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RESEARCH PAPER

SHORELINE CHANGE ANALYSIS OF THE COASTLINE OF TESHIE IN ACCRA, GHANA

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ABSTRACT

The coastal zones of Ghana, including Teshie are attacked by coastal processes and human activities which are changing its morphology and threatening life and properties. Studies on shoreline changes in Ghana have been regionally based. However, sustainable coastal zone management of risks-prone areas focuses on specific shoreline sectors. Thus, this study was carried out in Teshie an erosional hotspot in Accra to assess the extent and the rate of shoreline change between 1986 and 2016 as well as investigate the underlying causes. The analyses of the shoreline change were undertaken using three Landsat years images 1986, 2003 and 2016. The shoreline was analysed using Digital Shoreline Analysis Systems software in ARCGIS. Field exploration and literature review were conducted to decipher the driving forces of the shoreline dynamics. Results showed that 40.7% of the entire coast was experiencing erosion with 59.3% accreting between 1986 and 2016. Average NSM accretion over the period is 12.7 m with an annual rate of 0.9 m/yr. Average coastline erosion was 10.4 m with an annual erosion rate of 0.7 m/yr. A multiplicity of natural and anthropogenic factors such as tidal and sea level rise, sand and rock mining are the driving forces for the changes in the Teshie coastline. There is the need for the development of an integrated coastal zone management policy which will include establishing a coastal protection structure and enforcing regulations on beach sand and rock mining to safeguard and protect the coastline of the locality.

Keywords: Coastal erosion, Geographic Information System, Remote sensing, Geomorphology, shoreline analysis, Teshie.

INTRODUCTION

Changes in coastline is a very dynamic natural process in response to coastal forcing factors such as high tides, geomorphology of the coastline, sea level rise and human activities including sand mining (Boateng, 2012; Kusimi and Kusimi, 2021; Kusimi and Dika, 2012; Ly,1980; Mensah, 1997). However, since the middle of the 20th century increased human activities along coastlines coupled with climate change resulting in rapid increases in sea levels and extreme weather conditions have exacerbated the rate of coastal erosions and flooding of most coastlines globally (Liu et al. 2022; Trisos et al. 2022). In contrast to accretion, the rates at which the coastlines are eroding pose danger to man and the environment. Despite the hazards prone nature of coastal zone, man's activities have increased in these areas over the past decades (Crowell et al. 2010). Reports from studies show that 70% of the world's population is affected by climate change resulting in coastal erosion and denudation (Nicholls and 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 it is increasing over time (Small and Nicholls, 2003). Thus, efforts to control retreating coastlines are a burden on the monetary budgets of coastal nations. In an assessment Marchand et al. (2011) 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 last decades in a quest to attain geomorphic equilibrium, threatening socio-economic activities (Anim, 2013; Ly, 1980). Ghana's coastal zone has been inhabited by various communities for over a century (Oteng-Ababio et al. 2011). The coastal zone covers about 7% of the total land mass, but 80% of the country's enterprises, organisations and business activities are concentrated in the enclave (Appeaning-Addo and Lamptey, 2013; Armah and Amlalo, 1998). These coastal communities are susceptible to several risks associated with coastal erosion and its effects on socio-economic activities (Adger et al. 2005). Studies conducted show the whole Ghanaian coastline to be retreating (Nail et al. 1993; Armah, 1991). The intensity of coastal erosion worsens from east to west (Ly, 1980). Both natural variables such as sea level rise and tidal waves and human elements including coastal engineering and sand mining have affected Ghana's coastline (Appeaning-Addo, 2013). These factors deprive 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).

Studies conducted so far sought to find the remote causes and patterns of coastal erosion. Appeaning-Addo et al. (2011), examined the expected impacts of sea level rise in three communities in the Dansoman coastal area of Accra, Ghana. The study revealed that about 650,000 people, 926 buildings and a total area of about 0.80 km^2 of land are vulnerable to permanent inundation by the year 2100. 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. He found that the loss of sediments to the ocean because of the damming of the Volta River at Akosombo between 1961 and 1965 was one of the causes of the rapid rate of coastal erosion of the eastern coastline of Ghana including Keta. Nail et al. (1993) identified twenty-four (24) hotspots, which proved the whole coast of Ghana is experiencing erosion. There have also been regional and local shoreline studies of the coast of Accra. Kusimi and Dika (2012), assessed the impacts of sea erosion at Ada Foah, the eastern boundary of Accra and proposed mitigation measures. They found that Ada Foah shoreline has been receding since 1926 to date with a mean change in shoreline of 280.49 m and an average annual rate of 3.46 m/year. In a shoreline change analysis, Appeaning-Addo et al. (2008) found that 18% of the coastline of Accra to be steady or accumulating with 82% receding at 1.13 m/yr ± 0.17 m/yr. The erosion rate for the central part of the Accra coastline was also found to be 0.40 m/yr ± 0.17 m/yr (Appeaning-Addo, 2010). Kusimi and Kusimi, (2021) have also found that the coastline of the Densu delta in Accra is experiencing erosion, flooding and accretion. They found that about 96% of the coastline was receding while only 4% was accreting between 1975 and 2018. Total shoreline recession over the 43-year period (NSM) ranged from 0.1 to 150 m. Mean annual rate of recession was 1.8 m/yr, while mean accretion was 0.2 m/yr). Besides the regional study by Appeaning-Addo et al. (2008) for the whole of Accra coastline, no local study on the coastline of Teshie which is one of the erosional enclaves of the region have been conducted to assessthe nature of shoreline changes in the locality and the underlying forces in order for policy makers to proffer appropriate coastal zone management measures for such a situation. This research was focused on Teshie which lies in the Central coastline of Accra to provide a better knowledge of the localised coastline dynamics in a short-term frame.

GEOGRAPHICAL SETTING OF AREA OF STUDY

The landscape of Ghana's coastline stretches over 550 km (Boateng, 2010). The study is carried out in a coastal community call Teshie in Accra, Ghana within West Africa (Fig.1). Teshie is a coastal town in the Ledzokuku-Krowor Municipal Assembly area (LEKMA) in the south-eastern part of the Greater Accra Region, Ghana (Fig. 1). The coastline is about 5.1 km long and trends east-west as shown in Fig. 1. It is bounded to the west by the Kpeshie and Kordjor Rivers and to the east by Nungua township. The northern boundary is the Spinters road while the Gulf of Guinea fringes the southern limit of the locale.

The population of Ledzokuku Krowor Municipality, according to the 2010 Population and Housing Census, is 227,932 representing 5.7% of the region's total population. The first settlers of Teshie are believed to have migrated from Kpeshie in Togo led by Numo Trebi and his family. The indigenes are primarily fishers and fishmongers with little commercial and service activities (Ghana Statistical Service, 2014).

The coastline is made up of Precambrian Dahomeyan schists, granodiorites, granites gneiss and amphibolites and late Precambrian Togo Series comprising quartzite, phillites, phylitones and quartz breccias. Apart from these formations Palaeozoic Accraian sediments including sandstones, shales and interbedded sandstone-shale with gypsum lenses are also found in the area. Soils are formed from drifted/deposited materials by wind erosion; alluvial and marine mottled clays of comparatively recent origin derived from underlying shales; residual clays and gravels derived from weathered quartzites, gneiss and schist rocks, and lateritic sandy clay soils derived from weathered Accraian sandstone bedrock formations (Ghana Statistical Service, 2014).

LEKMA lies in the dry equatorial climatic zone which experiences a double maxima rainy season pattern. The average annual rainfall is about 730mm, which falls primarily

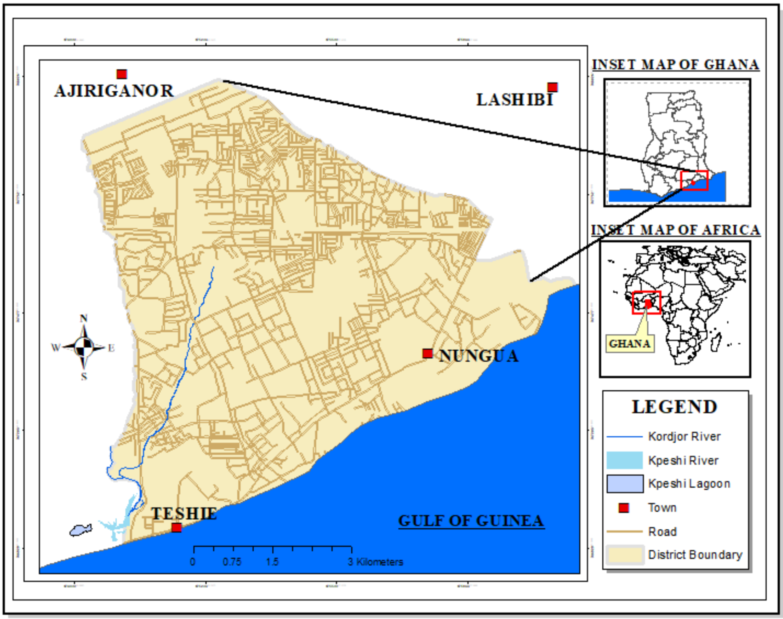

Fig. 1 Map of the study area

during the two rainy seasons. The first season begins in May and ends in mid-July while the second season begins in mid-August and ends in October. The predominant wind direction in the LEKMA area is WSW to NNE with speeds normally ranging between 8 to 16 km/hr. High wind gusts are characterised by thunderstorm activity, which pass in squall along the coastal portions (Dickson and Benneh, 1995; Ghana Statistical Service, 2014).

Two types of waves approach this coast, the waves generated by the weak local monsoons and the swell generated by storms in the southern part of the Atlantic Ocean (Jayson-Quashigah, 2011). The global wave model data from NOAA shows that average wave height for the area is about 1.39m but may reach a height of about 3m (Jayson-Quashigah, 2011). The waves normally arrive from the direction between south and southwest with an average period of 10.91s but may reach a maximum of 19.68s (Svašek Hydraulics, 2006). This coast is influenced by a semi-diurnal tide with an average range of about 1 m. The average Neap and Spring tides for the Accra coast are 0.62 m and 1.26 m respectively, and they increase from west to east (Appeaning-Addo et al. 2008; Wellens-Mensah et al. 2002). The Guinea current flows offshore from west to east with velocity between 1 m/s (max 1.5 m/s) in summer and 0.5 m/s (max 0.7 m/s) in winter (Allersma and Tilsman, 1991; Jayson-Quashigah, 2011; Sorenson et al. 2003).

The vegetative cover of the coastline is primarily coastal scrub interspersed with grass and mangroves in marshlands and lagoons, but these have been cleared as a result of multiply human activities including urbanization.

MATERIALS AND METHODS

The study involved shoreline change analysis using Digital Shoreline Analysis System

(DSAS) software in ARCGIS 10.4 and field exploration of the coastline (Kusimi and Dika, 2012; Kusimi and Kusimi, 2021). Shoreline change was carried out between 1986 and

2016 using shorelines derived from three (3) satellite images downloaded from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov). The shorelines have been overlaid on the 2016 image (Fig.2A) and that of 1986 and 2016 have been shown in Fig.2B to indicate their positions. The images are Landsat Multispectral Scanner (MSS) 1986, Landsat ETM+ 2003, Landsat ETM+ 2016 which span a 30-year frame. These were the available images of 10% cloud cover or less that were suitable for the study. The images were radiometrically and geometrically corrected and projected to World Geodetic System (WGS) 1984, Universal Transverse Mercator (UTM) zone 30˚N. A polyline shapefile of the coastline was on-screen

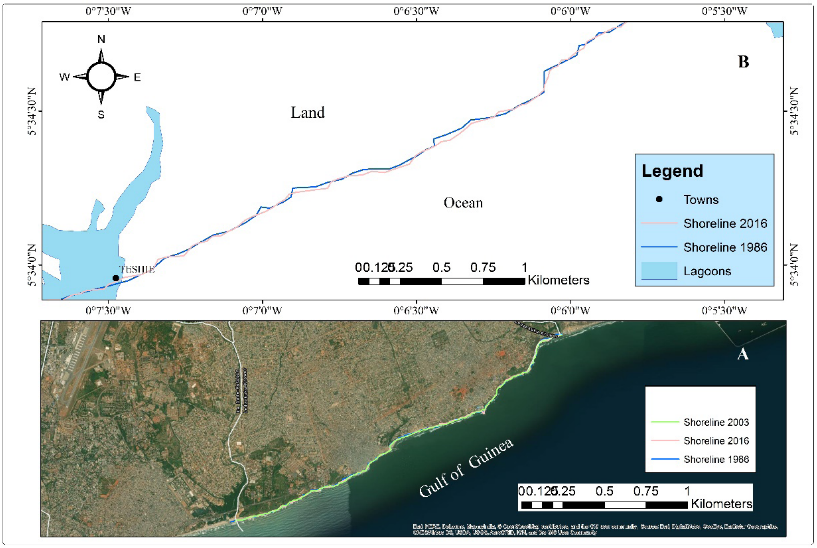

Fig. 2 A Overlay of digitized shorelines of 1986, 2003 and 2016 on 2016 image. B the overall shoreline dynamics between 1986 and 2016.

digitized for the various years and a geodatabase of the shorelines created in ArcCatalog in ARGIS. The coastlines were appended as 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. Transects were cast perpendicular to the baseline. Five Hundred and eight (508) transects were developed at a 20 m interval to calculate the changes in shoreline (Kusimi and Dika, 2012; Kusimi and Kusimi, 2021). The extent and rate of change between the periods were calculated using net shoreline movement (NSM) and end rate (EPR) methods. NSM calculates the distance between the oldest and the youngest shorelines for each transect (Himmelstoss, 2009; Jayson-Quashigah, 2011) whereas EPR calculates the rate of change of shorelines between the periods. It is calculated by dividing the distance between the two shorelines by the number of years that have elapsed. EPR is expressed mathematically as:

$R_1 = Dm/T$ .... (1)

where R_1 is the rate, *Dm* is the distance in meters between the two dates, and *T* is the time between the two shoreline positions (Himmelstoss, 2009; Kusimi and Kusimi, 2021). NSM and EPR were calculated between 1986 and 2003, and 2003 and 2016.

RESULTS

Results of the Teshie shoreline change analysis for the 30-year period shows it has been experiencing both accretion and erosion. Fig. 2A shows the positions of the shorelines (1986, 2003 and 2016) on the 2016 satellite image.

Table 1 Shoreline average rates of Net Shoreline Movement and End Point Rate from 1986 to 2016.

Period	Average Net Shoreline Movement (NSM) (m/yr)		Average End Point Rate (EPR) (m/yr)	
	Erosion (m/yr)	Accretion	Erosion	Accretion
1986 - 2003	8.87	14.31	-0.55	0.89
2003 - 2016	11.94	11.05	-0.93	0.85
1986 - 2016	10.41	12.68	-0.74	0.87

Table 1 shows the average shoreline change between 1986 and 2016. Accretion dominated the entire shoreline with 56.7% of the transects recording accretion while erosion was 43.3% between 1986 and 2003. NSM accretion ranged between 0.1 m and 71.7 m with an average of 14 m and annual rate of about 0.89 m/yr whiles shoreline recession ranged between 0.1 and 33.96 m with an average of 8.9 m and annual rate of 0.55 m/yr between 1986 and 2003 (Fig. 3 and Table 1). Accretion was high between transects 141 - 176, 228 and 272 and from transect 486 to the end of the coastline (Fig. 3).

There were several erosion hotspots notably transect 8 – 113, 177 – 195 and many more spots to the end of the coastline (Fig. 3). During 2003-2016 erosion was dominant covering about 54% of the shoreline while accretion occurred along 46%. NSM accretion ranged between 0.51 and 98.9 m with an average of 11.1 m at annual rate of about 0.85 m/yr (Table 1). Coastal accretion prevailed from transect 1 – 141, 163 – 168 and two additional spots towards the eastern end of the coastline particularly from transect 485 to 510. Erosion ranged from 0.03 to 61.95 m averaged at 11.9 m with

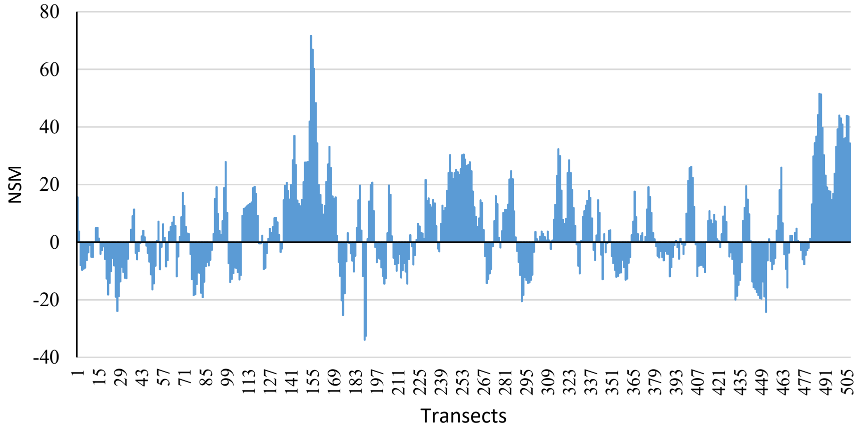

Fig. 3 Net Shoreline Movement from 1986-2003

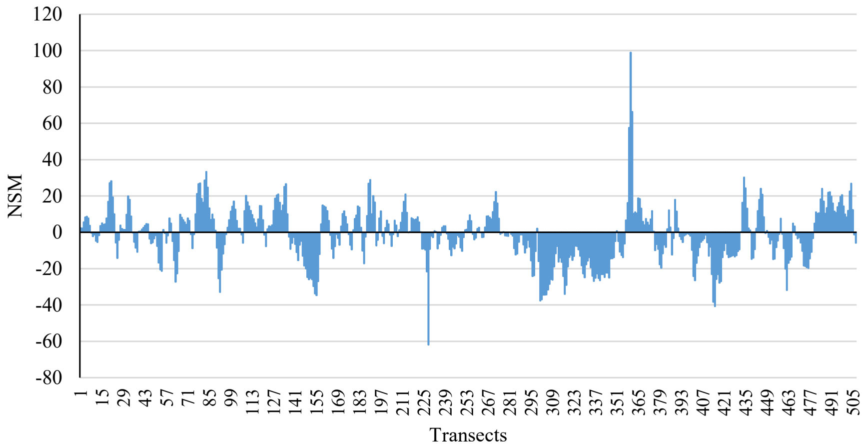

Fig. 4 Net Shoreline Movement from 2003–2016.

an annual rate of 0.93 m/yr (Fig. 4 and Table 1). Zones of large scale and severe erosion were between transects 142 and 162, 280 and 361 and 381 and 484. Fig. 5 taken during field exploration shows a section of eroding rocky coastline and buildings that are threatened by the wave attacks whiles Fig. 6 shows a coastline which is now accreting after serious erosion which was approaching homes.

The overall Teshie shoreline dynamics between 1986 and 2016 is shown on Fig. 2B. The evaluation between 1986 and 2016 showed that 40.7% of the entire coast was experiencing erosion with 59.3% accreting or stable. Average NSM accretion over the period is 12.7 m with an annual rate of 0.87 m/yr. Average coastline erosion was 10.4 m with an annual erosion rate of 0.74 m/yr for the 30 years periods (Table 1). The annual rate of erosion 0.74 m/yr for the 30 years is lesser than a longer period of 43 years 1.8 m/yr annual erosional rate obtained by Kusimi and Kusimi 2021 and is also lesser than shorter-term rates of 9 years (1.4 m/yr) and 4 years

(1.2 m/yr) obtained by Amoani et al. (2012) and Appeaning-Addo and Adeyemi (2013) within the coastline of Accra.

DISCUSSION

A comparison of the results of this study to that of previous studies show that there are variabilities in localized erosion along the coastline of Accra. However, the causes of the coastline changes do not differ much from previous studies of other coastal zones of Accra. Any coastal zone management should therefore examine the peculiarities of the local conditions in different zones and develop suitable measures of coastal zone management.

Field exploration and literature show that there are several natural and human factors that are influencing coastal erosion and accretion processes along the coast. The natural elements include tidal waves, ocean level rise, topography, geomorphology of the coastline and low littoral sediment transport, while the anthropogenic factors include coastal engineering, sand mining and urbanisation. Sections of the coastline that are underlain by the Precambrain Dahomeyan formations are more resistant to wave attack (Fig. 5) as compared to the Accraian sedimentary formations (Fig. 7) that are more weatherable and erodible. The extensive rocky Teshie coastlines experienced imperceptible retreat. Sedimentary coasts are defenceless to erosion and are at risk of geomorphic shapes (Masselink and Hughes, 2003). As such, sandy shores (soft rocks) particularly the low-lying coastal lagoons inlets and marshlands are vulnerable to erosion by longshore currents and tidal action (Fig. 7). Low-lying coastlines are attacked by waves, sea level rise, storm surges and high tides causing erosion and inundation (Cai et al. 2009; Goussard and Ducrocq, 2014). Elevated coastlines as shown in Fig. 5 were also less erodible because much of the coastline is not within the reach of the waves unless in extreme cases of high tides and strong winds which produce devasting storms.

Fig. 5 Photograph showing a section of the eroding rocky coastline.

Fig. 6 Photograph showing residents mining sand

Beach sand mining and the mining of metamorphosed rocks are rife along the coast. Fig. 6 illustrates sand mining activity by residents. The sand and rocks are mined for building and construction. Littoral transported sediments deposited in bays and low energy beaches are removed for sale. These resources have been a wellspring of material for the Ghanaian construction industry in the coastal communities (Jonah 2015; Schlacher et al. 2007). Streets, houses and bridges have depended on sand and stones from the coastal regions over the years (Defeo et al. 2009; Pilkey et al. 2004). Sand mining exposes coastline to wave attack while rock mining weakens the bonding rock layers, hence, their inability to endure the harsh conditions of the wave actions (Armah, 1993). These acts are however illicit and are a threat to coastal zones (Mensah, 1997) but have festered because of weak enforcement of regulations. Urbanisation and industrialisation have prompted settlements expansion 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). Sand mining has been identified as one of the major anthropogenic causes of coastal erosion of Accra coastline (Appeaning-Addo, 2010; Kusimi and Kusimi, 2021).

Tidal waves are one of the main triggers of coastal erosion at Teshie and the threat of tidal action has been happening yearly for decades. These extreme waves are caused by rising sea levels and storm surges. Rising sea level inundates coastlines and enhances wave and tidal activities which degrade coastlines. A study by Romine et al. (2013) on the coastline retreat in Hawaii, indicated ocean level rise as the main cause. Sea-level records of Takoradi indicate a rise in sea level of Ghana by 202 mm, 2.5 mm/yr from 1929 to 2008 (Fig. 8). Between 1929 and 1973, the rise in sea level rise was very fast with an average rise of 6.3 mm/yr. But it dropped by 512 mm between 1973 and 1985 and assumed a rising trajectory again between 1985 and 2008, going up about 437 mm. When the tidal waves are at their pinnacle, the Kpeshie Lagoon and low-lying coastal zones are inundated and eroded (Fig. 7). Where tidal waves are effective, erosion was eminent from field investigations. As shown in Fig. 5, the coastline is under attack by sea waves at high tides. The picture was taken at low tides immediately after a high tide.

Fig. 7 Low-lying sandy coastline underlain by sedimentary formations

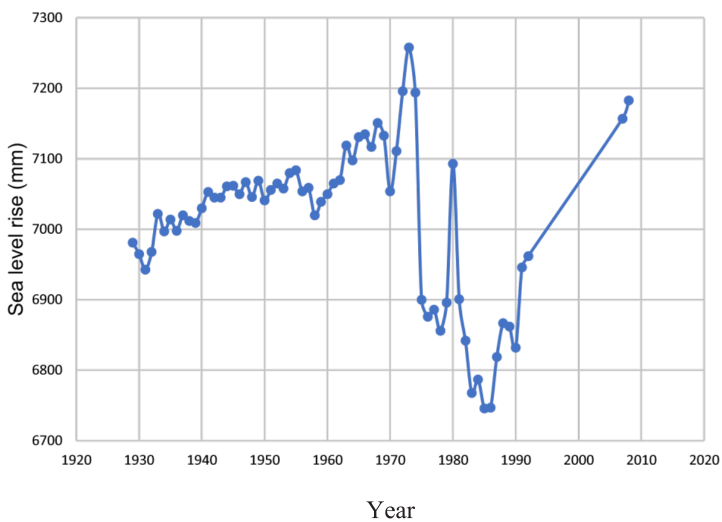

Fig. 8 Sea-level data at Takoradi from 1929 to 2008 Source: Permanent Service for Mean Sea Level (PSMSL). (2019). "Tide Gauge Data", Retrieved 14 Feb 2019from [http://www.psmsl .org/data/obtaining/](http://www.psmsl.org/data/obtaining/)

The construction of the Weija Dam over the Densu River about 13 km west of Teshie is one of the main sources of shoreline erosion in the Accra coastal region. This is because the dam has reduced the sediment supply to the littoral zone resulting in imbalance in the sediment budget of the coastal zone of Accra (Appeaning-Addo, 2010). Groynes and sea defence walls have been placed along Accra's coastline west of Teshie where coastal erosion is intense. These structures will not only have wave energy transfer to the enjoining coastline of Teshie which is unprotected since the longshore drift is eastwards but they also trap sediments of the longshore drift and thus can trigger erosion along the Teshie coastline. Appeaning Addo and Lamptey (2013) stated that the development of piers in 1906 in Jamestown west of Accra to protect Jamestown Harbour has led to an increase in erosion at adjoining areas such as La and Teshie. It was also observed that resistant rock outcrops had the same sediment trapping effect like sea defence structures. Sediments were trap at the leeward sides of headlands in bays and around rock crops especially at low tides forming incipient beaches which get washed away at high tides.

The socio-economic effects of the erosional processes of the Teshie coastline include the destruction of homes and property, displacement and loss of economic livelihoods. 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 or they lose their livelihoods. This triggers poverty among fisherfolks who are impacted by the ravaging sea. The coastal erosion has also rendered some residents homeless when their buildings are eroded by the sea. This has forced a couple of affected residents to migrate to take refuge elsewhere. Structures including walls of hotels and recreational/resort centres along the coast have also been destroyed by the sea. The resorts along the coastline include the Shining Beach, Black Mama Beach and Next Door Beach and Cocoa Beach and these areas provide fun for revellers. Because of the removal of the beach sand the beach is no longer appealing to visitors hence there is a reduction in the patronage of people to the resorts along the coastline. Shining Beach, which got its name from its previous sparkling beach sand has seen low turn-out of events they organise. 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.

CONCLUSION AND RECOMMENDATION

The study has been useful in revealing the trends in shoreline change (erosion and accretion) along the coast of Teshie. It throws more light on the dynamics of shoreline change in the community than small scale studies of the whole coastline of Accra. The evaluation between 1986 and 2016 showed that 40.7% of the entire coast was experiencing erosion with 59.3% accreting or stable. Average NSM accretion over the period is 12.7 m with an annual rate of 0.87 m/yr while average coastline erosion was 10.4 m with an annual erosion rate of 0.74 m/yr for the 30 years periods. These morpho-dynamics of the coastline is caused by several natural and human forces like tidal activities and sand and rock mining among others. The socio-economic effects of the erosional processes of the Teshie coastline include the destruction of homes and property along the coastline, displacement of people resident along the coast and the loss of economic livelihoods of fisherfolks. There is the need for the local government to develop an integrated coastal zone management policy that will ensure the establishment of a coastal protection structure and enforce regulations on beach sand and rock mining to safeguard and protect the coastline of the locality.

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