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Assessment of housing exposure to accelerated coastal erosion in Keta Municipality of Ghana

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1. Introduction

Housing plays important role in both economic and social development of every country. However, the UN-HABITAT (2009) [1] reports that, rapid population growth and urbanization have resulted in severe housing shortages and poor housing conditions in many cities; especially in Africa [2]. The situation is not different from Ghana's housing challenges as a required housing stock of over 1.5 million was estimated to be needed for the growing population as at the year 2000 [3]. This number is estimated to have increased to over 1.7 million as at 2017 [4]. Although the housing situation is evident through-out Ghana, characteristics of the coastal zone make the problem unique.

The Coastal area represents about 6.5% of the total land area of Ghana [4] but nearly 25% of the population lives in this zone [5]. This population concentration as suggested by studies [6,7]; is because about 80% of Ghana's companies and establishments are sited within this area. With extended family houses (compound houses) dominating the housing stock in Ghana, many housing in the coastal zone may have existed since the colonial era when the coastal zone served as the main trading routes and the starting point of Ghana's urbanization [5]. The leasehold of residential land-use in Ghana is 99 years and because over 80% of lands belong to families [6], residential properties are able to last more than a century without being replaced due to extended family system practice in Ghana, financial commitments challenges and others. It is no surprise that; most houses in the coastal zones are old and in deplorable conditions [7].

The problem of housing deficits in Ghana has generated many interventions and a number of researches on the way forward. Many of these research have attributed the problem of housing deficit to; land acquisition/litigation, lack of access to finance/capital, housing policy challenges [8], population growth and urbanization, high cost of land and living [9] among others. However, global examples suggest that, impacts from climate induced disasters could be a major contributor. Studies have evidenced how climate change and its associated events such as sea level rise, flooding, storm surges, coastal erosion and other climate induced disasters pose severe threats to communities and their infrastructures including housing [10,11]. For instance, the 2019 Townsville flood in the eastern coast of Queensland, Australia was estimated to have caused damage to more than 3300 houses and about 1500 homes were rendered unhabitable [12]. On the other hand, the 2004 tsunami in Aceh Nias in Indonesia was estimated to have damaged or caused partial destruction to more than 210,000 houses in both areas [13]. Besides the physical damage by disasters, the displaced population equally put pressure on existing housing stock as many of the affected persons are housed by relatives, families and friends' homes [13]. The evidence from these suggest a further recognition of the role of climate change and its induced events to the case of Ghana since the country is experiencing its share of climate change effects in the economy and the environment [14].

The Intergovernmental Panel on Climate Change (IPCC) however estimates that, the cost of adaptation to climate induced disasters could amount to at least 5%–10% of Gross Domestic Product (GDP) [2]. With the economies of developing countries such Ghana already threatened by climate events [3], the type of adaption strategy is very critical.

Ghana adopted its Climate Change Adaptation Strategies (NCCAS 2010–2020) with the aim of reducing the impacts of climate change induced disasters such as sea erosion. According to Ghana Environmental Protection Agency (EPA, 2000), the coastline of Ghana is below the 30 m contour above sea level and therefore vulnerable to sea erosion and other coastal disasters [8].

The need for urgent identification of causes and solution to averting the estimated housing deficit of over 2.5million by 2020 [8] requires the inclusion of all possible scenarios for community resilience and vulnerability reduction. With interventions and efforts of safeguarding the housing sector mainly being swayed to the problem of urban management and population increase, this research is however to highlight the role sea level rise may play in compounding the housing challenges particularly since there is expected population increase in the coastal

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Fig. 1. Map of study area.
Source: KeMA, MTDP, 2014–2017.

zone as a result of crude oil discovery and exploration in the west coast of Ghana.

Keta municipality serves as a model case study for assessing the impact of erosion because of its characteristics [15]. One of such is its severe housing deficits. The Municipality had a housing deficit of 12,570 as at 2014 for about 64,107 persons [15]; indicating, a further loss of houses and properties in the could have a huge consequences on the population.

This paper assesses the potential impacts of sea level rise and shoreline change on housing distribution in the Municipality using field survey socio-economic data, IPCC's AR5 scenarios and Remote Sensing data collection and analysis. The study estimates Ghana's Sea level rise by years 2020, 2060 and 2100. Representative Concentration Pathways (RCP) 4.5 scenario modelling (at low sensitivity) is used to estimate the corresponding shoreline erosion by the year 2100.

Estimation of the exposed building to these scenarios are equally examined together with population to be displaced. The study again examines the contributing factors to the vulnerabilities of houses in the municipality and analyses possible counters measures.

2. Study area and erosion condition

The study area is in the Keta Municipality in the Volta region of Ghana, West Africa. It is located within Longitudes 0.30E and 1.05W and Latitudes 5.45 N and 6.005S. The Municipality It is about 160 km to the east of Accra, off the Accra-Aflao main road. It shares borders with Akatsi South District to the north, Ketu North and South Districts to the east, South Tongu District to the west with its south facing the Gulf of Guinea. Out of the total surface area of 1,086km2, approximately 362km2 (about 30%) is covered by water bodies [1]. The highest elevation point is 53 m above sea level and the lowest ranges between 1 m and 3.5 m below sea level. The Keta Lagoon is located within the center of the Municipality [7]. The presence of a lagoon the Municipality as well as the ocean; delineates a littoral strip of land between them and these restricts physical development expansion. Nevertheless, this strip homes 6 out of the 10 highly populated communities in the area and is the most urbanized area in the municipality [15] it is also the location of many facilities and services for the entire municipal.

The Municipality has a total population of about 147,618; which is dominated by the Ewe ethnic group (98%) with other tribes constituting less than 2%. Keta Municipality is mainly an agrarian dominated economy although over 53% of the population lives in urban areas. The population is mainly engaged in activities such as crop farming, livestock keeping, fishing and other agric related activities and trading [15]. The average population density of the Municipality is 196.0 persons/km2 (excluding all water bodies). However, the littoral strip, which is the most urbanized has density of about 500 p/km2. The entire municipality has a total shoreline of about 50 km and its geology is basically sandy beach with absence of rocky formation, hence its susceptibility to severe erosion [15]. There is an estimated sand deficit of 2–7 cubic meters per annun.

Coastal erosion in the Municipality has been a major threat to the area since it was first estimated to be eroding at a rate of 8 m per annun (Ly, 1980, as cited by Refs. [16,17]). Although the construction of a sea defence system (KSDP, 2001–2004) may have contributed to the reduction in erosion to about 2.3 m per annun [18], other studies argue that the defence structures have worsen certain areas such that, the post-construction erosion rates are rather getting higher in the Municipality [19]. Coastal erosion is said to be a major disaster in the Municipality due to the challenges it has brought to many areas and communities [15]. According studies [20], Keta Municipality was a major trading hub in the 14th and late 20th century by which its port at that time played a significant role. However, coastal erosion has caused major destruction to the areas such that, vessels no long docks. Again the erosion has destroyed the local fishing and salt industries (which was one of the major source of income) in the area [20,21]. Coastal erosion is also said to have caused loss of cultural and historical sites, development areas, infrastructures and others [17,18,20,21]. The situation was declared as dire when a news report and documentary was carried out in 2016 [22]. According to the reports, many homes are being lost as a result of erosion either during high tides or gradual washing of their building foundations. For instance, a town called Kporkporgbor in the Municipality with a population of 500 had a little more than 50 houses with a community playground. However, high tides and erosion have washed all houses with the exception of one. The population there, together with affected person from other areas have been declared as "climate refugees" [23].

The study focuses on the littoral coastal strip and the factors listed above are the main reasons for the choice of area. However, due to limited time and resources, a sample study area of 8 km is extracted from the municipality's 50 km coastline for primary data collection and includes communities such as Keta, Adzidzo, Vodza and Kedzi. Fig. 1 shows the study area.

3. Vulnerabilities of coastal areas and measurement

3.1. Adapting to climate change induced disasters in coastal settlements

Church et al., 2010 [24] outlines how coastal zones have changed over time in terms of growing population and their economies and that; many mega cities in the world are located within this zone. Yet, sea level rise and its impacts have been identified as a significant threat to low lying places such as the coastal area [25].

Nicholls, R.J. 2011 suggests that, the rise in sea levels would affects major cities along the coast and that; some places would experience exacerbated flooding, coastal erosion, salinization of surface and ground waters, and degradation of coastal habitats such as wetlands [26]. Besides the above-mentioned impacts, the population aspect is equally highly emphasized because globally; it is estimated that, over 200 million people living in coastal areas are vulnerable to the impacts of extreme sea level events such as flooding and many others [24]. However, the rate of coastal erosion disasters is estimated to be increasing in recent years due to increasing levels of oceans and storm surges [27]. About 70% of the world's beaches are estimated to be eroding [28] and studies conducted by Mentaschi et al., 2017 [29] suggest that, more than 28,000km2 of land has been eroded between 1984 and 2015. This area which is eroded by coastal erosion is equivalent to the size of Haiti. Nevertheless, the impacts of sea level rise related impacts and its severity is dependent on the characteristics and circumstances of the area. These include (1) the magnitude of sea level rise, (2) coastal physiography or geophysical characteristics of the area, (3) the magnitude and manner of coastal development, and (4) the success (or failure) of adaptation [26].

Therefore, the counter response to these may include climate change mitigation. Mitigating strategies are usually undertaken at a macro scale, and adaptation; which is usually implemented at the local level sometime lack the connection between nationally (macro level) and adopted mitigation measures at the local.

Many local level approaches have seemed to work effectively depending on the implementation or the planning process. For instance; in the US state of Delaware, the process of adaptation involves two processes. The first is the planning and implementation adaptation measures, and the second is the building of adaptive capacity. The first aspect is termed as the "on-the-ground actions", which is more of a "hard" action and it involves raising or elevating structures out of flood prone areas, building dikes to keep water out of low-lying areas, avoiding placement of new structures in vulnerable areas and restoring wetlands to improve flood benefits to upland areas. These approaches can be categorized as part of physical planning measures.

All these measures, according to the Delaware's Sea Level Rise Advisory Committee, 2013 [30], involves collective approach from all stakeholders within the local level. These local groups; as identified, include the government agencies, land and property owners, businesses and many others. This approaches therefore emphasizes the importance of local level agencies or stakeholders in the planning of adaption strategies for vulnerability reduction.

The latter; which involves adaptive capacity building is the assessment by both government officials and all the stakeholders to estimate their readiness for the disaster. These are usually done by ensuring that, there is availability of data and information, availability of technical assistance, availability of funding, ability to cooperate and communicate, and ability to gain support for adaptation measures.

This Delaware case sums up the general approach given by Nicholls, R.J. 2011 from the IPCC Report of the Coastal Zone Management Subgroup (IPCC CZMS, 1990). Nicholls, R.J. 2011 summarizes approaches to adaptation strategy into;

- *(Planned) Retreat*: this is where all the natural system effects are allowed to occur and human impacts are minimized by pulling back from the coast via land-use planning, development controls, and other means.
- *Accommodation.* This aspect is where all the natural system effects are allowed to occur and human impacts are minimized by adjusting human use of the coastal zone via flood-resilience measures, such as warning systems and insurance.
- *Protection.* Natural-system effects are controlled by soft or hard engineering (e.g., nourished beaches and dunes, or seawalls), reducing human impacts in the zone that would be impacted without protection.

Although the study gives the importance of applying these strategies to reducing impacts of sea level rise to the coastal settlements, it however admits that, the application of the type of strategy and methods partly depend on an area-specific characteristic as well as the technical and financial capabilities to undertake them. On the other hand, understanding the vulnerability of the coastal areas and identifying the appropriate measure require a full diagnosis of the study area in question.

3.2. Trend in shoreline change and erosion vulnerability analysis

There are quite a number of approaches undertaken by various researchers analyzing and predicting vulnerabilities in the coastal area for current and future impacts. The type of approach has however been influenced by the objectives of the research because as listed by Cooper et al., 2004, analyzing and predicting shoreline change and coastal vulnerabilities are quite a complex phenomenon because there are several underlying variables such as the local geomorphological, sedimentological characteristics, including the geological framework, sediment supply and dispersal rates, sediment type, vegetation, lithification rates, abrasion, contemporary dynamics, human influences and many others [31]. Cooper et al., 2004 however admits that, despite the numerous limitations, the most widely used methodology for shoreline analysis is the Bruun Rule (1954, 1988). The rule argues that, there is an equilibrium form at the shoreline between the level of the sea water and the beach sand dune and that; a new set of equilibrium would be formed when there is a change in the level of the sea water.

However, the advancement in remote sensing technologies have also brought about a different dimension to the measurement of shoreline change and erosion [32]. These methodologies often combine image processing techniques and statistical models to observe changes in the shoreline. The most commonly used models are the End Point Rate (EPR) model and the Linear Regression Rate (LRR) models.

The EPR model usually requires at least two sets of shoreline data (in the form of digital maps) and it assesses the change by determining the net shoreline change between the two images over time [33]. The LRR on the other hand uses more than two sets of digital data sets and determined by fitting a least squares regression line to all shoreline points for a particular transect. The rate for this model is the slope of the line that is formed [18].

4. Methodology

This research was conducted using remote sensing/Geographic Information System (GIS) and field surveys (questionnaire, interviews and observation) data collection. Field survey data was analyzed using Microsoft Excel and SPSS while ArcGIS was used to analyze erosion and housing distribution and others.

Table 1
Landsat data characteristics.

Data Type	Date Acquired	Resolution
Landsat 5 TM	01/13/1986	30 m
Landsat 7 ETM	January 04, 2000	30 m
Landsat 8 OLI_TIRS	April 03, 2016	30 m

4.1. Shoreline delineation

Cloud-free muilti-band satellite images were acquired from the United States Geological Survey (USGS) glovis website. It included dataset for the years; 1986, 2000 and 2016 as shown in the Table 1;

The shoreline delineation and positions were compiled in ArcGIS software. Bands 2 and 5 (from Landsat 5) and bands 3 and 5 (from Landsat 8) were used to perform a Normalized Difference Water Index (NDWI) to separate water and land interface by using the formula in Eqn. (1);

$$NDWI = \frac{(Green\ Band - NIR)}{Green\ Band + NIR)} \tag{1}$$

The results are then segmented, reclassified and converted from raster to vector to establish the shoreline positions at the various years (see Fig. 2).

4.2. Shoreline rate of change and erosion

A geodatabase was created in ArcGIS from which all extracted shorelines were imported. Each shoreline had attributes of ID, Date and uncertainty. To calculate the rate of shoreline, change from 1986 to 2000, the 2000-year image was buffered to a distance of 200 m and the buffer outline was traced to represent onshore baseline with a cast direction of 1. The 2000-year shoreline was appended to the 1986 shoreline which is a pre-requisite requirement for the use of the End Point Rate of Change model (which requires two sets of images). This procedure was repeated for the calculation of shoreline rate of change from 2000 to 2016. The LLR was used to calculated the changes from 1986 to 2016. However, this calculation requires the use of the three sets of images since the model. Therefore, the 2016 shoreline was appended to both 1986 and 2000 shorelines for the calculation of the rates from 1986 to 2016.

DSAS, which is ArcGIS extension was used in calculating the rates. This extension allows the calculation of shoreline rates of change from a time series of multiple shoreline positions. Using the DSAS, a total of 470 transects were cast (north to south) from the onshore direction at an interval of 100 m. The rates were then calculated using the End Point Rate (EPR) for short period and the Linear Regression Rate (LRR) for long period. The EPR calculates the rates by dividing distance of the shoreline movement by the time elapsed between the two datasets. That

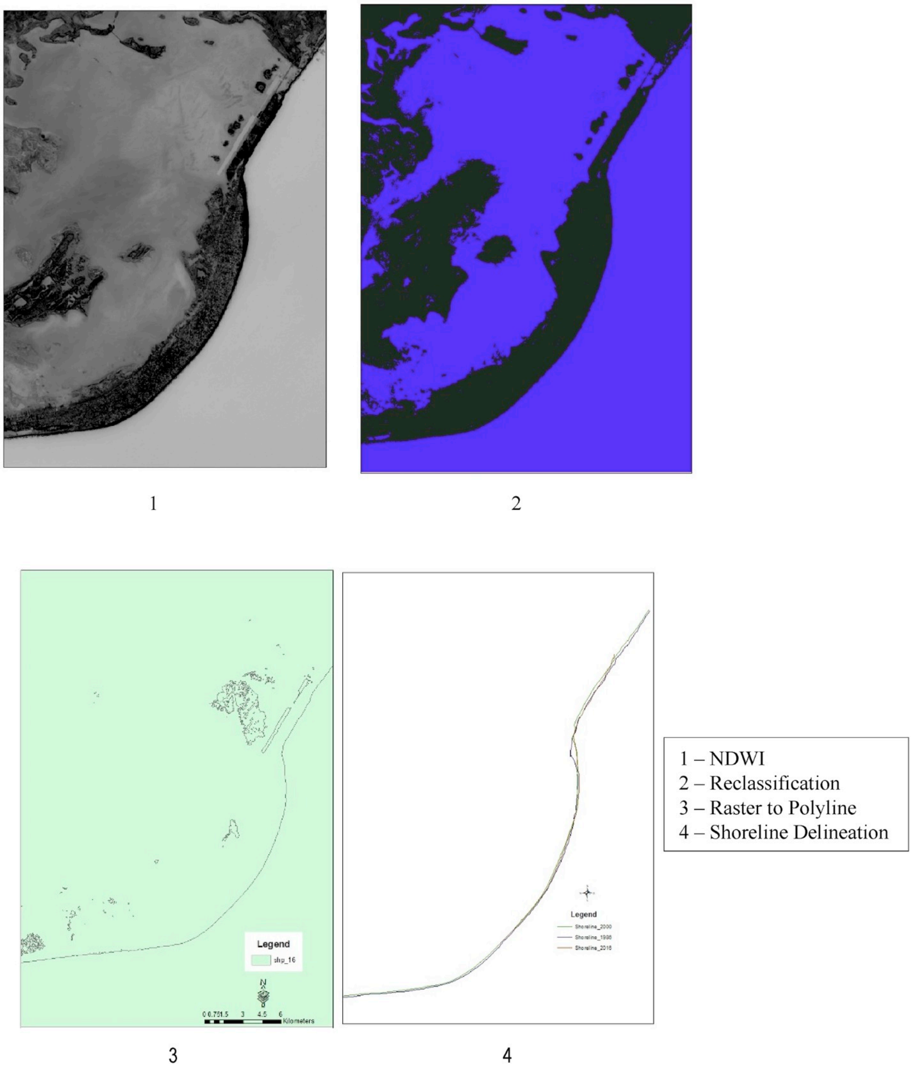
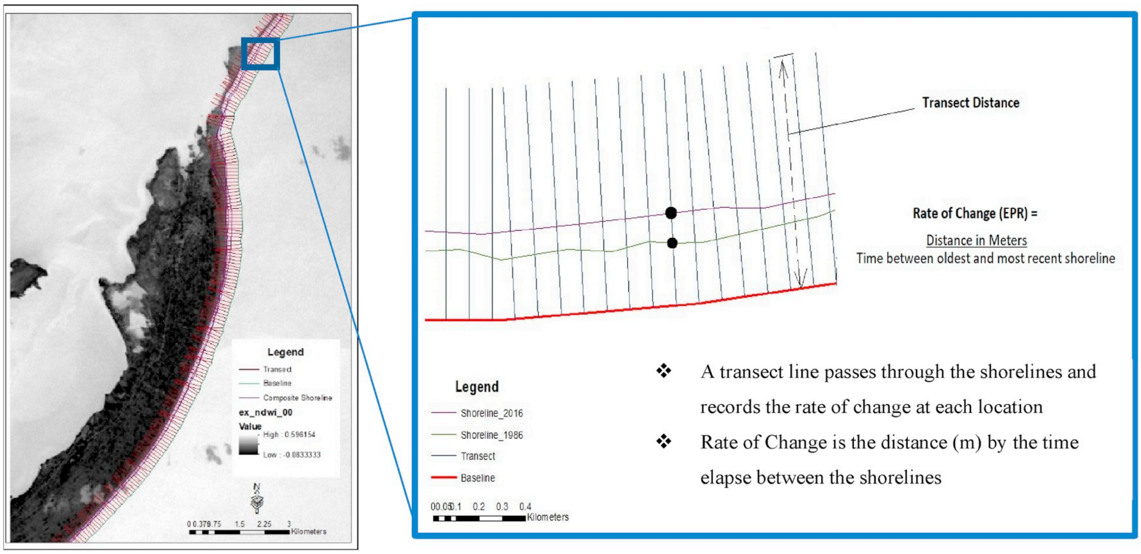


Fig. 2. Shoreline delineation process.



- ❖ A transect line passes through the shorelines and records the rate of change at each location
- ❖ Rate of Change is the distance (m) by the time elapse between the shorelines

Fig. 3. Shoreline rate of change.

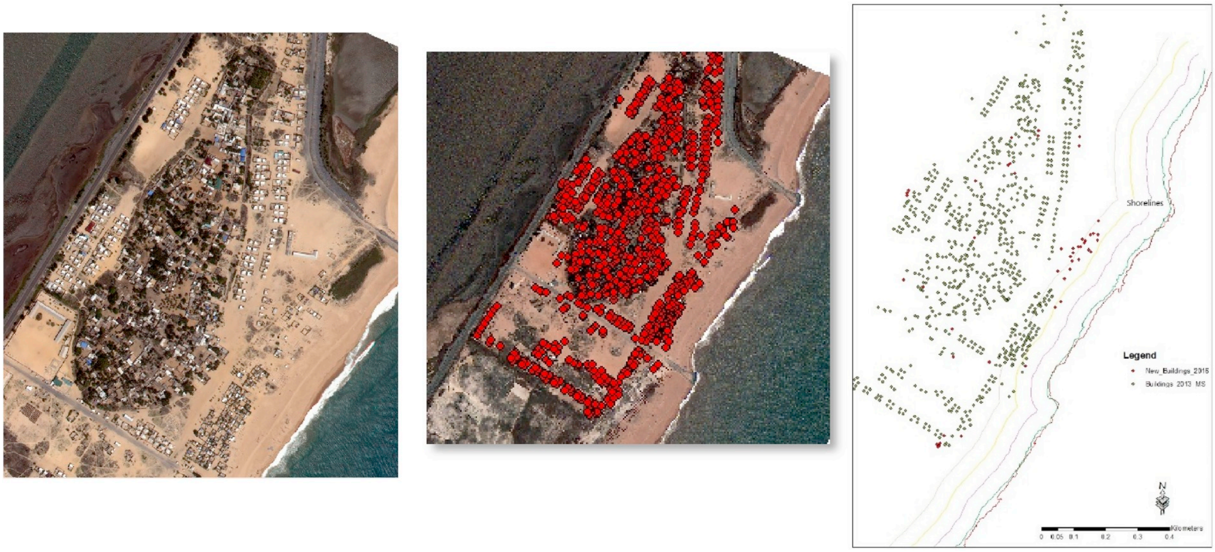


Fig. 4. Identification of housing distribution.

is Eqn. (2)

$$EPR = \frac{D\ (m)}{T} \tag{2}$$

where D = Distance in meters, T = the period between the shorelines.

LRR on the other hand determines the rate of change by fitting a least squares regression line to all the shoreline for a particular transect. The rate is the slope of the line. An uncertainty of ±0.4 was assumed and an 80% confidence level was adopted to account for all other uncertainties. This process is shown in Fig. 3.

4.3. Identification of current housing and spatial distribution

Geo-rectified Panchromatic and multi-spectral satellite images of QuickBird (acquired on 8-17-2013) and WorldView-3 (acquired on 3-16-2016) were used for building identification and change detection. To determine how the buildings have changed by spatial distribution between 2013 and 2016, the QuickBird (2013) image was assumed as reference year for the change assessment.

WorldView-3 panchromatic image with a resolution of 30 cm was used as a "master image" and the QuickBird panchromatic image was resampled from a resolution of 60 cm–30 cm and "slaved". Contrasted on the master to detect the changes between the two images, point features were placed on buildings on each image. To reduce errors, the multi-spectral images of 1.2 m resolution WorldView-3 image and 2.4 m resolution QuickBird image served as references to the housing detection.

On the other hand, Google Earth software was also used to examine the relative physical expansion of the communities in the study area from 2003, 2010 and 2016 (see Fig. 4).

4.4. Assessment of housing condition

Fieldwork survey was conducted to assess the condition of houses in the study area to ascertain the extent to which erosion is affection the physical condition of the houses in the municipality. Using the analysis of erosion rates above, an-8km stretch of the shoreline consistently experience both erosion and accretion over the years was sampled for the survey. The assessment of the housing conditions adopted some

Table 2
Criteria for housing assessment.

Walls condition - Cracks				
None	One wall	Two side walls	Three or more walls	Code No.
Good	Fair	Bad	Worse	
	x			1
x				2
Condition of Roof				
None	Ripped (quarter)	Ripped (half)	Ripped (complete)	Code No.
Good	Fair	Bad	Worse	
x				1
	x			2

assessment criteria which is shown in Table 2.

The criteria for the housing condition assessment assumes that, each house is a four-sided façade. The table was filled with “x” to denote the condition. With no data on total houses, every 4th other house randomly selected for assessment.

4.5. *Population and institutional assessment*

Characteristics, perceptions, and views from residents and the city authorities were solicited from the field survey using questionnaires, interviews and observation. The sampled area consisted of four communities namely; Keta, Adzido, Vodza, and Kedzi. A total of 80 questionnaires (20 each) were administered at simple random sampling to house owners, tenants, leader of each of the four communities as well as interviews with municipality’s government officers.

4.6. *Assessment of houses and erosion prone areas*

This stage of the methodology assesses the elements which may be at risk in the future; should there be changes in the height of the sea. To undertake this analysis, Line features were extracted from WorldView-3 (2016) multi-spectral image of 1.2 m resolution using Trimble eGognition GIS software to indicate the position of 2016 shoreline which also served as the base year.

This shoreline was offset to indicate the new position of the shoreline based on the results from Eqn. (3):

$$Y = \frac{X}{Xr} \times Sr \tag{3}$$

where:

Sr – Local Shoreline rate of change.
X – Global Predicted SLR.
Xr - National rate of SLR.
Y - Hazard zone.

This model; as used by Kate Sagoe-Addy et al., 2011 [34] to predict the effect of sea level rise on tourism locations in Ghana assumes that, a change in sea level with result in a corresponding ratio of that rise on the shoreline. Therefore, a predicted annual rise in sea level for Ghana used by this model was assumed as 3.34 mm [34]. SimCLIM software with an in-built climate data from Coupled Model Intercomparison Project (CMIP5) was then used to model the AR5’s Representative Concentration Pathway (RCP) 4.5 sensitivity scenarios at global level using low sensitivity. Houses within the 8-km sampled stretch of the shoreline are analyzed for the effects.

5. Results and discussion

5.1. *Erosion characteristics*

The result from the calculation reveals an annual erosion rate between 1986 and 2000 to be 5.0 m per annum with accretion of 7.0 m. However, the accretion rate is concentrated in specific areas representing just 15% of the shoreline. Areas along the 83rd transect experienced higher accretion and these extreme land gains may have contributed to the overall higher accretion rate. On the other hand, areas within the 40th transect experienced the highest erosion. The percentage of the shoreline experiencing erosion is 85. These areas are within Keta and Kedzi respectively.

The rates between 2000 and 2016-year period however showed quite the opposite of the previous rates. In this period, rate of erosion reduces to 2.8 m representing just 5.5% of the total shoreline coverage while accretion was 4.7 m (representing 94.5% of the shoreline). The sharp reduction of the erosion rates in this period can be attributed to the construction of the Keta Sea Defence System (KSDP) which included land re-clamation project undertaken within this period. The results are shown in Figs. 5–7.

The overall shoreline changes from 1986 to 2016, using LRR shows an average rate of 1.5 m erosion and 2.9 m accretion for the municipality. Comparing the previous rates to this suggest that, the Keta Sea Defence Project highly influenced the average rates to the extent that, erosion in the municipality is reduced significantly below an initially predicted rate of 2 m [18]. However, erosion is widespread and occupies about 68% of the entire shoreline.

An annual erosion rate of 1.5 m may seem highly positive but this period eroded about 60.17ha of land. Aerial photo comparison between 2004 and 2016 also shows how closer the sea is getting to the communities with some houses in 2004 being abandoned in 2016 (see Figs. 8–10).

5.2. *Population and housing characteristics and contribution to housing vulnerability*

Per the housing criteria, nearly 40% of the houses in sampled areas are dilapidated in terms of physical condition (roofing, walling and housing structure). The erosion has rendered some houses and rooms uninhabitable according to the residents. Housing maintenance frequency was however 15% and over 60% of houses are aged over 20 years. This buttresses the already acclaimed notion that, Africa and particularly, Ghana has poor building maintenance attitude [35,36]. In Ghana, Obeng-Odoom, and Amedzro (2011) states that, *“dwellings in Ghana are in poor condition because the occupants do not have a responsible attitude*

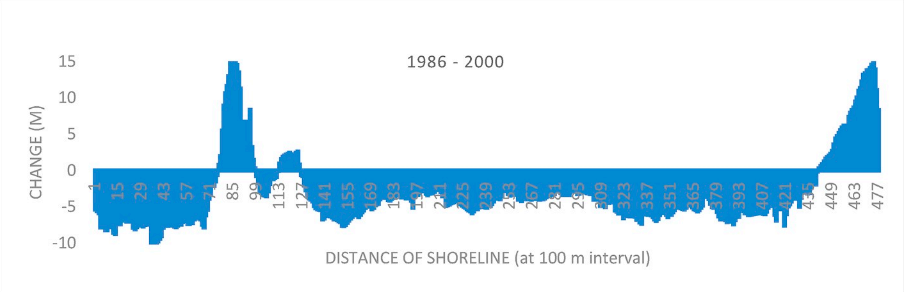


Fig. 5. Erosion and accretion, 1986–2000.

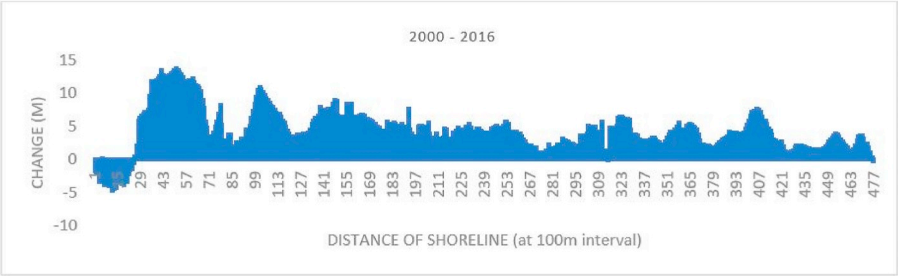


Fig. 6. Erosion and accretion, 2000–2016.

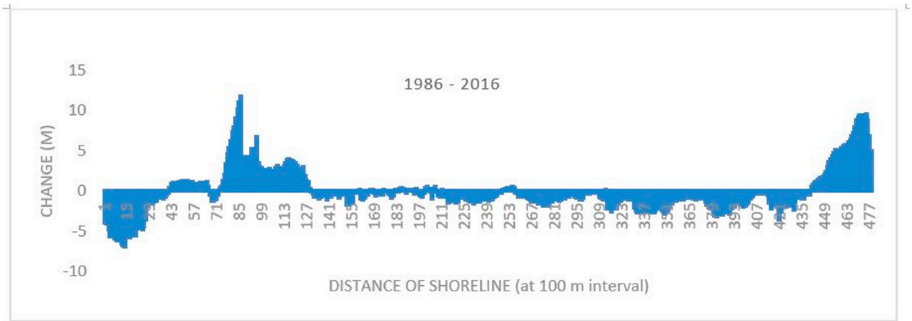


Fig. 7. Erosion and accretion, 1986–2016.

Fig. 8. Location of building to sea (2004).
Source: Google Earth

Fig. 9. Location of building distance to sea (2016).

Fig. 10. Effect of erosion on buildings.

Fig. 11. Pebbles mined from shoreline for housing construction.

toward maintaining their buildings” [36]

It is also established that, the main material for building is cement and sand (72%) while other materials constitute 28%. The demand for sand for construction is prompting the extraction of sand and pebbles from the shoreline (see Fig. 11). These practices further expose the

Table 3
SLR and Shoreline Reaction, sea level rise per annum 3.34 mm

Year	RCP 4.5 Global SLR (cm)	Local SLR in mm from base year	Local SLR in cm	No of years from baseline of 2016	Shoreline (m) per change in SLR	Total Houses in Hazard Zone	Population to be displaced	Population Affected
2020	5.92	13.36	1.3	4	27	0	0	0
2060	20.37	146.96	14.7	44	91	71	362	362
2100	35.07	280.56	28.1	84	158	303	1545	1545

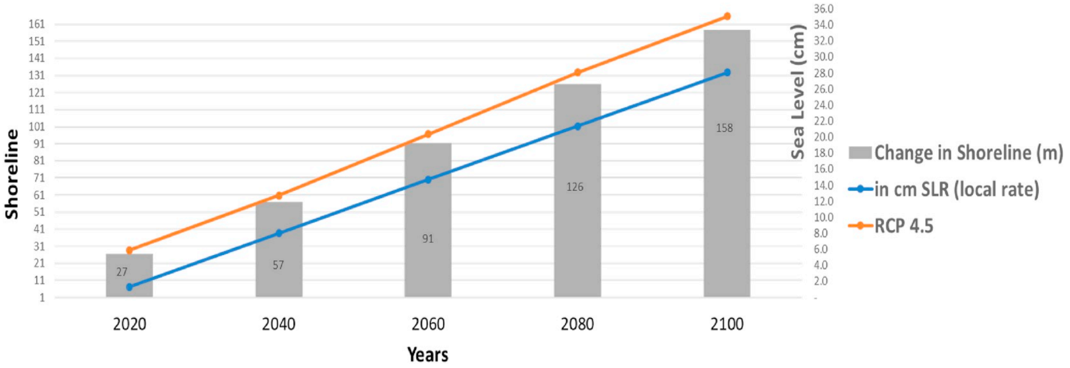


Fig. 12. Sea level rise and shoreline change.

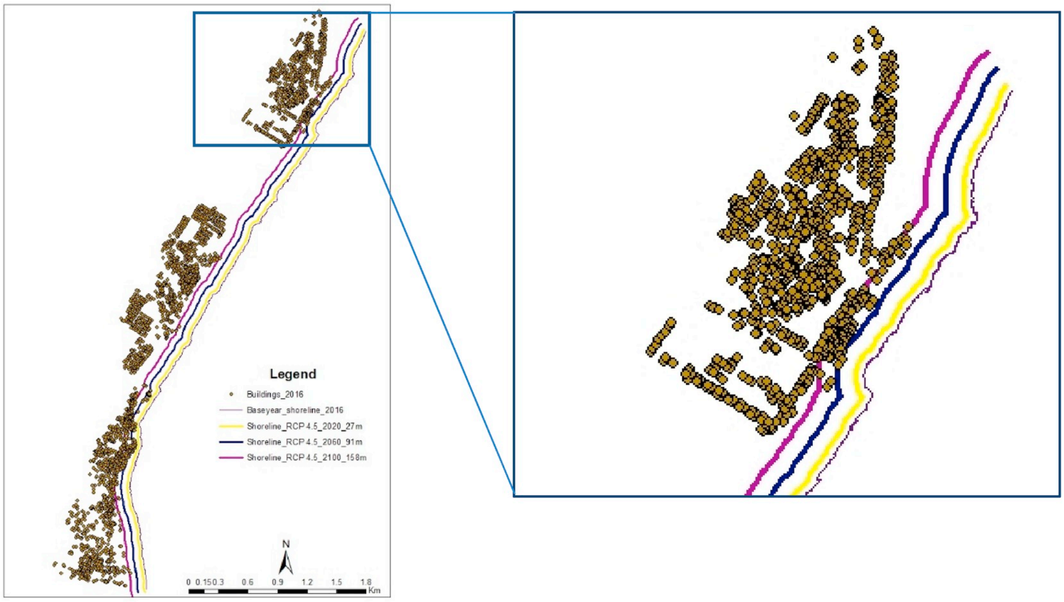


Fig. 13. Map of shoreline changes and buildings.

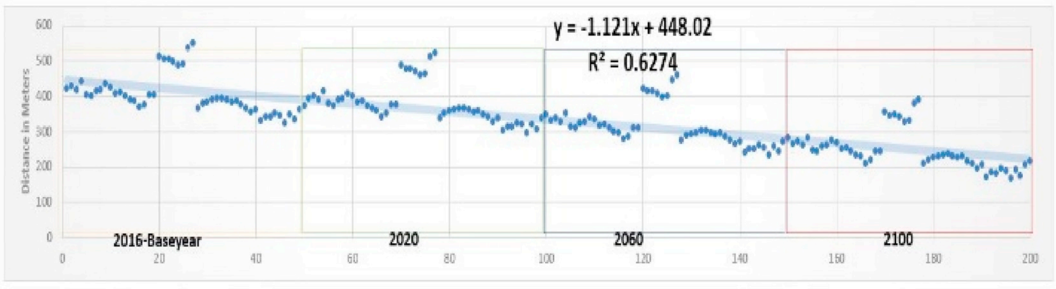


Fig. 14. Trend of building distances.

buildings and their physical strength to be vulnerable to the erosion. Although population increase in the coastal strip is a concerning phenomenon, the concentration of facilities and services in this area seem to be the population driving force to the coastal strip. The average population density of the Municipality is 196 p/km2 excluding water bodies but the density in the coastal strip is 500 p/km2; further pressure on buildings.

5.3. Sea level rise induce erosion and subsequent effects

Using the Intergovernmental Panel on Climate Change (IPCCs) greenhouse gas concentrations scenario of Representative Concentration Pathway (RCP) 4.5, Table 3 shows the reactions of projected global sea level rise on local contexts its reaction erosion on the shoreline.

At a sea level rise of nearly 6 cm by 2020, the municipality's shoreline will erode by 27 m (horizontal distance). It will erode to 158 m when level of the sea changes to 35 cm in 2100. The chain effects are shown in Fig. 12, Fig. 13.

Using sample of 50 buildings and point to object analysis in GIS, Fig. 14 shows the linear trend of absolute location of building and distances to the shoreline. At the change in shoreline in each period from a baseline of 2016, there is at least 1 m reduction of distance between the buildings and the shoreline with an R2 of 63%.

5.4. Perspective of stakeholders' erosion adaptation strategies

As a decentralized institution, the Town and Country Planning Department (TCPD) of the Municipal Assembly is in-charge of physical planning activities together with the Statutory Planning Committee (SPC) of the Municipality. However, interview with officers from this department and the Development Planning Department reveal a lack of physical development/spatial plans near the coastal strip. The inability to prepare development plans is because the municipality lack enough personnel, funding/logistics and the necessary base maps. The situation is again hindered by the fact that; lands in the area belong to families and without the appropriate consultations, compensations and resources gathering, authorities are not be able to control physical development.

Lack of physical development plans and land ownership have contributed to the residents' construction and development of houses close to the sea. Interviews revealed a collective admonition of exposure of houses in the municipality to erosion but while the population wish for a sea defence as the only solution to the problem, authorities on the other hand revealed their inability to offer such a solution. This indication shows how diverse the opinions of erosion adaptation and such situation may result in conflicting approaches as well as challenge to a lasting solution. However, a strong collaboration between all stakeholders have proven to be the only way for such situations.

6. Conclusion

It is revealed that erosion is having a huge impact on houses in the municipality as over 40% of houses are deemed bad or dilapidated due to erosion. Although the rate of erosion is considered reduced from initially predicted 2 m–1.5 m pa (per this study), its impact on houses is highly fueled by the spatial coverage of the erosion (about 60% of the shoreline) and how the houses are spatially distributed near the shoreline. With building maintenance frequency of 15% and a relatively aged houses; houses are constantly becoming vulnerable to the erosion.

Even-though nearly 92% of the population are aware of the erosion and its impacts within the municipality, the littoral strip is continuously attracting population due to the availability of facilities and services. However, most of the people currently living in the area wish to relocate but only when the government through the Keta Municipal Assembly provide alternative places and accommodation. These alternatives, according to the residents should not be far away from their current location because their livelihoods depend on easy accessibility to the sea, market and other places which are in walking distances at the moment. Their alternative to these demands is for the government to construct a sea defence walls along their communities. However, limited funding and other managerial challenges suggest that, all the demands by the residents may not be realized by authorities.

This study therefore estimates that, if this current situation is to continue as a "business as usual", then with global prediction of potential sea level rise, the municipality could lose a horizontal shoreline of 158 m by 2100 to erosion and this will affect over 300 of the current houses and a population displacement of over 1500. This would be a major disaster in the area far more than what was reported in 2016 because the cost of constructing decent house in Ghana is now estimated to cost over USD25,000 [37]. Besides this, schools, markets, fish landing sites and other auxiliary facilities currently supporting the livelihood of the people would be destroyed. This would not only affect the people living in the area but also the economy of the municipality.

To avert these consequences, the study proposes the need for population re-distribution through the use of its municipality's Medium-Term Development Plan to re-distribute facilities and service to other parts of the municipality to reverse the concentration within the littoral strip.

It also advocates for capacity building/information sharing for both authorities and the population on erosion adaption practices to guide a collective approach towards reducing the impacts. Preparation of spatial development plans to control building distribution is also highly recommended.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2019.101450.

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