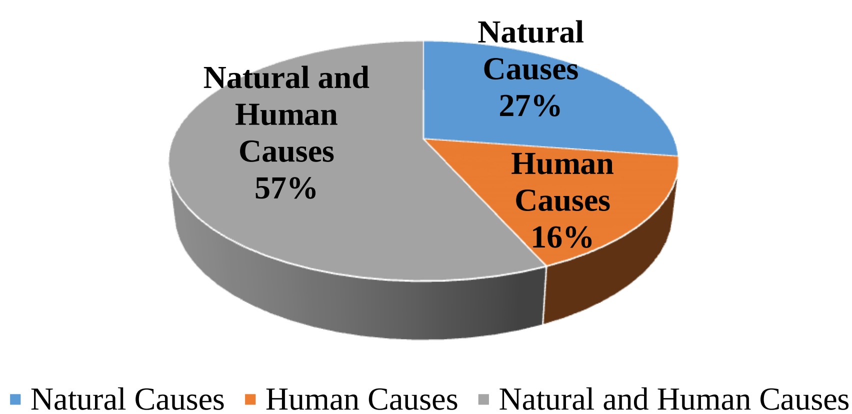


Figure 4.13 Causes of coastal erosion.

The natural causes, Figure 4.14 shows 29.3% indicated Tidal waves to be the natural cause while 22.7% indicated Climate Change and Sea level rise. Alike, 8% indicated Rainfall. Similarly, 4.7% indicated Tidal waves and Climate Change. Four percent (4%) indicated Tidal waves and Climate Change. Moreover, 2% indicated Tidal waves and Sea level rise while 6.7% indicated Tidal waves, Climate Change and Sea level rise. As regards the statistic given, Tidal waves are tipped by respondents to cause adverse effects on the coastline; this is coupled with the other causes, which include Sea level rise and Climate Change and Rainfall.

> *"Tidal waves are one of the main reasons for coastal erosion at Teshie and the threat of tidal action has been happening yearly for as far back a decade. Amid periods when the tidal waves are at their pinnacle, we could not cross over the Songor Lagoon. Where the tidal waves were effective, there was no place for any movement to occur, since the ocean had flooded the whole of the shore,"* (Response by the Chief fisherman).

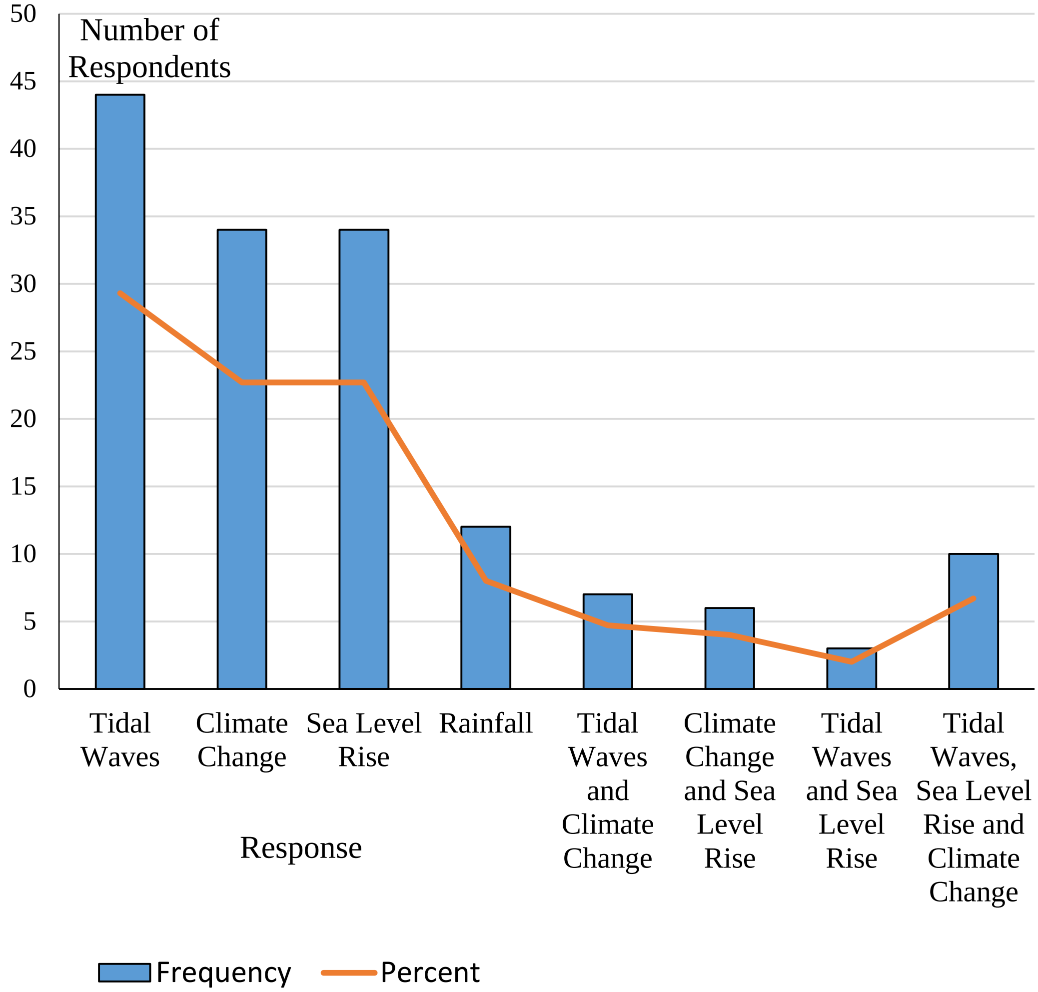


Figure 4.14 Natural causes of erosion.

Human factors, Figure 4.14 shows 48% indicated Sand mining to be the major human cause. Seventeen percent (17.3%) indicated Sand Mining and Coastal Engineering. Twelve percent (12%) indicated Urbanisation. Eleven percent (10.7%) indicated Urbanisation and Sand Mining. Ten percent (10%) indicated Coastal Engineering. Two percent (2%) indicated Urbanisation, Sand Mining and Coastal Engineering. Regarding existing knowledge of the coastline and the human factors. The results show that the engagement of the locals in sand mining is rife. The phenomenon of sand mining was experienced during the researcher's fieldwork (Plate 4.1)

> *"Sand mining was a seasonal activity, which took place in the dry season after the rains have brought sediments from upstream. The sediments were removed from the rocky columns of the coastline. Sometimes sand removal depends on the sediments, the littoral transport deposits."* (Response by the EPA officer)

> *"Sand mining is a reason for the present state of the coastline. Decades ago the coastline of Teshie was sandy. Due to the activities of sand mining, the underlying rocks have been exposed, causing the entire coastline to retreat."* (Assembly member)

Plate 4.1 Photograph showing residents sand mining.

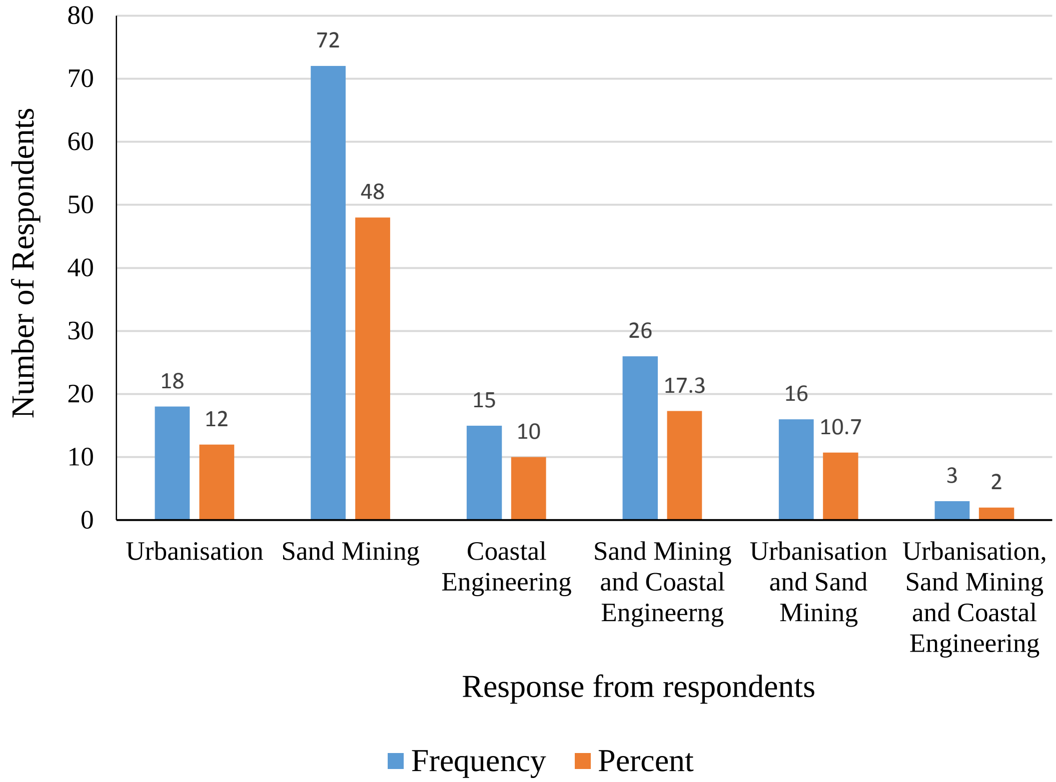


Figure 4.15 Human causes of erosion.

4.4 "Hotspots" along the coastal zone of Teshie

The second objective of this study discussed the hotspots, which was a derivative of the assessment of the erosion rate. Hotspots are areas, which erode faster than other section of the coastline. Tending to the hotspot zones, the Teshie coastline, which traverses 5.073 km was arbitrarily sectioned into three key regions: Western, Central and Eastern. The Western section spans from La-Boma beach resort (mouth of the Kpeshie Lagoon) to Kpokpaanaa (Firing Squad); the Central section spans from Kpokpaanaa (Firing Squad) to Sharpener while the Eastern section spans from Sharpener to Teshie-Nungua desalination plant. Each part of the coastline was 1.69 km. Figures 4.16, 4.17 and 4.18 are graphs showing (Linear Regression Rate) of the Teshie coastline. The x-axis shows a representation of the transect spacing of 20 metres of the coastline while the y-axis shows the rates of either accretion or erosion for Linear Regression Rate (LRR).

The sum of the erosion rates indicated that the Western segment had -31.13 m, -46.82 m for the Central and -33.08 m for the Eastern areas (Equation 1). The number of eroded transects was 91, 95 and 86 for the Western, Central and Eastern areas, respectively (Equation 2). In trying to quantify the threshold for the hotspots within the Teshie coast, a - 0.40653 was adopted. The justification for the threshold figure is based on the arithmetic mean of the eroded transects. This means that linear regression rates less than -0.41 represent the hotspots (Equation 3). Therefore, this research found the percentage of hotspots within each section of the coast. Equation 3 shows how the percentage of hotspots were obtained.

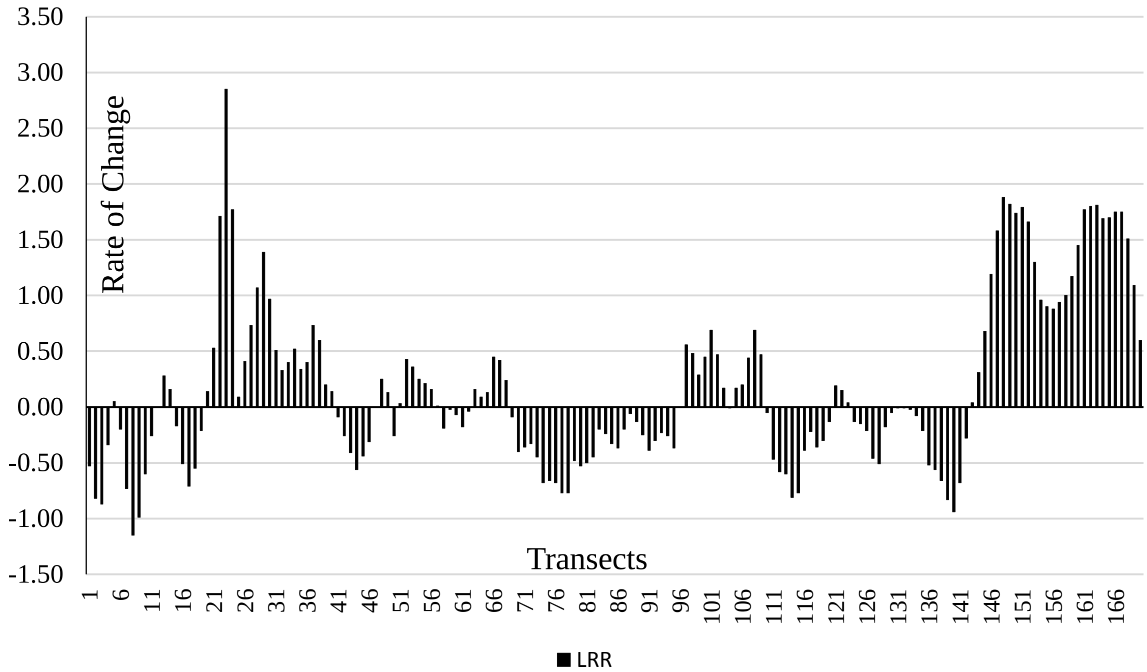


Figure 4.16 Linear Rate of Regression graph of the Eastern section.

Figure 4.16 shows the eastern segment of the Teshie coastline with a rate scope of -1.15m/yr. and 2.85m/yr and the rate of erosion to be -0.39 m/yr. The level of erosion for the eastern segment of Teshie's coastline was observed to be 38.67%. Between transects 20 – 40, 97 – 109 and 114 – 170 showed sections of the Eastern coastline accreting. Between transects 1 – 19, 41 – 46, 69 – 95 and 112 – 142 showed sections of the Eastern coastline eroding.

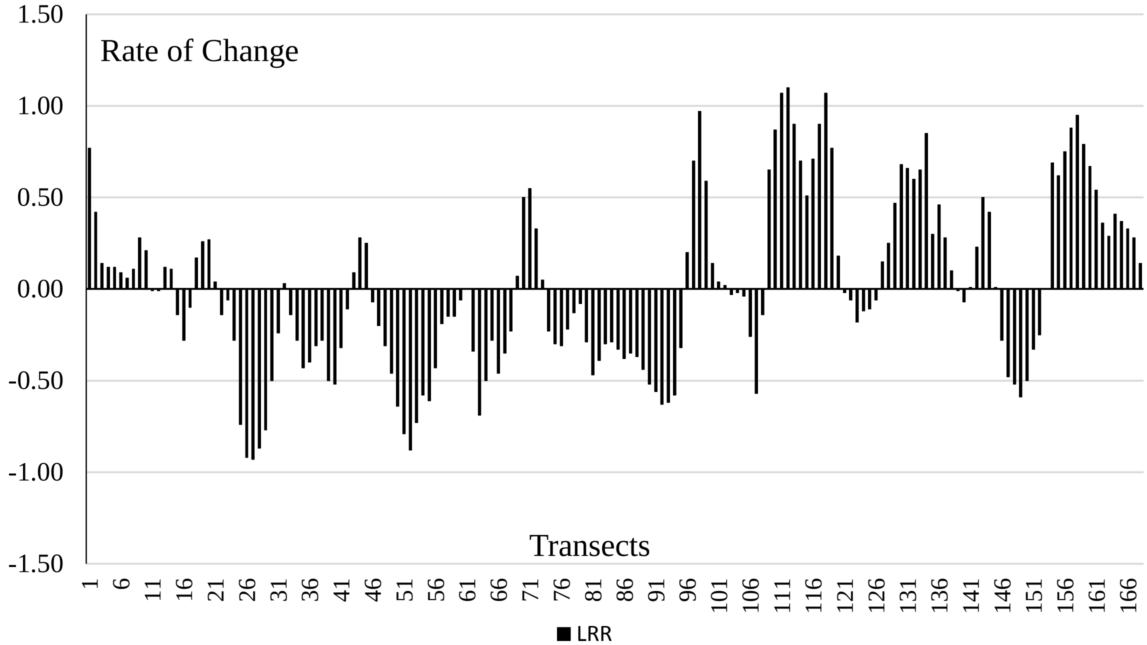


Figure 4.17 Linear Rate of Regression graph of the Western section.

Figure 4.17 shows the Western segment of the Teshie coastline having a rate scope of -0.93 m/yr. and 1.10 m/yr and the rate of erosion to be -0.35 m/yr. The level of erosion for the Western area of Teshie's coastline was observed to be 34.21%. Between transects 1 – 14, 69 – 73, 96 – 101, 109 – 120, 129 – 144 and 154 – 167 showed sections of the Western coastline accreting. Between transects 22 – 31, 33 – 41, 46 – 60, 74 – 95, 105 – 108 and 146 – 152 showed sections of the Western coastline eroding.

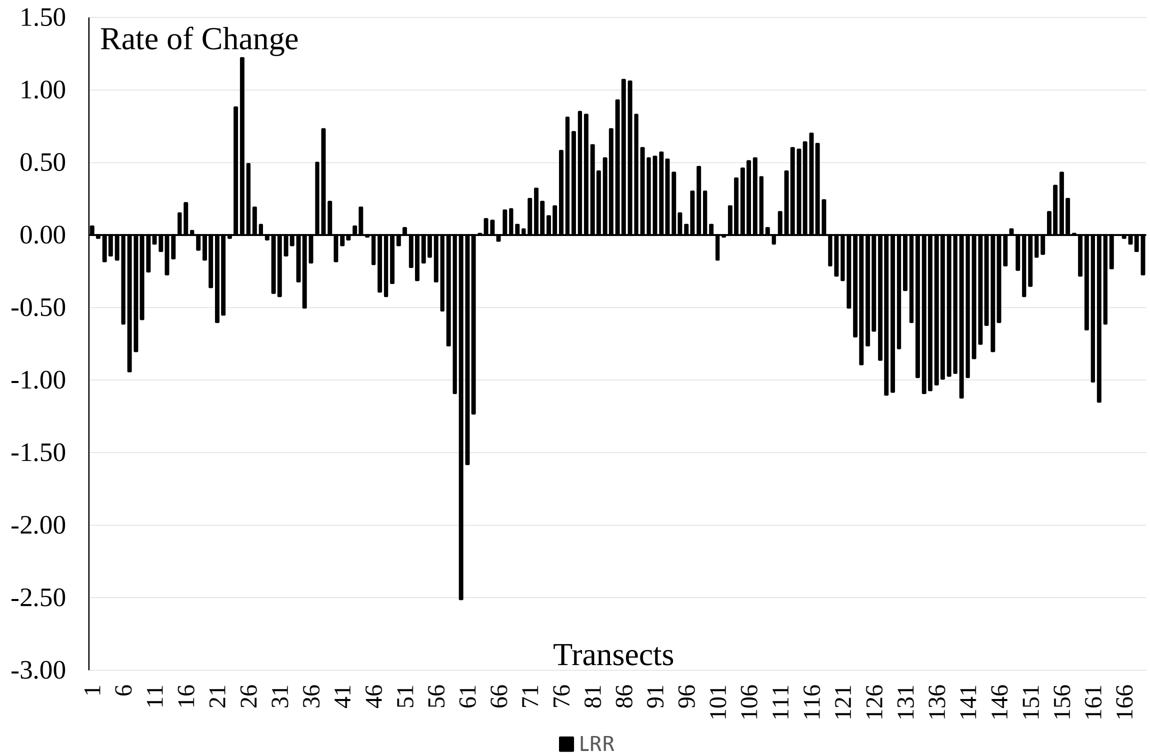


Figure 4.18 Linear Rate of Regression graph of the Central section.

Figure 4.18 shows the Central area of the Teshie coastline. The Central segment encountered an erosion range of -2.51m/yr and 1.22m/yr and the rate of erosion to be -0.49 m/yr. The level of erosion for the Central segment of Teshie's coastline was observed to be 49.28%. A photograph showing the Central part of the Teshie coastline is appended (Plate 4.1). Between transects 24 – 28, 37 – 44, 64 – 118 and 154 – 157 showed sections of the Central coastline accreting..

Between transects 3 – 14, 18 – 22, 30 – 36, 46 – 62, 119 – 153 and 159 – 169 showed sections of the Central coastline eroding.

In view of the coastline change for the hotspots; the erosion range is -1.15 and 2.85 m/yr for the eastern area, - 2.51 and 1.22 m/yr for the central segment and - 0.93 and 1.10 m/yr for the western segment. The central area eroded at a faster rate when contrasted with the eastern and western segments. The geomorphology on the shoreline hinted at the causal elements and the components of comparison. If the same variability were recorded for coastal erosion, then it could be assumed that both erosive and resistive forces are in a state of dynamic equilibrium. This observation suggests that the specific characteristics of the site play a fundamental role in the modelling of coastal erosion in the study area.

The results from Figure 4.19 show 44.7% indicated the Eastern section to be eroding. The remaining 28.7% indicated the whole coastline to be eroding. Further, 9.3% indicated the Central and Western to be eroding and 4.7% indicated the Western and Eastern to be eroding. Three percent (3.3%) indicated the Western to be eroding. Three percent (3.3%) indicated the Central and Eastern sections to be eroding while 6% indicated the Central section was eroding most. The Central part of the coastline was eroding most as compared to the other areas (Plate 4.2).

Based on the results from the GIS and the findings from the questionnaires, there was a contrast on the information obtained regarding which area was the hotspot of the Teshie coastline. The results from the GIS indicated the Central section as the hotspot while the findings from the questionnaires indicated Eastern. The findings based on the interviews and respondents could be because of the familiarity with the Eastern section as compared to the other areas.

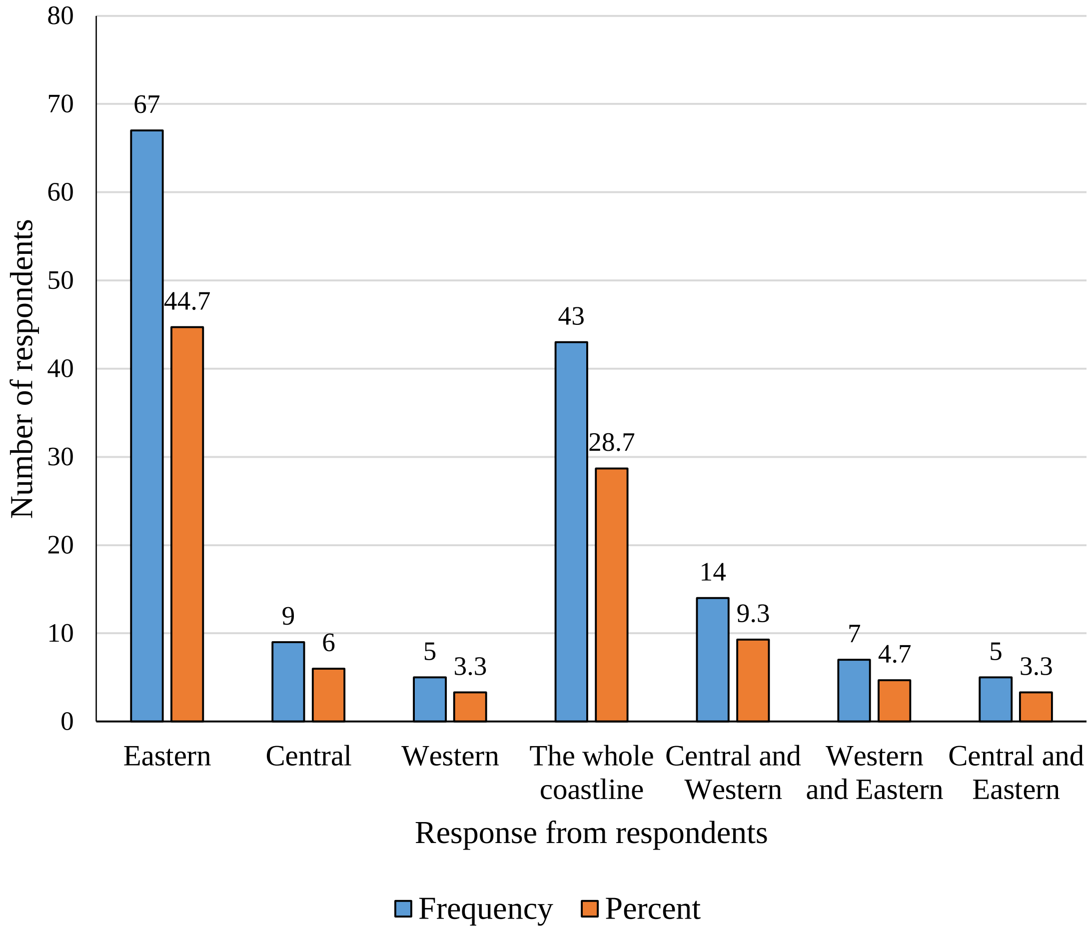


Figure 4.19 Eroding sections of the coastline.

Plate 4.2 Photograph showing a section of the eroding coastline.

4.5 Chapter summary

This chapter focused on the results and discussions of the study. In line with objectives 1 and 2, this chapter analysed the rate of coastal erosion and hotspot identification. The chapter analysed the rate and extent of shoreline at Teshie. In addition, the opinions of locals gave subjective views on the extent of shoreline change and which section are eroding faster. The qualitative aspect to the research is discussed in the next chapter.

CHAPTER FIVE

ANALYSIS ON THE SOCIO-ECONOMIC AND CULTURAL EFFECTS OF COASTAL EROSION AND THE ADOPTED COPING STRATEGIES

5.0 Introduction

In line with the objectives, this chapter provides the results on the socio-economic and cultural effects and the coping strategies adopted. The chapter presents the discussions linked to the literature to place the issues within a wider context. In accordance, the discussions present a detailed description of the demographic characteristics of respondents, the views on the socio-economic effects and the adopted coping strategies.

5.1 Demographics of respondents

Studies have shown that there is a connection between individuals' demographic characteristics and their attitudes and perceptions towards certain phenomena (MacKenzie *et al*., 2014). In this vein, some demographic characteristics that are seen to have a relationship with individuals' attitudes and perceptions were considered for the investigation. These include sex, age, level of education, income, marital status and occupation.

Table 5.1 shows the descriptive statistics of the survey respondents. Of the 150 surveyed respondents; 70.7% were men while 29.3% were women. Potential factor for the biassed sexual distribution was that most men are engaged in fishing and were closer to their homes during and after working hours. This included the elderly and unemployed. Most women within the study area were engaged in petty trading amongst other businesses which kept them away from home. Therefore, with this, most of the men were available in their homes during the exercise of the survey and the interviews.

Regarding the duration of the stay in the community, the results show that of the 150 respondents; 33.3% have stayed in the community between 15 and 20 years; 13.3% have stayed in the community between 21 and 25 years; 14.0% have stayed in the community between 26 and 30 years and 39.3% have stayed in the community for over 30 years. An interesting fact about the finding is that a larger proportion of respondents have lived in the community in the last twenty-five years; this shows the familiarity with the coastal area. The longer the length of stay in the area suggested a certain familiarity with the area.

In Table 5.1, 36.7% reported having a basic level of education. Twenty-one (20.7%) indicated that they had had a secondary education while 15.3% indicated that they had a tertiary level education. Twenty-eight percent (27.3%) indicated that they did not have a formal education.

Table 5.1 Demographics of respondents.

Variable	Categories	Frequency	Percentage (%)
Sex	Male	106	70.7
	Female	44	29.3
Age	15-20	17	11.3
	21-30	37	24.0
	31-40	25	17.3
	41-50	38	24.7
	51-60	17	12.0
	61-70	11	7.3
	71 and above	5	3.3
Duration of stay in community	15-20	50	33.3
	21-25	20	13.3
	26-30	21	14.0
	Over 30	59	39.3
Level of education	No formal education	41	27.3
	Basic education	55	36.7
	Secondary level education	31	20.7
	Tertiary education	23	15.3
Monthly income of respondents	GH¢ 0-200	83	55.3
	GH¢ 201-500	44	29.3
	GH¢501-800	17	11.3
	GH¢ 801-1000	6	4.1
	GH¢ 1000 and above	0	0.0
Occupation	Public Formal	8	5.3
	Private Informal	53	35.3
	Private formal	35	23.3
	Unemployed	54	36.0

The income results show more than half (55.3%) of the sample size earning between (GH¢) 0-200. Twenty-nine percent (29.3%) earning between GH¢ 201-500. Eleven percent (11.3%) earned between GH¢ 501-801 while only 4.1% earning between GH¢ 801-1000. The results show that income levels in the study area are low.

In addition, the results show that 35.3% are engaged in private informal activities and 36.0% are unemployed. The private informal sector involves activities such as wholesale and retail trade, agriculture and skilled and unskilled crafts. According to the Ghana Statistics Service (2010), the private informal sector is the largest employer in the country and represents 86.1% of total employment in the country. Five percent (5.3%) were involved in the public formal. The private formal sector recorded 23.3%. The results corroborate the views that Ghana's economy is informal (Grant, 2009). When juxtaposed with the results on the level of income, it can be concluded that most of the informal activities or businesses in which the respondents participate are based on survival. This is because the income earned from these activities is not enough to employ people. The potential for expansion may be there although this discussion is not part of the current study.

Regarding marital status, Figure 5.1 shows that 53% are single, 35% are married while 12% are divorced. The result is not surprising given the fact that the substantial proportion of respondents is within the 20 to 30-year cohort. The results are like the national figures, which indicate that about 42.0% of the population 12 years and older are not married, whiles about 42.9% of this same age cohort are married (Ghana Statistical Service, 2010).

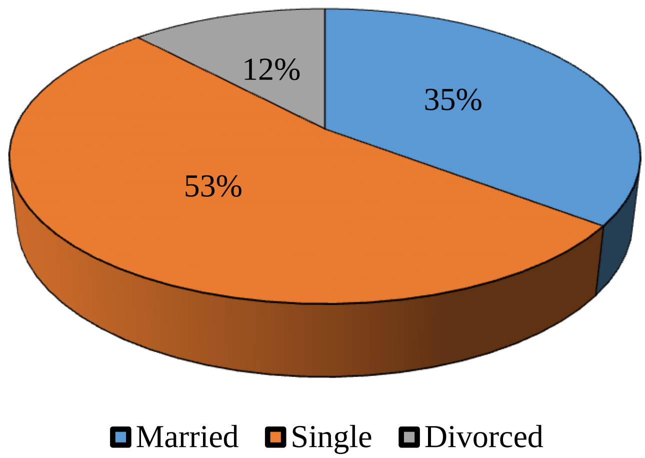


Figure 5.1 Marital status of respondents.

5.2 The effects of coastal erosion on socio-economic and cultural activities

Further, towards understanding the perception and experiences of respondents, questionnaires were administered on the socio-economic and cultural effects. Figure 5.2 shows respondents' views on socio-economic and cultural effects of coastal erosion on residents. The results show 39% indicated unemployment to be the major socio-economic effect of coastal erosion. Thirty-seven percent (37%) indicated Poverty. Sixteen percent (16%) indicated Homelessness. Seven percent (7%) indicated Migration. Furthermore, 1% indicated the loss of identity. The harsh conditions of the coastal erosion have caused effects on life and property. Because of coastal erosion, the Teshie area has lost most of its sandy beaches, including its landing beaches. The effects of coastal erosion have led to the wrecking of some canoes and destroyed fishing nets. This has rendered fishermen unemployed. This situation is widespread among fisher folks in Teshie as canoes are destroyed yearly due to tidal waves. As regards poverty, income generated from fishing is low, thus the little amount generated is spent on fuel, fixing parts of the canoes, buying nets and also looking after their families. Since the income generated is little, nothing is left to save. Thus, their wards are made to drop out of school and are taught how to fish. The effects of coastal erosion rendered residents homeless. This is evident with dilapidated buildings along the coast. This forced a couple (residents) to migrate from areas along the coast to take refuge elsewhere. The shores of Teshie used to be a place of destination for revellers but due to the effect of coastal erosion, it has lost its identity.

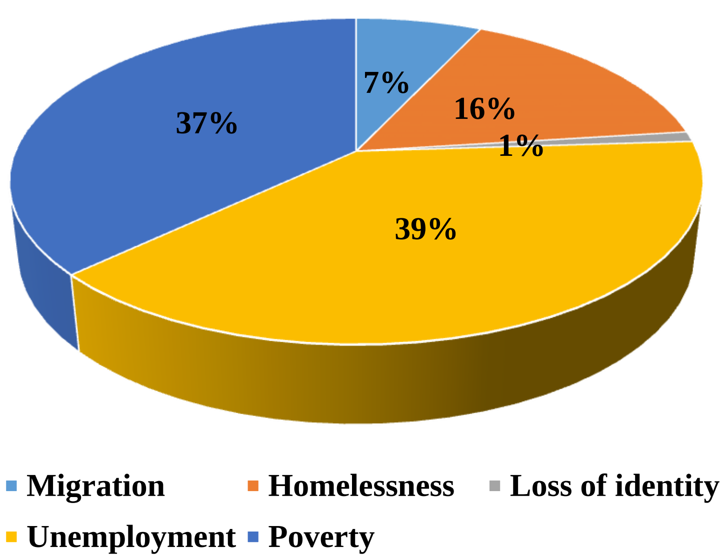


Figure 5.2 Socio-economic effects of coastal erosion on residents.

Figure 5.3 shows 36% indicated the major challenge accompanying coastal erosion is the loss of landing sites. Twenty-five percent (25.3%) indicated low fish catch. Eighteen percent (18%) indicated the loss of landing sites and low fish catch. Eight percent (8%) indicated the loss of landing sites, low beach turn-out and low fish catch. Seven percent (6.7%) indicated low beach turn-out whiles 6% indicated low beach turn-out and loss of landing sites. Due to the menace and rate of erosion, many socio-economic and cultural practices have been affected. Perceptions and experiences shared on unemployment include the loss of beaches and land, destruction of walls of hotels, destruction of canoes and loss of life.

The coastal zone presented opportunities and they include hotels and beaches. Due to such areas being affected by coastal erosion, this has diminished the opportunities in these areas. The beaches along the coastline include the Shining Beach, Black Mama Beach and Bosue Beach and these areas provide fun for revellers. Due to the effects of sand mining and coastal erosion, the underlying rocks have been exposed, hence reducing the aesthetic and economic values of these areas. Shining Beach, which got its name from the sparkling beach sand has seen low turn-out of events organised.

As regards low fish catch, a recount from the chief fisherman indicated that 5 years ago, there were over 100 canoes but now the canoes are below 30; this was due to effects of tidal waves. This has affected the fish catch, thus a ripple effect on fishmongers, customers and other related businesses. Due to the spate of erosion along the coastline most beaches have been taken over by the sea. This has affected the fishermen because in the past decades these beaches provided natural landing sites for the fishermen. These were areas where they sat to mend their nets. Due to these beaches being eroded, this has exposed the bare rocks and has forced the fishermen to mend their nets inland. The tidal waves caused damage to their canoes. Hotels, which include Next Door Beach and Cocoa Beach in recent decades offered the luxury of beaches. Losing beaches due to coastal erosion has left rock promontories in these areas. As for Coco beach, it experiences the harshness of the tidal waves every year and most of the time it is left with broken walls.

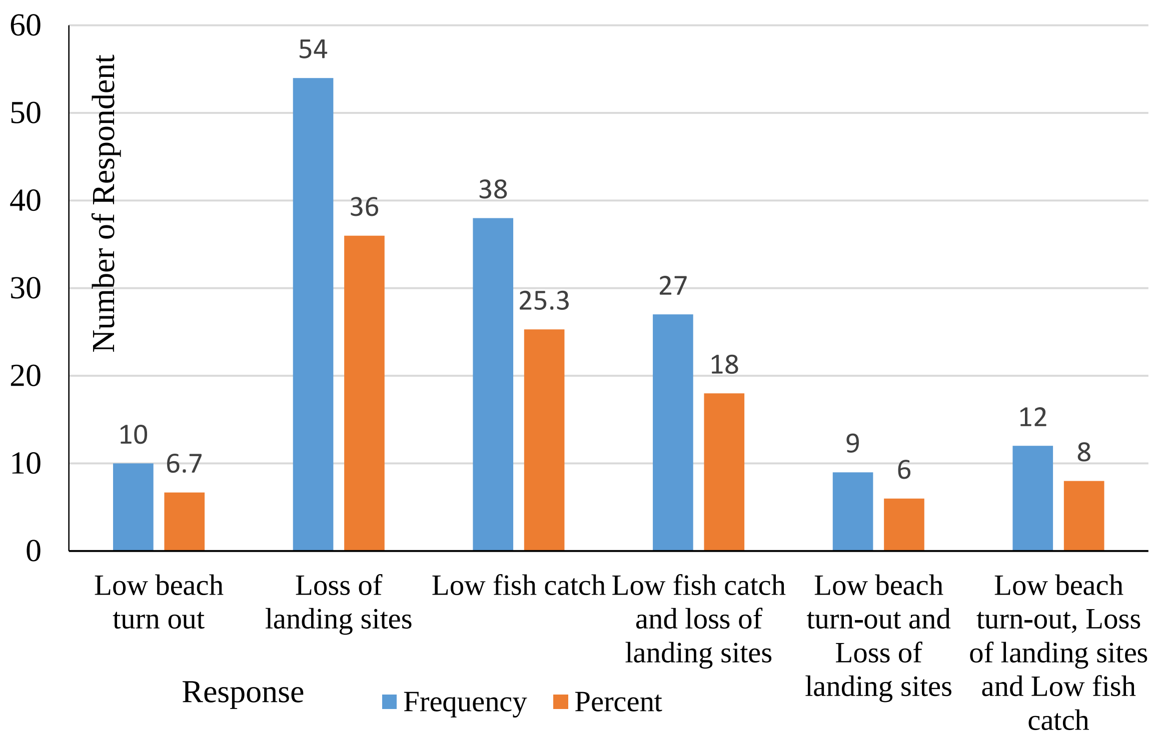


Figure 5.3 Effects of coastal erosion.

5.5 Assess the coping strategies which local people have put in place

5.5.1 The role of government

Figure 5.4 shows respondents' views on the government's intervention to curb the impacts of coastal erosion. The results show 76.7% indicated that the government's intervention will help curb the extent of erosion. Further, 23.3% indicated that the government's intervention will not curb the extent of erosion. When this research took place, there was no mitigation strategy put in place to lessen the socio-economic effects of coastal erosion. The numerous recounts buttressed this by locals on the construction of wharfs for over a decade which has been ignored by the government.

The reports of the interviews revealed the government is the main stakeholder. The local population hoped the government could be relied on to address the pertinent issues: they include the review of the existing legislative requirement, monitor coastal areas, control mangrove felling, control the construction of structures near the waterline and control the mining of sand on the beaches. The EPA says discussions are on-going to salvage the problem but expect the coastal communities to be guardians of these areas. As of now, groynes have been placed in certain portions of the coastline (Plate 5.1).

> *"We have been informed of pending coastal defence structures to be constructed, which will shield the coastline. This pledge, which was made to us a decade is yet to materialise"* (Response by the fishermen).

"Groynes have been placed along Accra's coastline in areas where coastal erosion is intense. Due to the nature of the Teshie coastline and the socio-economic challenges, no form of coastal protection has been put in place to reduce the rate of erosion" (Response by the inn caretaker).

Plate 5.1 Photograph showing groynes put at a section of the coastline.

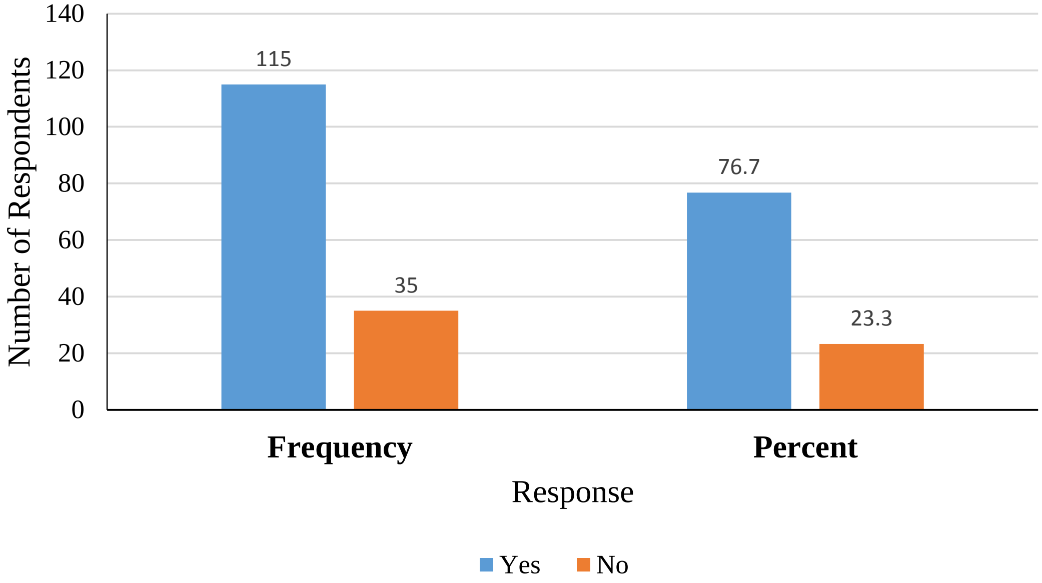


Figure 5.4 Government intervention to curb erosion.

5.5.2 Coping strategies

Figure 5.5 show 10.7% indicated there was a system put in place to curb erosion. Eighty-nine percent (89.3%) indicated there was no form of a devised system put in place. The Teshie coastal strip can be compared to be a destitute zone; this is due to the little development this area has experienced. The coastal area of Teshie has its share of socio-economic challenges, hence the luxury of having a devised system is impossible. Owners and caretakers of beaches along the coastline had devised means to cope with erosion and these were 10.7%. As a result of the length of stay, the locals at Teshie know the physical changes occurring along the coastline. Thus, the locals have adopted coping strategies. First, fishermen realised that in the wet season, the ocean tides were strong and this destroyed their canoes. So, in such periods, the fishermen tied their canoes to the mangroves on the Songor Lagoon to serve as anchors. Along the stretch of the Teshie coastline, most of the infrastructure now fall within the high tide zones of the ocean. During the high tide period, residents evacuate sandy beaches.

> *"In order to reduce the spate of erosion and the propensity of the tidal waves, which sweep the coastline, we have sought to pilling sandbags and car tyres along the sandy beaches of the coastline*" (Response by the residents).

Regarding relocation, residents did not think of it as a necessary choice. The idea of relocation was not taken and answered. This was because of the nostalgic, social and cultural ties the participant had with the area. A deduction from their statements clarified their quest on how the coastline could be managed better. The participant asked that instead of being moved, wharves be constructed to reduce the effects of the tidal waves. In their opinion, the construction of wharves will mitigate the effects of coastal erosion.

> "*If we are to relocate; it would have dire consequences on livelihoods and may even incur the wrath of the gods. The cultural ties with the fishing and other socio-economic activities have been handed down from generations and breaking the tradition means harsh consequences,"* (Response by the Chief fisherman and residents).

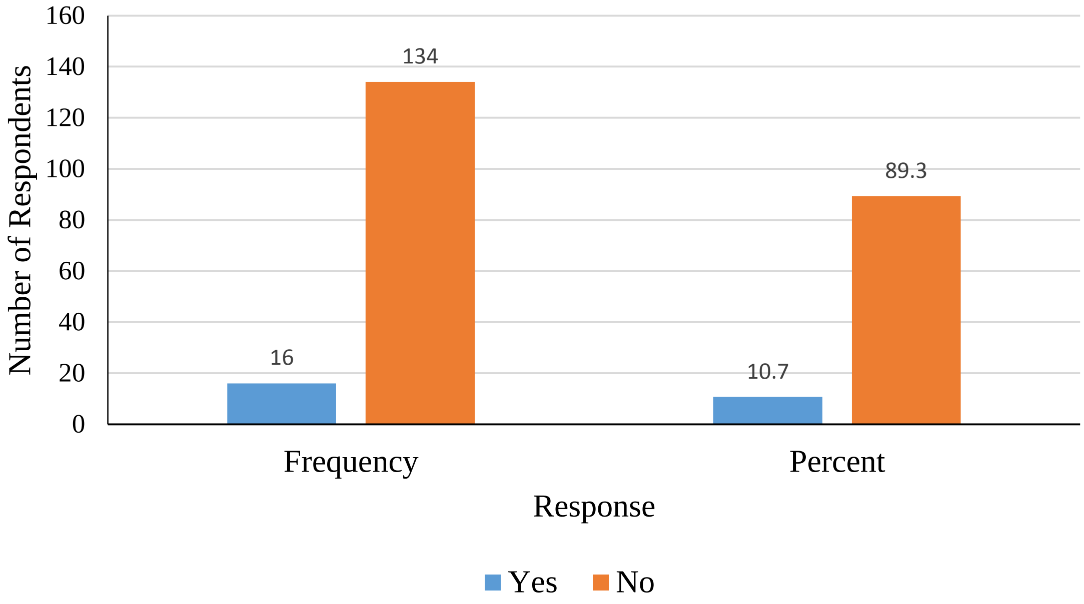


Figure 5.5 Coping strategies.

5.6 Chapter summary

In line with the objectives, this chapter focused on the discussion of the results of the study. The first section discussed the demographic characteristics of the respondents. Discussions were also made on the socio-economic and cultural effects of erosion and the adopted coping strategies.

CHAPTER SIX

SUMMARY OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

The proposition for the research showed the effects of coastal erosion being caused by both natural and human factors, through literature, interviews and questionnaires. Over the 30-year frame, the coastline was analysed and causal effects showed correlation. This is because human factors intensified natural factors. This research showing a multi-variable process had led to the current state of the coastline. This observation confirms the research proposition and the general aim of the research.

The first and second objectives examined the rate of erosion and hotspots in the study area. The research assessed the erosion rate along the entire study area considered in the short-term. According to the findings, the coastline is accreting more than eroding. The average coastline erosion rate is -0.41 m/yr and 0.52 m/yr for average accretion rate recorded for the short-term (30-year) period.

In line with the second objective, the research revealed that the Central Section of the study area was eroding faster than the Eastern and Western Sections. The general findings from the analysis showed site-specific conditions influencing the coastal erosion rates. This finding is in line with the first objective of the research.

Based on the literature, this suggests how bonded the rocks are; hence, the sheer strength of the rocks. The proximity and exposure of the bedrock along some parts of the coastline had caused resistance to some erosive actions while parts contain unconsolidated material. Other areas were interlaced with both hard and soft rock materials. The Eastern Section where soft rock materials can be found gave high rates of erosion. The area was boarded with a hydraulic feature, low-lying and had extensive beach cover. This made it easier for erosion to take place. The Western segment had a few similitudes toward the Eastern area but was however rockier. The Central section differed from both the Eastern and Western. It was attributed to rocks and interlaced with soft material. Some sections of the coastline had groynes in place (which include the Central and Western Sections). Evident of erosion at these sections were different coastal denudation.

The third and fourth objective examined the views of the local people on the socio-economic and the cultural causes and effects of coastal erosion at Teshie and adaptive coping strategies. The analysis of the data revealed unemployment and poverty to be the main effects of coastal erosion on socio-economic activity. The study also revealed that the main economic activity was fishing and a relationship was shown with poverty. Thus, the effects of coastal erosion on socio-economic activity have led to poverty. Other socio-economic effects include homelessness, migration and loss of identity. The adaptive strategies were piling sandbags and tyres along the coastline and the use of the banks of the Songor Lagoon as a landing site.

6.1 Conclusions

The results have been useful in revealing the trends in shoreline change (erosion and accretion) along the coast of Teshie. Though the study assessed only the Teshie coastline, the method can be applied elsewhere.

Using satellite images proved vital in the trend's assessment of coastal change. Using extracted coastlines, the DSAS aided in calculating the coastline rate of change. The rates were calculated along transects, which were cast along the entire coastline using the Linear Regression Rate, End Point Rate and the Net Coastline Movement. The results confirm the high rates reported for this area with the geomorphology of the study area being the primary cause. Average rates for erosion and accretion of the study area was estimated at -0.41 m/yr and 0.52 m/yr with the central, eastern and western sections experiencing high rates of retreat, respectively. Thus, the first and second objectives of the study were achieved.

The results from the first and second objectives were integrated with the third and fourth objectives for a better understanding of the study. The effects of the high rates of erosion accrued were evident from the socio-economic activities and coping strategies adopted. Based on the interviews and questionnaires, Tidal waves was found to be the main cause along the Teshie coastline. This applied to the study since it indicated how coastal erosion had affected livelihoods.

6.2 Recommendations

In the absence of data (satellite imagery) regarding Ghana's coastline, an alternative will be to assess the impact of coastal erosion on livelihoods. First-hand information from victims will aid in understanding the pertinent issues while finding solutions to the problem.

The assessment of coastal erosion in the study area could serve as a blueprint for other areas facing similar challenges. This calls for pragmatic measures to curb the effects of coastal erosion along the study area and the entire coastline of Ghana. The Environmental Protection Agency (EPA), policymakers and law enforcing agencies should ensure that measures are used in order that the effects of coastal erosion are minimised. Likewise, non-state actors should take the initiative in checking coastal erosion.

The changes regarding both natural and human activities subject the coastal to change, thus; the study recommends regular and continuous analyses of the shoreline, to know, understand and predict shoreline changes.

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6.3 Implications for future research

The study revealed that coastal erosion had affected the socio-economic activities of the locals. It is, therefore, recommended that future studies should look at the reasons behind this revelation. Furthermore, the study discovered that the locals, especially the youth and the uneducated people, are not educated on the effects of sand mining. So, future studies should look at how to educate the locals on the effects of sand mining.

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APPENDIX

UNIVERSITY OF GHANA

This study is directed by an understudy of the above Institution as a prerequisite to the honour of MPhil in Geography and Resource Development. The research seeks to assess coastal erosion at Teshie in the Ledzokuku/Krowor region in Ghana. Respondents are guaranteed that all reactions are entirely for scholarly purposes and will be dealt with privately.

All data given will entirely be dealt with as secret and for scholarly purposes as it were.

INTERVIEW GUIDE

INTERVIEW GUIDE FOR LOCALS

1. Age
2. What is your occupation?
3. How would you describe the coastline of Teshie tracing it from the past to present?
4. Do you think the coastline has eroded and if so what do you think may account for this?
5. Which areas of the coastline are eroding most?

6. In your opinion, is the rate of erosion a small one or a huge one?
7. Do you think the geological composition of the Teshie's coastal has influenced the current state of the coastline? (Nature and type of soil).
8. How has coastal erosion influenced activities along the coast?
9. Aside sand mining would you say you are mindful of any ecological practices, which have urged on erosion along the Teshie coastline?
10. What is the magnitude of the wave activity that sweeps along the coastline?
11. What are the socio-economic opportunities available to the people of Teshie?
12. Do you consider coastal erosion a major threat to the livelihoods in Teshie?
13. Have you endured any impact because of erosion? If yes, how did you cope?
14. Has the erosion of the coastline engendered movement or migration out of the settlement?

INTERVIEW GUIDE FOR EXPERTS

1. What sort of defensive measures has been attempted along the coastline to recover a portion of the terrains?
2. Are there any ongoing works that have been undertaken by the government to curb erosion?
3. Do you think the government's role in curbing erosion has come to fruition?
4. What coastal environmental management laws and policies exist in Ghana and how are they applied to achieve coastal environmental sustainability?

5. Do you engage community members in any form of environmental sensitisation? (Education on best practices, building locations, livelihood strategies).
6. Do you think stakeholders can manage the coastal environment? (Knowledge, techniques, finance, human resource and commitment)? How?
7. Do you engage community members in any form of environmental sensitisation? (Education on best practices, building locations, livelihood strategies).
8. What local or traditional (strategies adopted by the institution) approaches are employed by your institution in protecting the coastline from retreating?
9. Are there any notices to educate residents of the coastal zone of looming dangers?
10. Do you think government's scientific engineering approach to sea erosion is effective and appropriate? (Arguments are that engineering methods are temporal and only seeks to transfer the problem to adjoining areas).
11. What coastal environmental management laws and policies exist in Ghana and how are they applied to achieve stability in the coastal areas?

QUESTIONNAIRES

PART ONE: BACKGROUND DATA

1. Age

   a. 15-20 [ ] b. 21-30 [ ] c. 31-40 [ ] d. 41-50 [ ] e. 51-60 [ ] f. 61-70 [ ] g. Over 70 [ ]

2. Gender

   a. Male [ ] b. Female [ ]

3. Marital Status

   a. Married [ ] b. Single [ ] c. Divorce [ ] d. Other…………………

4. Level of education

   J. H. S/ Middle [ ] b. S. H. S. [ ] c. Tertiary [ ] d. Other specify…………….

5. Level of income

   a. GHc 0-200 [ ] b. GHc 201-500 [ ] c. GHc 501-800 [ ] d. GHc 800-1000 [ ] e. Over GHc 1000

6. Occupation

   a. Private Formal [ ] b. Private Informal [ ] c. Public Formal [ ]

   d. Unemployed [ ]

PART ONE: ASSESSING THE EXTENT OF COASTAL EROSION AND THE HOTSPOTS WITHIN THE TESHIE COASTLINE

7. How long have you been staying here?

   a. 15-20 [ ] b. 21-25 [ ] c. 26-30 [ ] d. over 30 years [ ]

8. Are you aware of any form of ongoing coastal erosion at Teshie?

   a. Yes [ ] b. No [ ]

9. Which areas of the coastline are eroding most?

   ....

10. How would you assess the severity of erosion in this area? Please start from high to low.

    a. High [ ] b. Medium [ ] c. Low [ ]

11. What do you think are the reasons for coastal erosion?

    a. Natural causes [ ] b. Human causes [ ] c. Both (Natural & Human) [ ]

12. What are some natural causes of coastal erosion?

    a. Tidal waves [ ] b. Climate change [ ] c. Sea level rise [ ]

    d. Others…......................

13. What are some human causes of coastal erosion?

    a. Urbanisation [ ] b. Sand Mining [ ] c. Coastal engineering [ ]

    d. Others…………..

14. To what extent do you think human activities have caused coastal erosion?

    a. High [ ] b. Medium [ ] c. Low [ ]

15. What are the effects of coastal erosion?

    a. Low beach turn-out [ ]   b. Loss of landing site (s) [ ]   c. Low fish catch [ ]

    d. Others……………

PART TWO: ASSESSING THE SOCIO-ECONOMIC EFFECTS OF COASTAL EROSION

16. Have you ever suffered from any disaster due to coastal erosion?

    a. Yes [ ]   b. No [ ]

17. If yes what type of disaster have you suffered and what was affected? …………………………………………………………………………………

18. How did you recover from such a disaster?

    a. Personal resources [ ]
    b. Family and friends support [ ]
    c. Government and NGOs support [ ]
    d. Others……..…………………………………………………………………………

    …

19. How much did you have to spend in order to recover from the disaster?

    a. Gh50-100 [ ]   b. Gh110-200 [ ]   c. Gh210-300 [ ]

    d. over Gh300 [ ]

20. In what ways would you say the erosion of the coast has affected you socio-economically?

    ....

21. Which of the following is a socio-economic effect of the sea erosion in Teshie?

    a. Migration [ ] b. Unemployment [ ] c. Homelessness [ ] d. Poverty [ ]

    e. Loss of identity [ ] f. Isolation of communities [ ]

22. When was the last time you experienced any coastal disaster as a result of coastal erosion?

    a. 1 year ago [ ] b. 2 years ago [ ] c. over 3 years [ ] d. Other………………………………….

23. How would you rate the form of disaster you experienced?

    a. High [ ] b. Medium [ ] c. Low [ ]

24. Has coastal erosion affected your socio-economic activity?

    a. Yes [ ] b. No [ ]

PART 3: ASSESSING THE COPING STRATEGIES ADAPTED BY THE LOCAL PEOPLE AT TESHIE.

25. Do you think your current location is safe enough to withstand any threat of sea erosion? Explain, your choice of the answer above.

    a. Yes [ ] b. No [ ]

26. Where is your building located?

a. Along the coast [ ] b. Near the shore [ ] c. Far inland [ ]

27. Did you ever have to relocate as a result of the threat of sea erosion?

a. Yes [ ] b. No [ ]

28. If yes, can you trace your earlier location?

29. What strategies do you adopt in controlling the effects of sea erosion?

30. Do you have any defined warning systems you make use of during sea erosion?

a. Yes [ ] b. No [ ]

31. If Yes, what warning systems do you make use of in responding to impending hazards?

32. Do you think government's coastal protection project will mitigate or prevent the pervasive sea erosion? Explain your answer.

a. Yes [ ] b. No [ ]

33. Do you receive any form of capacity building from the local government on safe guarding the environment?

a. Yes [ ] b. No [ ]

34. If yes, what form of capacity building have you ever received from the local government?

APPENDIX 1 LINEAR REGRESSION RATE STATISTICS DATA BETWEEN 1986 AND 2016

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9

Object ID	Transect ID	TCD	LRR	LR2	LSE	LCI99_9
1.00	6.00	100.00	0.77	0.83	5.66	7.88
2.00	7.00	120.00	0.42	0.45	7.50	10.44
3.00	8.00	140.00	0.14	0.05	9.28	12.91
4.00	9.00	160.00	0.12	0.05	8.53	11.87
5.00	10.00	180.00	0.12	0.06	7.59	10.56
6.00	11.00	200.00	0.09	0.04	7.11	9.90
7.00	12.00	220.00	0.06	0.02	6.41	8.92
8.00	13.00	240.00	0.11	0.04	8.94	12.45
9.00	14.00	260.00	0.28	0.10	13.73	19.11
10.00	15.00	280.00	0.21	0.05	15.07	20.98
11.00	16.00	300.00	-0.01	0.00	11.50	16.01
12.00	17.00	320.00	-0.01	0.00	6.09	8.48
13.00	18.00	340.00	0.12	0.54	1.82	2.54
14.00	19.00	360.00	0.11	0.07	6.39	8.89
15.00	20.00	380.00	-0.14	0.03	12.32	17.15
16.00	21.00	400.00	-0.28	0.18	9.58	13.33
17.00	22.00	420.00	-0.10	0.08	5.68	7.90
18.00	23.00	440.00	0.17	0.41	3.16	4.40
19.00	24.00	460.00	0.26	0.24	7.50	10.45
20.00	25.00	480.00	0.27	0.10	13.33	18.55
21.00	26.00	500.00	0.04	0.00	16.13	22.45
22.00	27.00	520.00	-0.14	0.03	13.64	18.99
23.00	28.00	540.00	-0.06	0.02	5.91	8.22
24.00	29.00	560.00	-0.28	0.58	3.80	5.29
25.00	30.00	580.00	-0.74	0.95	2.63	3.66
26.00	31.00	600.00	-0.92	0.89	5.07	7.06
27.00	32.00	620.00	-0.93	0.68	10.36	14.43
28.00	33.00	640.00	-0.87	0.63	10.81	15.05
29.00	34.00	660.00	-0.77	0.51	12.06	16.78
30.00	35.00	680.00	-0.50	0.46	8.67	12.07
31.00	36.00	700.00	-0.24	0.16	8.89	12.37
32.00	37.00	720.00	0.03	0.00	11.38	15.85
33.00	38.00	740.00	-0.14	0.03	13.42	18.68
34.00	39.00	760.00	-0.28	0.10	13.31	18.53
35.00	40.00	780.00	-0.43	0.18	14.62	20.35
36.00	41.00	800.00	-0.40	0.18	13.70	19.07
37.00	42.00	820.00	-0.31	0.13	13.21	18.39

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
38.00	43.00	840.00	-0.28	0.11	13.04	18.15
39.00	44.00	860.00	-0.50	0.27	13.28	18.48
40.00	45.00	880.00	-0.52	0.35	11.55	16.08
41.00	46.00	900.00	-0.32	0.24	8.95	12.46
42.00	47.00	920.00	-0.11	0.07	6.36	8.86
43.00	48.00	940.00	0.09	0.14	3.64	5.07
44.00	49.00	960.00	0.28	0.97	0.84	1.17
45.00	50.00	980.00	0.25	0.85	1.69	2.35
46.00	51.00	1000.00	-0.07	0.10	3.39	4.71
47.00	52.00	1020.00	-0.20	0.29	4.97	6.92
48.00	53.00	1040.00	-0.31	0.60	4.06	5.65
49.00	54.00	1060.00	-0.46	0.88	2.70	3.76
50.00	55.00	1080.00	-0.64	0.89	3.67	5.11
51.00	56.00	1100.00	-0.79	0.98	1.57	2.19
52.00	57.00	1120.00	-0.88	0.94	3.47	4.84
53.00	58.00	1140.00	-0.73	0.73	7.15	9.95
54.00	59.00	1160.00	-0.58	0.47	9.89	13.76
55.00	60.00	1180.00	-0.61	0.43	11.27	15.68
56.00	61.00	1200.00	-0.43	0.24	12.41	17.27
57.00	62.00	1220.00	-0.19	0.12	8.57	11.92
58.00	63.00	1240.00	-0.15	0.17	5.31	7.39
59.00	64.00	1260.00	-0.15	0.15	5.82	8.11
60.00	65.00	1280.00	-0.06	0.07	3.18	4.43
61.00	66.00	1300.00	0.00	0.00	2.71	3.77
62.00	67.00	1320.00	-0.34	0.43	6.29	8.76
63.00	68.00	1340.00	-0.69	0.52	10.61	14.77
64.00	69.00	1360.00	-0.50	0.40	9.82	13.67
65.00	70.00	1380.00	-0.28	0.31	6.80	9.47
66.00	71.00	1400.00	-0.46	0.22	13.90	19.35
67.00	72.00	1420.00	-0.35	0.11	15.70	21.86
68.00	73.00	1440.00	-0.23	0.04	18.05	25.12
69.00	74.00	1460.00	0.07	0.01	14.69	20.45
70.00	75.00	1480.00	0.50	0.42	9.33	12.98
71.00	76.00	1500.00	0.55	0.73	5.43	7.55
72.00	77.00	1520.00	0.33	0.83	2.37	3.30
73.00	78.00	1540.00	0.05	0.33	1.26	1.75
74.00	79.00	1560.00	-0.23	0.49	3.84	5.34

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
75.00	80.00	1580.00	-0.30	0.61	3.75	5.22
76.00	81.00	1600.00	-0.31	0.23	9.02	12.56
77.00	82.00	1620.00	-0.22	0.05	14.67	20.42
78.00	83.00	1640.00	-0.13	0.01	18.21	25.34
79.00	84.00	1660.00	-0.08	0.00	19.89	27.68
80.00	85.00	1680.00	-0.29	0.05	20.19	28.11
81.00	86.00	1700.00	-0.47	0.09	23.13	32.20
82.00	87.00	1720.00	-0.39	0.05	28.02	39.00
83.00	88.00	1740.00	-0.30	0.03	29.44	40.98
84.00	89.00	1760.00	-0.29	0.04	24.11	33.56
85.00	90.00	1780.00	-0.33	0.08	17.62	24.53
86.00	91.00	1800.00	-0.38	0.18	13.30	18.52
87.00	92.00	1820.00	-0.35	0.13	14.30	19.90
88.00	93.00	1840.00	-0.37	0.15	13.87	19.31
89.00	94.00	1860.00	-0.44	0.22	13.09	18.22
90.00	95.00	1880.00	-0.52	0.31	12.52	17.43
91.00	96.00	1900.00	-0.56	0.27	14.98	20.85
92.00	97.00	1920.00	-0.63	0.25	17.27	24.04
93.00	98.00	1940.00	-0.62	0.35	13.50	18.80
94.00	99.00	1960.00	-0.58	0.36	12.57	17.49
95.00	100.00	1980.00	-0.32	0.34	7.13	9.92
96.00	101.00	2000.00	0.20	0.63	2.44	3.39
97.00	102.00	2020.00	0.70	0.87	4.40	6.12
98.00	103.00	2040.00	0.97	0.72	9.81	13.66
99.00	104.00	2060.00	0.59	0.74	5.51	7.67
100.00	105.00	2080.00	0.14	0.09	6.87	9.56
101.00	106.00	2100.00	0.04	0.01	9.06	12.61
102.00	107.00	2120.00	0.02	0.00	7.57	10.54
103.00	108.00	2140.00	-0.03	0.01	6.88	9.57
104.00	109.00	2160.00	-0.02	0.00	8.32	11.58
105.00	110.00	2180.00	-0.04	0.01	8.00	11.14
106.00	111.00	2200.00	-0.26	0.34	5.83	8.12
107.00	112.00	2220.00	-0.57	0.87	3.48	4.85
108.00	113.00	2240.00	-0.14	0.08	7.94	11.06
109.00	114.00	2260.00	0.65	0.42	12.39	17.25
110.00	115.00	2280.00	0.87	0.92	4.06	5.65
111.00	116.00	2300.00	1.07	0.89	6.08	8.46

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
112.00	117.00	2320.00	1.10	0.80	8.91	12.41
113.00	118.00	2340.00	0.90	0.92	4.10	5.70
114.00	119.00	2360.00	0.70	0.99	1.30	1.81
115.00	120.00	2380.00	0.51	0.70	5.36	7.46
116.00	121.00	2400.00	0.71	0.87	4.37	6.09
117.00	122.00	2420.00	0.90	0.96	2.76	3.84
118.00	123.00	2440.00	1.07	1.00	0.53	0.74
119.00	124.00	2460.00	0.77	0.96	2.49	3.47
120.00	125.00	2480.00	0.18	0.61	2.38	3.31
121.00	126.00	2500.00	-0.02	0.03	1.67	2.32
122.00	127.00	2520.00	-0.06	0.04	4.87	6.78
123.00	128.00	2540.00	-0.18	0.28	4.56	6.35
124.00	129.00	2560.00	-0.12	0.17	4.48	6.24
125.00	130.00	2580.00	-0.11	0.22	3.34	4.65
126.00	131.00	2600.00	-0.06	0.01	8.27	11.51
127.00	132.00	2620.00	0.15	0.03	14.39	20.02
128.00	133.00	2640.00	0.25	0.05	17.39	24.20
129.00	134.00	2660.00	0.47	0.21	14.62	20.36
130.00	135.00	2680.00	0.68	0.48	11.52	16.03
131.00	136.00	2700.00	0.66	0.70	6.94	9.65
132.00	137.00	2720.00	0.60	0.95	2.30	3.21
133.00	138.00	2740.00	0.65	0.83	4.64	6.45
134.00	139.00	2760.00	0.85	0.64	10.33	14.38
135.00	140.00	2780.00	0.30	0.06	19.50	27.14
136.00	141.00	2800.00	0.46	0.23	13.54	18.85
137.00	142.00	2820.00	0.28	0.10	13.08	18.21
138.00	143.00	2840.00	0.10	0.01	14.18	19.73
139.00	144.00	2860.00	-0.01	0.00	16.83	23.42
140.00	145.00	2880.00	-0.07	0.00	18.44	25.66
141.00	146.00	2900.00	0.01	0.00	18.02	25.09
142.00	147.00	2920.00	0.23	0.04	18.14	25.25
143.00	148.00	2940.00	0.50	0.17	17.93	24.96
144.00	149.00	2960.00	0.42	0.19	13.99	19.47
145.00	150.00	2980.00	0.01	0.00	13.13	18.28
146.00	151.00	3000.00	-0.28	0.10	13.74	19.13
147.00	152.00	3020.00	-0.48	0.22	14.23	19.81
148.00	153.00	3040.00	-0.52	0.20	16.89	23.51

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
149.00	154.00	3060.00	-0.59	0.15	22.40	31.18
150.00	155.00	3080.00	-0.50	0.08	26.78	37.28
151.00	156.00	3100.00	-0.33	0.05	22.72	31.62
152.00	157.00	3120.00	-0.25	0.04	20.35	28.33
153.00	158.00	3140.00	0.00	0.00	26.87	37.40
154.00	159.00	3160.00	0.69	0.07	38.94	54.20
155.00	160.00	3180.00	0.62	0.07	35.44	49.33
156.00	161.00	3200.00	0.75	0.14	29.74	41.40
157.00	162.00	3220.00	0.88	0.29	22.30	31.04
158.00	163.00	3240.00	0.95	0.46	16.34	22.74
159.00	164.00	3260.00	0.79	0.45	14.10	19.63
160.00	165.00	3280.00	0.67	0.38	13.66	19.02
161.00	166.00	3300.00	0.54	0.30	13.30	18.51
162.00	167.00	3320.00	0.36	0.17	12.90	17.95
163.00	168.00	3340.00	0.29	0.12	12.81	17.84
164.00	169.00	3360.00	0.41	0.26	11.35	15.80
165.00	170.00	3380.00	0.37	0.15	14.09	19.61
166.00	171.00	3400.00	0.33	0.07	18.66	25.98
167.00	172.00	3420.00	0.28	0.07	16.10	22.41
168.00	173.00	3440.00	0.14	0.03	14.21	19.79
169.00	174.00	3460.00	0.06	0.00	13.83	19.24
170.00	175.00	3480.00	-0.02	0.00	13.60	18.94
171.00	176.00	3500.00	-0.18	0.05	12.82	17.84
172.00	177.00	3520.00	-0.14	0.05	9.44	13.14
173.00	178.00	3540.00	-0.17	0.10	8.21	11.42
174.00	179.00	3560.00	-0.61	0.50	9.79	13.63
175.00	180.00	3580.00	-0.94	0.69	10.17	14.15
176.00	181.00	3600.00	-0.80	0.82	6.10	8.50
177.00	182.00	3620.00	-0.58	0.85	3.96	5.52
178.00	183.00	3640.00	-0.25	0.48	4.26	5.92
179.00	184.00	3660.00	-0.06	0.08	2.98	4.14
180.00	185.00	3680.00	-0.11	0.05	8.35	11.62
181.00	186.00	3700.00	-0.27	0.10	12.78	17.79
182.00	187.00	3720.00	-0.16	0.05	11.87	16.53
183.00	188.00	3740.00	0.15	0.09	7.29	10.15
184.00	189.00	3760.00	0.22	0.82	1.62	2.26
185.00	190.00	3780.00	0.03	0.00	8.77	12.20

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
186.00	191.00	3800.00	-0.10	0.01	13.31	18.53
187.00	192.00	3820.00	-0.17	0.10	8.14	11.33
188.00	193.00	3840.00	-0.36	0.24	10.15	14.12
189.00	194.00	3860.00	-0.60	0.19	19.75	27.49
190.00	195.00	3880.00	-0.55	0.15	21.36	29.73
191.00	196.00	3900.00	-0.02	0.00	13.84	19.26
192.00	197.00	3920.00	0.88	0.66	10.23	14.24
193.00	198.00	3940.00	1.22	1.00	1.02	1.42
194.00	199.00	3960.00	0.49	0.51	7.64	10.64
195.00	200.00	3980.00	0.19	0.32	4.49	6.25
196.00	201.00	4000.00	0.07	0.05	5.06	7.04
197.00	202.00	4020.00	-0.03	0.00	7.81	10.88
198.00	203.00	4040.00	-0.40	0.65	4.69	6.53
199.00	204.00	4060.00	-0.42	0.99	0.64	0.89
200.00	205.00	4080.00	-0.14	0.20	4.40	6.12
201.00	206.00	4100.00	-0.07	0.02	7.08	9.85
202.00	207.00	4120.00	-0.32	0.47	5.38	7.50
203.00	208.00	4140.00	-0.50	0.89	2.79	3.88
204.00	209.00	4160.00	-0.19	0.40	3.66	5.09
205.00	210.00	4180.00	0.50	0.51	7.88	10.98
206.00	211.00	4200.00	0.73	0.92	3.38	4.71
207.00	212.00	4220.00	0.23	0.90	1.24	1.72
208.00	213.00	4240.00	-0.18	0.49	3.01	4.18
209.00	214.00	4260.00	-0.07	0.03	6.16	8.58
210.00	215.00	4280.00	-0.03	0.01	6.70	9.32
211.00	216.00	4300.00	0.06	0.03	5.46	7.61
212.00	217.00	4320.00	0.19	0.08	9.98	13.90
213.00	218.00	4340.00	-0.01	0.00	13.49	18.77
214.00	219.00	4360.00	-0.20	0.11	9.27	12.90
215.00	220.00	4380.00	-0.39	0.62	4.95	6.89
216.00	221.00	4400.00	-0.42	0.78	3.60	5.01
217.00	222.00	4420.00	-0.33	0.38	6.80	9.46
218.00	223.00	4440.00	-0.07	0.04	5.17	7.19
219.00	224.00	4460.00	0.05	0.01	9.19	12.79
220.00	225.00	4480.00	-0.22	0.06	14.24	19.82
221.00	226.00	4500.00	-0.31	0.15	11.85	16.49
222.00	227.00	4520.00	-0.19	0.13	8.03	11.17

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
223.00	228.00	4540.00	-0.15	0.12	6.33	8.81
224.00	229.00	4560.00	-0.32	0.22	9.45	13.15
225.00	230.00	4580.00	-0.52	0.23	15.30	21.29
226.00	231.00	4600.00	-0.76	0.28	19.87	27.66
227.00	232.00	4620.00	-1.09	0.47	18.69	26.01
228.00	233.00	4640.00	-2.51	0.69	26.69	37.15
229.00	234.00	4660.00	-1.58	0.11	71.49	99.51
230.00	235.00	4680.00	-1.23	0.10	58.26	81.09
231.00	236.00	4700.00	0.01	0.00	15.91	22.14
232.00	237.00	4720.00	0.11	0.02	13.39	18.64
233.00	238.00	4740.00	0.10	0.02	12.27	17.08
234.00	239.00	4760.00	-0.04	0.00	11.36	15.82
235.00	240.00	4780.00	0.17	0.15	6.55	9.12
236.00	241.00	4800.00	0.18	0.61	2.33	3.25
237.00	242.00	4820.00	0.07	0.14	2.69	3.74
238.00	243.00	4840.00	0.04	0.06	2.49	3.47
239.00	244.00	4860.00	0.25	0.65	2.98	4.15
240.00	245.00	4880.00	0.32	0.50	5.12	7.12
241.00	246.00	4900.00	0.23	0.44	4.15	5.78
242.00	247.00	4920.00	0.13	0.10	6.09	8.47
243.00	248.00	4940.00	0.20	0.12	8.66	12.06
244.00	249.00	4960.00	0.58	0.53	8.76	12.19
245.00	250.00	4980.00	0.81	0.60	10.66	14.84
246.00	251.00	5000.00	0.71	0.64	8.47	11.79
247.00	252.00	5020.00	0.85	0.77	7.40	10.30
248.00	253.00	5040.00	0.83	0.77	7.25	10.09
249.00	254.00	5060.00	0.62	0.54	9.14	12.72
250.00	255.00	5080.00	0.44	0.33	9.97	13.88
251.00	256.00	5100.00	0.53	0.41	10.13	14.10
252.00	257.00	5120.00	0.73	0.60	9.64	13.42
253.00	258.00	5140.00	0.93	0.70	9.80	13.64
254.00	259.00	5160.00	1.07	0.77	9.46	13.16
255.00	260.00	5180.00	1.06	0.73	10.35	14.41
256.00	261.00	5200.00	0.83	0.55	12.05	16.77
257.00	262.00	5220.00	0.60	0.33	13.48	18.76
258.00	263.00	5240.00	0.53	0.26	14.14	19.68
259.00	264.00	5260.00	0.54	0.38	11.07	15.42

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
260.00	265.00	5280.00	0.57	0.71	5.85	8.14
261.00	266.00	5300.00	0.52	0.93	2.26	3.15
262.00	267.00	5320.00	0.43	0.68	4.68	6.51
263.00	268.00	5340.00	0.15	0.42	2.84	3.95
264.00	269.00	5360.00	0.07	0.04	5.63	7.84
265.00	270.00	5380.00	0.30	0.17	10.87	15.13
266.00	271.00	5400.00	0.47	0.33	10.64	14.81
267.00	272.00	5420.00	0.30	0.44	5.41	7.53
268.00	273.00	5440.00	0.07	0.07	3.95	5.50
269.00	274.00	5460.00	-0.17	0.13	6.97	9.70
270.00	275.00	5480.00	-0.01	0.00	7.39	10.28
271.00	276.00	5500.00	0.20	0.13	8.25	11.49
272.00	277.00	5520.00	0.39	0.31	9.52	13.25
273.00	278.00	5540.00	0.46	0.64	5.52	7.69
274.00	279.00	5560.00	0.51	0.99	0.59	0.82
275.00	280.00	5580.00	0.53	0.79	4.42	6.15
276.00	281.00	5600.00	0.40	0.70	4.16	5.79
277.00	282.00	5620.00	0.05	0.60	0.62	0.86
278.00	283.00	5640.00	-0.06	0.13	2.47	3.43
279.00	284.00	5660.00	0.16	0.35	3.57	4.97
280.00	285.00	5680.00	0.44	0.58	6.08	8.47
281.00	286.00	5700.00	0.60	0.63	7.32	10.19
282.00	287.00	5720.00	0.59	0.56	8.35	11.62
283.00	288.00	5740.00	0.64	0.55	9.16	12.74
284.00	289.00	5760.00	0.70	0.50	11.07	15.41
285.00	290.00	5780.00	0.63	0.43	11.62	16.18
286.00	291.00	5800.00	0.24	0.12	10.72	14.92
287.00	292.00	5820.00	-0.21	0.05	15.24	21.21
288.00	293.00	5840.00	-0.28	0.16	10.37	14.44
289.00	294.00	5860.00	-0.31	0.46	5.42	7.54
290.00	295.00	5880.00	-0.50	0.99	0.93	1.30
291.00	296.00	5900.00	-0.70	0.93	2.97	4.13
292.00	297.00	5920.00	-0.89	0.89	5.03	7.00
293.00	298.00	5940.00	-0.76	0.92	3.56	4.96
294.00	299.00	5960.00	-0.66	0.98	1.43	1.99
295.00	300.00	5980.00	-0.86	0.90	4.52	6.29
296.00	301.00	6000.00	-1.10	0.82	8.20	11.42

Object ID	Transect ID	TCD	LRR	LR2	LSE	LCI99_9
297.00	302.00	6020.00	-1.08	0.82	8.21	11.43
298.00	303.00	6040.00	-0.78	0.99	1.00	1.39
299.00	304.00	6060.00	-0.38	0.71	3.93	5.48
300.00	305.00	6080.00	-0.60	0.81	4.60	6.40
301.00	306.00	6100.00	-0.98	0.56	13.86	19.30
302.00	307.00	6120.00	-1.09	0.66	12.53	17.45
303.00	308.00	6140.00	-1.07	0.70	11.26	15.67
304.00	309.00	6160.00	-1.03	0.67	11.59	16.13
305.00	310.00	6180.00	-0.99	0.64	11.93	16.60
306.00	311.00	6200.00	-0.97	0.67	10.96	15.25
307.00	312.00	6220.00	-0.95	0.70	9.93	13.83
308.00	313.00	6240.00	-1.12	0.65	13.36	18.59
309.00	314.00	6260.00	-0.98	0.61	12.68	17.64
310.00	315.00	6280.00	-0.85	0.62	10.64	14.81
311.00	316.00	6300.00	-0.75	0.58	10.25	14.27
312.00	317.00	6320.00	-0.62	0.34	13.97	19.45
313.00	318.00	6340.00	-0.80	0.29	20.29	28.25
314.00	319.00	6360.00	-0.60	0.16	22.43	31.22
315.00	320.00	6380.00	-0.21	0.03	20.46	28.48
316.00	321.00	6400.00	0.04	0.00	19.39	27.00
317.00	322.00	6420.00	-0.24	0.04	19.56	27.22
318.00	323.00	6440.00	-0.42	0.18	14.36	19.98
319.00	324.00	6460.00	-0.35	0.33	8.07	11.23
320.00	325.00	6480.00	-0.15	0.12	6.51	9.06
321.00	326.00	6500.00	-0.13	0.10	6.14	8.54
322.00	327.00	6520.00	0.16	0.04	12.88	17.92
323.00	328.00	6540.00	0.34	0.13	14.16	19.71
324.00	329.00	6560.00	0.43	0.29	10.70	14.90
325.00	330.00	6580.00	0.25	0.18	8.62	12.00
326.00	331.00	6600.00	0.01	0.00	7.04	9.80
327.00	332.00	6620.00	-0.28	0.37	5.98	8.32
328.00	333.00	6640.00	-0.65	0.77	5.66	7.88
329.00	334.00	6660.00	-1.01	0.91	5.24	7.30
330.00	335.00	6680.00	-1.15	0.91	5.63	7.83
331.00	336.00	6700.00	-0.61	0.73	5.97	8.31
332.00	337.00	6720.00	-0.23	0.20	7.38	10.28
333.00	338.00	6740.00	0.00	0.00	7.54	10.50

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
334.00	339.00	6760.00	-0.02	0.00	11.04	15.37
335.00	340.00	6780.00	-0.06	0.01	13.65	19.00
336.00	341.00	6800.00	-0.11	0.02	14.06	19.57
337.00	342.00	6820.00	-0.27	0.12	12.00	16.71
338.00	343.00	6840.00	-0.53	0.43	9.73	13.55
339.00	344.00	6860.00	-0.82	0.72	8.31	11.56
340.00	345.00	6880.00	-0.87	0.65	10.29	14.33
341.00	346.00	6900.00	-0.34	0.13	14.18	19.74
342.00	347.00	6920.00	0.05	0.00	15.18	21.13
343.00	348.00	6940.00	-0.20	0.05	13.65	19.01
344.00	349.00	6960.00	-0.73	0.67	8.30	11.55
345.00	350.00	6980.00	-1.15	0.95	4.17	5.81
346.00	351.00	7000.00	-0.99	0.61	12.77	17.77
347.00	352.00	7020.00	-0.60	0.87	3.74	5.21
348.00	353.00	7040.00	-0.26	0.16	9.29	12.94
349.00	354.00	7060.00	0.00	0.00	12.16	16.93
350.00	355.00	7080.00	0.28	0.15	10.63	14.80
351.00	356.00	7100.00	0.16	0.05	11.03	15.35
352.00	357.00	7120.00	-0.17	0.09	8.83	12.30
353.00	358.00	7140.00	-0.51	0.59	6.81	9.48
354.00	359.00	7160.00	-0.71	0.86	4.68	6.51
355.00	360.00	7180.00	-0.55	0.37	11.43	15.91
356.00	361.00	7200.00	-0.21	0.06	13.27	18.46
357.00	362.00	7220.00	0.14	0.04	11.48	15.98
358.00	363.00	7240.00	0.53	0.42	9.97	13.87
359.00	364.00	7260.00	1.71	0.63	21.12	29.39
360.00	365.00	7280.00	2.85	0.63	35.09	48.84
361.00	366.00	7300.00	1.77	0.57	24.52	34.13
362.00	367.00	7320.00	0.09	0.07	5.17	7.20
363.00	368.00	7340.00	0.41	0.33	9.23	12.85
364.00	369.00	7360.00	0.73	0.55	10.47	14.57
365.00	370.00	7380.00	1.07	0.82	7.99	11.13
366.00	371.00	7400.00	1.39	0.94	5.83	8.12
367.00	372.00	7420.00	0.97	0.78	8.19	11.40
368.00	373.00	7440.00	0.51	0.53	7.74	10.77
369.00	374.00	7460.00	0.33	0.38	6.82	9.49
370.00	375.00	7480.00	0.40	0.81	3.11	4.33

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
371.00	376.00	7500.00	0.52	0.52	8.07	11.23
372.00	377.00	7520.00	0.34	0.36	7.33	10.21
373.00	378.00	7540.00	0.40	0.75	3.66	5.09
374.00	379.00	7560.00	0.73	0.97	2.21	3.07
375.00	380.00	7580.00	0.60	0.73	5.81	8.08
376.00	381.00	7600.00	0.20	0.17	7.26	10.11
377.00	382.00	7620.00	0.14	0.18	4.72	6.57
378.00	383.00	7640.00	-0.09	0.07	5.17	7.19
379.00	384.00	7660.00	-0.26	0.11	11.66	16.23
380.00	385.00	7680.00	-0.41	0.24	11.66	16.23
381.00	386.00	7700.00	-0.56	0.93	2.53	3.52
382.00	387.00	7720.00	-0.44	0.98	1.09	1.52
383.00	388.00	7740.00	-0.31	0.72	3.14	4.37
384.00	389.00	7760.00	0.00	0.00	4.88	6.79
385.00	390.00	7780.00	0.25	0.30	6.14	8.54
386.00	391.00	7800.00	0.13	0.12	5.72	7.97
387.00	392.00	7820.00	-0.26	0.14	10.37	14.44
388.00	393.00	7840.00	0.03	0.00	10.02	13.94
389.00	394.00	7860.00	0.43	0.23	12.75	17.74
390.00	395.00	7880.00	0.36	0.19	11.78	16.40
391.00	396.00	7900.00	0.25	0.09	12.77	17.77
392.00	397.00	7920.00	0.21	0.08	11.22	15.62
393.00	398.00	7940.00	0.16	0.07	9.31	12.95
394.00	399.00	7960.00	0.01	0.00	8.90	12.38
395.00	400.00	7980.00	-0.19	0.51	2.96	4.11
396.00	401.00	8000.00	-0.02	0.08	1.08	1.50
397.00	402.00	8020.00	-0.07	0.63	0.86	1.20
398.00	403.00	8040.00	-0.18	0.93	0.79	1.10
399.00	404.00	8060.00	-0.04	0.08	2.10	2.92
400.00	405.00	8080.00	0.16	0.11	7.28	10.13
401.00	406.00	8100.00	0.09	0.01	13.97	19.45
402.00	407.00	8120.00	0.13	0.02	15.33	21.33
403.00	408.00	8140.00	0.45	0.25	12.36	17.20
404.00	409.00	8160.00	0.42	0.31	10.03	13.96
405.00	410.00	8180.00	0.24	0.27	6.28	8.74
406.00	411.00	8200.00	-0.09	0.08	4.52	6.29
407.00	412.00	8220.00	-0.40	0.54	5.93	8.25

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
408.00	413.00	8240.00	-0.36	0.89	2.05	2.85
409.00	414.00	8260.00	-0.33	0.92	1.62	2.26
410.00	415.00	8280.00	-0.45	0.99	0.71	0.99
411.00	416.00	8300.00	-0.68	0.94	2.69	3.75
412.00	417.00	8320.00	-0.66	0.99	0.92	1.28
413.00	418.00	8340.00	-0.68	0.65	7.95	11.07
414.00	419.00	8360.00	-0.77	0.37	16.18	22.52
415.00	420.00	8380.00	-0.77	0.34	17.17	23.90
416.00	421.00	8400.00	-0.48	0.34	10.79	15.02
417.00	422.00	8420.00	-0.53	0.47	9.02	12.56
418.00	423.00	8440.00	-0.50	0.32	11.66	16.24
419.00	424.00	8460.00	-0.45	0.26	12.16	16.92
420.00	425.00	8480.00	-0.20	0.11	8.96	12.48
421.00	426.00	8500.00	-0.24	0.49	4.00	5.57
422.00	427.00	8520.00	-0.33	0.78	2.86	3.98
423.00	428.00	8540.00	-0.37	0.56	5.22	7.26
424.00	429.00	8560.00	-0.20	0.17	7.04	9.81
425.00	430.00	8580.00	-0.06	0.01	7.72	10.75
426.00	431.00	8600.00	-0.13	0.09	6.27	8.73
427.00	432.00	8620.00	-0.25	0.26	6.79	9.46
428.00	433.00	8640.00	-0.39	0.33	8.77	12.21
429.00	434.00	8660.00	-0.30	0.21	9.25	12.87
430.00	435.00	8680.00	-0.23	0.10	11.23	15.64
431.00	436.00	8700.00	-0.26	0.07	15.50	21.58
432.00	437.00	8720.00	-0.37	0.17	13.07	18.19
433.00	438.00	8740.00	0.00	0.00	10.95	15.24
434.00	439.00	8760.00	0.56	0.29	13.88	19.32
435.00	440.00	8780.00	0.48	0.28	12.23	17.02
436.00	441.00	8800.00	0.29	0.30	7.25	10.09
437.00	442.00	8820.00	0.45	0.75	4.20	5.85
438.00	443.00	8840.00	0.69	0.64	8.32	11.58
439.00	444.00	8860.00	0.47	0.24	13.33	18.55
440.00	445.00	8880.00	0.17	0.09	9.16	12.75
441.00	446.00	8900.00	-0.01	0.00	5.68	7.90
442.00	447.00	8920.00	0.17	0.44	3.16	4.40
443.00	448.00	8940.00	0.20	0.06	12.67	17.64
444.00	449.00	8960.00	0.44	0.14	17.19	23.92

Object ID	Transect ID	TCD	LRR	LR2	LSE	LCI99_9
445.00	450.00	8980.00	0.69	0.23	20.28	28.23
446.00	451.00	9000.00	0.47	0.15	17.90	24.92
447.00	452.00	9020.00	-0.05	0.00	13.59	18.92
448.00	453.00	9040.00	-0.47	0.38	9.60	13.37
449.00	454.00	9060.00	-0.58	0.69	6.27	8.72
450.00	455.00	9080.00	-0.60	0.92	2.75	3.83
451.00	456.00	9100.00	-0.81	0.92	3.76	5.23
452.00	457.00	9120.00	-0.77	0.63	9.38	13.06
453.00	458.00	9140.00	-0.39	0.22	11.89	16.56
454.00	459.00	9160.00	-0.22	0.13	9.24	12.86
455.00	460.00	9180.00	-0.36	0.56	5.09	7.09
456.00	461.00	9200.00	-0.30	0.36	6.55	9.12
457.00	462.00	9220.00	-0.13	0.10	6.13	8.53
458.00	463.00	9240.00	0.19	0.20	6.22	8.66
459.00	464.00	9260.00	0.15	0.64	1.77	2.46
460.00	465.00	9280.00	0.04	0.02	5.18	7.21
461.00	466.00	9300.00	-0.13	0.03	11.72	16.31
462.00	467.00	9320.00	-0.15	0.02	16.85	23.46
463.00	468.00	9340.00	-0.21	0.15	8.09	11.26
464.00	469.00	9360.00	-0.46	0.47	7.84	10.91
465.00	470.00	9380.00	-0.51	0.42	9.62	13.39
466.00	471.00	9400.00	-0.18	0.08	9.60	13.37
467.00	472.00	9420.00	-0.05	0.11	2.25	3.13
468.00	473.00	9440.00	-0.01	0.00	1.69	2.35
469.00	474.00	9460.00	-0.01	0.01	1.88	2.62
470.00	475.00	9480.00	-0.02	0.02	2.48	3.45
471.00	476.00	9500.00	-0.08	0.19	2.69	3.74
472.00	477.00	9520.00	-0.21	0.34	4.70	6.55
473.00	478.00	9540.00	-0.52	0.63	6.45	8.97
474.00	479.00	9560.00	-0.56	0.68	6.25	8.70
475.00	480.00	9580.00	-0.66	0.74	6.18	8.61
476.00	481.00	9600.00	-0.83	0.88	4.98	6.93
477.00	482.00	9620.00	-0.94	0.83	6.87	9.56
478.00	483.00	9640.00	-0.68	0.76	6.08	8.46
479.00	484.00	9660.00	-0.28	0.79	2.32	3.23
480.00	485.00	9680.00	0.04	0.07	2.59	3.60
481.00	486.00	9700.00	0.31	0.50	4.92	6.85

OBJECT ID	TRANSECT ID	TCD	LRR	LR2	LSE	LCI99_9
482.00	487.00	9720.00	0.68	0.85	4.62	6.44
483.00	488.00	9740.00	1.19	0.83	8.60	11.97
484.00	489.00	9760.00	1.58	0.89	8.91	12.40
485.00	490.00	9780.00	1.88	0.94	7.87	10.95
486.00	491.00	9800.00	1.82	0.85	12.30	17.12
487.00	492.00	9820.00	1.74	0.71	17.79	24.76
488.00	493.00	9840.00	1.79	0.70	18.64	25.95
489.00	494.00	9860.00	1.66	0.71	16.83	23.43
490.00	495.00	9880.00	1.30	0.59	17.44	24.28
491.00	496.00	9900.00	0.96	0.43	17.82	24.80
492.00	497.00	9920.00	0.90	0.65	10.63	14.79
493.00	498.00	9940.00	0.88	0.90	4.70	6.55
494.00	499.00	9960.00	0.94	0.98	1.90	2.64
495.00	500.00	9980.00	1.00	1.00	0.82	1.15
496.00	501.00	10000.00	1.17	0.99	1.39	1.94
497.00	502.00	10020.00	1.45	1.00	1.56	2.17
498.00	503.00	10040.00	1.77	0.98	3.57	4.97
499.00	504.00	10060.00	1.80	0.96	5.91	8.23
500.00	505.00	10080.00	1.81	0.92	8.56	11.91
501.00	506.00	10100.00	1.69	0.90	9.22	12.83
502.00	507.00	10120.00	1.70	0.91	8.43	11.73
503.00	508.00	10140.00	1.75	0.90	9.53	13.26
504.00	509.00	10160.00	1.75	0.79	14.63	20.37
505.00	510.00	10180.00	1.51	0.66	17.49	24.34
506.00	511.00	10200.00	1.09	0.47	18.55	25.82
507.00	512.00	10220.00	0.60	0.22	18.09	25.19