

## A STUDY ON THE SHORELINE CHANGES AND LAND USE/LAND COVER ALONG THE KETA COASTAL ZONE

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### ABSTRACT:

The Keta Municipality has undergone a rapid increase in population due to economic and commercial activities. This led to the municipal's coastal and shoreline zone being faced with severe environmental challenges throughout the years. The goal of the study was to evaluate Keta's shoreline changes and the coastal Land Use Land Cover (LULC) using multi-temporal remote sensing datasets. These datasets were subjected to the following image processing techniques such as image enhancement, image classification and shoreline extraction. The Digital Shoreline Analysis System (DSAS), a plugin tool in ArcGIS was utilized to assess the rate of shoreline changes (i.e., erosion or accretion) from 2000 to 2020. These were achieved based on the following statistical methods used; Linear Regression Rate (LRR), Net Shoreline Movement (NSM), and End Point Rate (EPR). The LULC analysis indicated that built-up areas and water bodies have increased rapidly from 14.71-18.43%, and 47.68-50.46% respectively from 2000 to 2021. In terms of the shoreline changes, LRR showed a mean of -0.95m/year with 68.22% faced with erosion and accretion of 31.78%. The EPR and NSM revealed a mean shoreline change of -1.19m/year and -26.3/period respectively from 2000 to 2021. The EPR and NSM results both revealed that 69.24% experienced erosion and 30.76% accretion, indicating the prevalence of erosion at the shoreline. This research is to contribute to both the development of Keta's shoreline protection and management measures as well as sustainable land use planning. Also, aids in achieving most of the Sustainable Development Goals in the municipal.

### 1. INTRODUCTION

A shoreline or coastline is defined as the interface, boundary or a narrow strip that exists between land and water bodies such as lakes or the sea. This area is dynamic in nature and is one of the rapidly changing linear features often affected and controlled by various coastal processes such as slope, tide fluctuation, sediment characteristics, wave dynamics, climate etc. (Misra and Balaji, 2015).

Littoral transport is one of the major processes responsible for shoreline change resulting in the movement of eroded material by means of waves and currents in the nearshore zone. Apart from the natural processes causing erosion or accretion, human-induced factors such as dredging, water extraction, sand winning, creation of dams etc. can also be responsible for causing changes at the shoreline (Engineers, 2002). The issue of shoreline changes has currently become a major environmental economic, and social concern. This has also been recognized as a near-future hazard by several countries along the coast of which Ghana is not an exemption (Chand and Acharya, 2010).

Erosion is considered as highly vulnerable as compared to accretion because the former causes removal of sediments from the coastline as compared to the latter which causes widening of the coast. Also, in an attempt for the shoreline to reach a state of equilibrium, it tends to change its configuration in terms of its sediment budget which may be observed over a period of time (Pandian et al., 2004). Studies by Donatus Bapentire Angnuureng (2019) indicate that about 70% of erosion threats faced in Ghana are visible along its entire coast and this has become a major environmental issue faced in the country. A report also by the Ghana National Committee for the Intergovernmental Hydrological Programme (IHP) identified about 25 visible erosion threatened points along the coast of Ghana. Keta municipality, the focus of this study, was identified

as the worst among the 25 erosion hotspots recorded (Nail et al., 1993). These threats faced by the municipality led to the establishment of the Keta Sea defence project between 2000 to 2004 (Boateng, 2009). However, this problem of erosion faced by the municipality has increased over the years due to increased anthropogenic activities, climate change and the global warming phenomenon. This has led to sea-level rise and several storm events faced by the study area.

By virtue of the complexities associated with the shoreline changes, assessing its change of rate as recommended by Zuzek et al. (2003) is considered very important for researchers, decision-makers and stakeholders in suggesting effective management measures. This exercise helps to identify the nature and processes that led to the changes in the shoreline. In addition, these studies enable the prediction of the extent of ecological and geomorphic changes that are taking place. These studies are also important for hazard zoning, and coastal zone management planning. However, delineation of shoreline using traditional ground surveying techniques is considered to be time-consuming and almost impossible for a large coastal belt though, this exercise is pertinent for coastal management, flood prediction etc. Therefore, integration of remotely sensed data in shoreline studies in recent times has proved to provide valuable information by virtue of its spatiotemporal scales, repetitive and synoptic data coverage, multispectral database, high resolution, and cost-effective as compared to conventional techniques. This has enabled the measurement of past and present shorelines practically possible and at a reasonable degree of accuracy (Misra and Balaji, 2015; Twumasi et al., 2005). However, it has become crucial to understand the process causing the rate of shoreline changes to ensure sustainable coastal management. This study aimed to utilize multi-temporal satellite data in characterizing Keta's shoreline changes from 2000 to 2021. Further, determine the Land Use Land Cover (LULC) changes, and the rate of Keta's shoreline changes. The Linear Regression,

Net Shoreline Movement, and the End Point Rate statistical techniques were used to assess the rate of Keta's shoreline changes.

## 2. STUDY AREA

Keta municipality is one of the eighteen municipalities located in the Volta Region of Ghana (Figure 1). The Municipality lies within Longitudes 0.30E and 1.05E and Latitudes 5.45N and 6.005N and is bounded by the Gulf of Guinea. The population of the Municipality according to the 2021 population and housing census is 78,862 with 36,986 males and 41,876 females (Keta Municipal, n.d.). The climatic conditions that prevail in this area are that of the dry central equatorial type which is characterized by the wet and dry seasons (Donatus Bapentire Angnuureng, 2019). The average annual rainfall experienced in the municipality is less than 1,000mm and is known to be one of the

driest municipalities along the coast of Ghana. The major rainy season recorded in the municipality falls between March and July, while the minor season is between September and November. This also coincides with the major and minor cropping seasons of the municipality (MOFA, n.d.).

The geology of the area is made up of unconsolidated sediments deposited by longshore drift. It comprises recent or quaternary rocks and unmerged sediments that are easily identified to consist of clay, loose sand, and gravel deposits. The municipality is a low-lying coastal plain with the highest point at 53 meters above sea level and the lowest point at 1-3.5 meters below sea level (MOFA, n.d.). Also, the municipality falls within the coastal savanna with five vegetation zones. These vegetation zones are the coastal strands, brackish water, freshwater, salt flat, and guinea savannah vegetation.

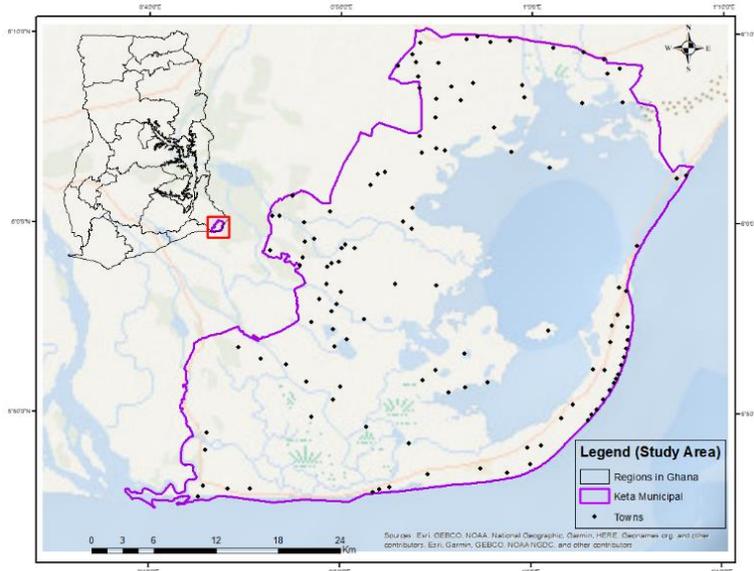


Figure 1. Study Area

## 3. DATA AND METHODOLOGY

The dataset for this study was obtained from Landsat satellite images for the period 2000 to 2021. The Landsat remote sensing dataset was used in this study because, it is the type of dataset that has been used for coastal and LULC applications for decades (Chand and Acharya, 2010). Some factors considered in using these imageries were less cloud cover, similar season data, and uniform projection factors.

These datasets were obtained from the US Geological Survey Earth Resources Observation and Science Center (EROS) website; <http://earthexplorer.usgs.gov/>. The Geographic Information System (GIS) software packages used were ENVI 4.7 and ArcGIS 10.5. The ENVI software was used specifically for atmospheric and geometric corrections of the images. The ArcGIS on the other hand was used for different image processing techniques, thus, image enhancement, image classification, and shoreline extraction.

### 3.1. Land Use Land Cover Mapping

In this study, the various Land Use Land Cover (LULC) classes for the municipality were assessed for the period 2000 to 2021 using a supervised classification method. This method comprises of three main steps; an initial spectral clustering, assignment of clusters to user-defined classes, and maximum

likelihood classification of the entire image (Misra and Balaji, 2015). Thus, each signature class were collected and assigned a signature file and finally appended together to classify the images using a maximum likelihood algorithm. Four LULC classes were identified in this study and these are; built-up areas, water bodies, open forest cover and closed forest cover. The built-up areas comprise of buildings, roads etc., while water bodies comprise of rivers and lagoons. All low vegetation cover, such as crops, and shrubs were characterized as open forest cover whereas closed forest cover comprised of mangroves or vegetation cover with thick canopy cover. No classified map has however been considered accurate without performing the accuracy assessment. Studies show that the confusion matrix is known to be the most suitable method used to determine the accuracy of any classified images (Biging et al., 1998; Oumer, 2009; Zhang et al., 2000; Murali and Kumar, 2015). In this study, the confusion matrix was determined by calculating the user's accuracy, producer's accuracy, Kappa co-efficient, and the overall accuracy of the classified image.

The formulae given below were used to determine the kappa coefficient, and the overall accuracy respectively;

$$K = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} X x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} X x_{+i})} \quad (1)$$

Where;  $N$  = total number of observations in the matrix

$r$  = number of rows in the matrix

$x_{ii}$  = number of observations in row  $i$  and column  $i$

$$\text{Overall accuracy} = \frac{\text{Total number of individual pixels correctly classified}}{\text{Total number of classified cells}} \times 100 \quad (2)$$

### 3.2. Shoreline Change Analysis

#### 3.2.1. Digitization of Shoreline

The extraction of the Keta’s shoreline and its analysis from Landsat datasets were achieved using ArcGIS 10.5. The shoreline features were identified using the tonal differences between the land and the sea and this was further digitized on georeferenced images.

#### 3.2.2. Study of Shoreline Change

The rate of shoreline change was quantified using Digital Shoreline Analysis System (DSASv5.1). DSAS is a plugin tool in ArcGIS that helps in casting transects and computing the rate of change from multiple historic shoreline positions (Thieler et al., 2009). A geodatabase for the digitized shoreline positions which comprised of the year, ID, shape, and uncertainty were created. The digitized shoreline for the period 2000, 2012, and 2021 in the vector format (.shp) was used as the input in DSAS to calculate the rate of the shoreline change. A hypothetical baseline in a vector format (.shp) was constructed onshore parallel to the general orientation of Keta’s shoreline. Whereas the transect (.shp) perpendicular to the baseline was laid at every 100m along the shoreline.

Three statistical methods thus, the Linear Regression Rate (LRR), Net Shoreline Movement (NSM), and End Point Rate (EPR) were used to calculate the rate of change of Keta’s

shoreline for the period 2000, 2012, and 2021. NSM calculates the distance between the oldest and the youngest shoreline for each transect cast. The EPR was obtained by dividing the distance between the shoreline movement, by the number of years elapsed between two shoreline positions (Thieler et al., 2009). Whereas the LRR estimates the average rate of change using several shoreline positions over time, with the change statistics of fitting a least squared regression line to all shoreline points of each transect. The linear extents with negative NSM or EPR values indicate erosion whereas the positive values indicate accretion.

## 4. RESULTS AND DISCUSSION

### 4.1. Mapping of Land Use Land Cover for Keta Municipality

#### 4.1.1 Accuracy Assessment

The accuracy of the classified imageries was determined by generating 250 reference points to obtain an error matrix using the formulas in the equation above (1-2). The results obtained are summarized in Table 1. As shown in the Table, the highest overall accuracy was recorded in 2021 (96.50%), whereas the lowest 85.43% was in 2012. The lowest accuracy was obtained in the 2012 image classification because of the low quality of the imagery as a result of clouds and scan lines.

**Table 1. Summary of Overall Accuracy and Kappa Coefficient**

LULC Feature Names	Producer’s Accuracy (%)			User’s Accuracy (%)		
	2000	2012	2021	2000	2012	2021
Waterbodies	100	100	100	100	98	100
Open Forest Cover	95	90	100	60	100	100
Closed Forest Cover	100	100	90	92	60	89
Built-up Areas	100	100	98	90	100	100
Overall Accuracy				93	90	98
Kappa coefficient				90.67	85.43	96.50

#### 4.1.2 Land Use Land Cover Analysis

The Land Use Land Cover classification was carried out to assess the changes in the land cover from 2000 to 2021. In this study, four LULC classes were identified (i.e., water bodies, open forest cover, closed forest cover, and built-up areas). These are presented in maps and Tables (i.e., Figure 2 and Table 2). The waterbodies recorded an increase in coverage from 2000 to 2021 ranging from 47.68% to 50.46%. The increase in the water bodies could be due to the periodic

flooding, sea-level rise, and inundation that is faced by the municipality. The built-up areas were observed to experience a gradual increase from 14.71% in 2000 to 18.43% in 2021. In addition, there was an increase in open forest cover from 30.79% in 2000 to 26.13% in 2021, whereas the closed forest cover recorded a decrease in land cover from 6.62% in 2000 to 2.16% in 2021. Consequently, since the municipality is known to be surrounded by lagoons, rivers, and the ocean, the decrease in the closed forest cover (i.e., the mangroves) from 2000 to 2021 is believed to be due to rapid urbanization and farming activities in the area.

**Table 2. Land Use Land Cover Classification**

LULC Feature Names	Percentage (%)		
	2000	2012	2021
Waterbodies	47.68	42.28	50.46
Open Forest Cover	30.79	40.84	26.13
Closed Forest Cover	6.62	4.97	2.16
Built-up Areas	14.71	14.90	18.43

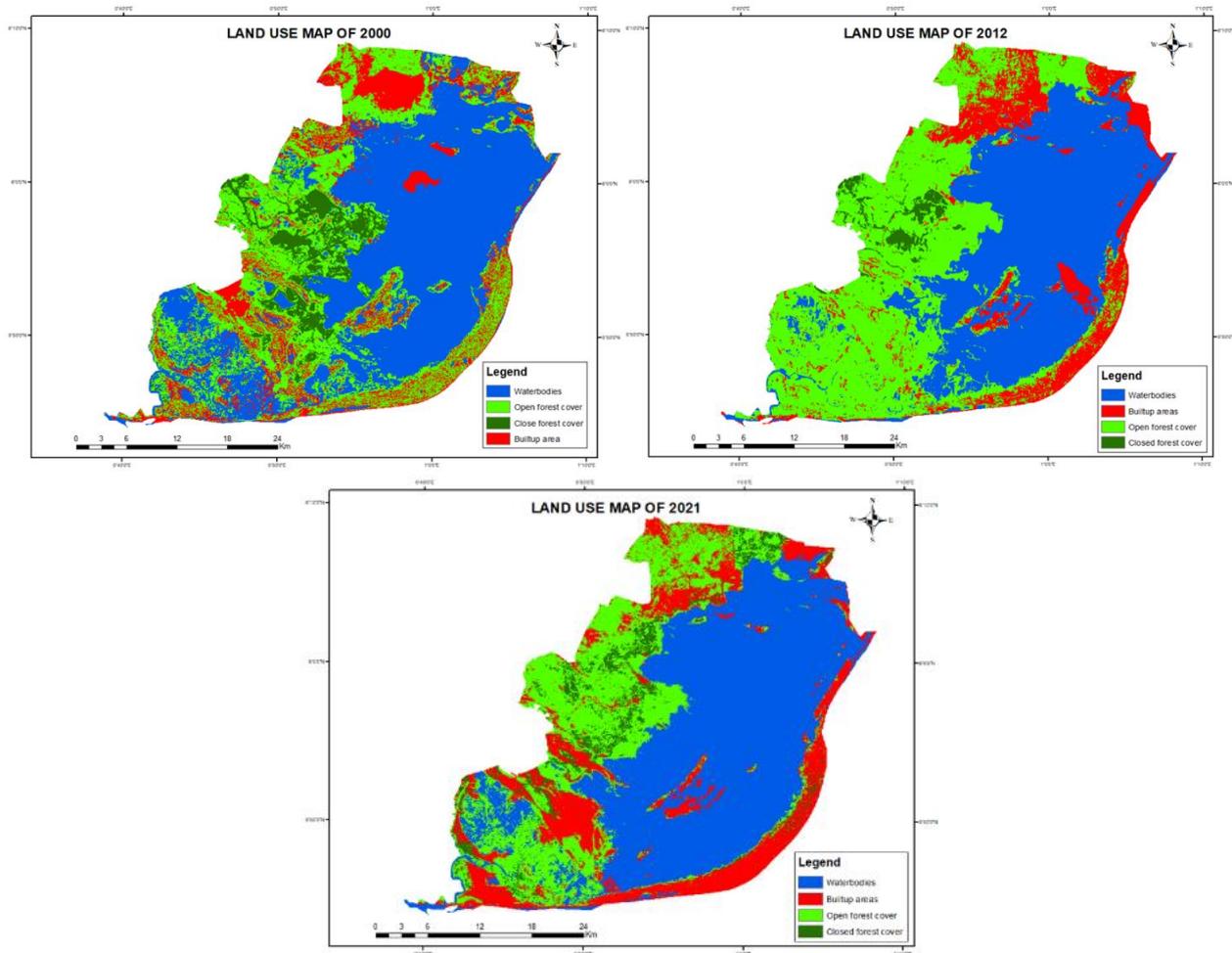


Figure 2. Land Use Land Cover 2000-2021

#### 4.2. Shoreline Change

The Keta Municipal shoreline changes were estimated using the DSAS tool embedded in ArcGIS 10.5. The extent of the shoreline accreting and eroding from the period 2000 to 2021 are shown in Figure 3 and Figure 4 respectively. A total number of 543 transects were generated with 100m spacing and the average rate of change was calculated from 2000 to 2021. Positive values of EPR and LRR as shown in Figure 3 and Figure 4 represent accretion (i.e., shoreline moving towards the sea), and negative values represent erosion (i.e., shoreline moving inland). Also, the total digitized coastal area as shown in Figure 5 for 2000, 2012, and 2021 are 5675.32 ha, 4414.75 ha, and 4909.95 ha respectively. The digitized area

shows a remarkable change in the shape of the coastal area that has occurred from 2000 to 2021.

The LRR analysis of Keta’s shoreline showed a mean of -0.95m/year where 68.22% of the transect fell under erosion and 31.78 recorded accretion. The EPR and NSM analysis revealed a mean shoreline change of -1.19m/year and -26.3m/period respectively from 2000 to 2021. They both also revealed 376 transects or 69.24% experiencing erosion and 30.76% experiencing accretion. Based on this result, it was evident that erosion was more significant in most of the sections along Keta’s shoreline. The accelerated erosion recorded during the study period might be also attributed to the increased human activities.

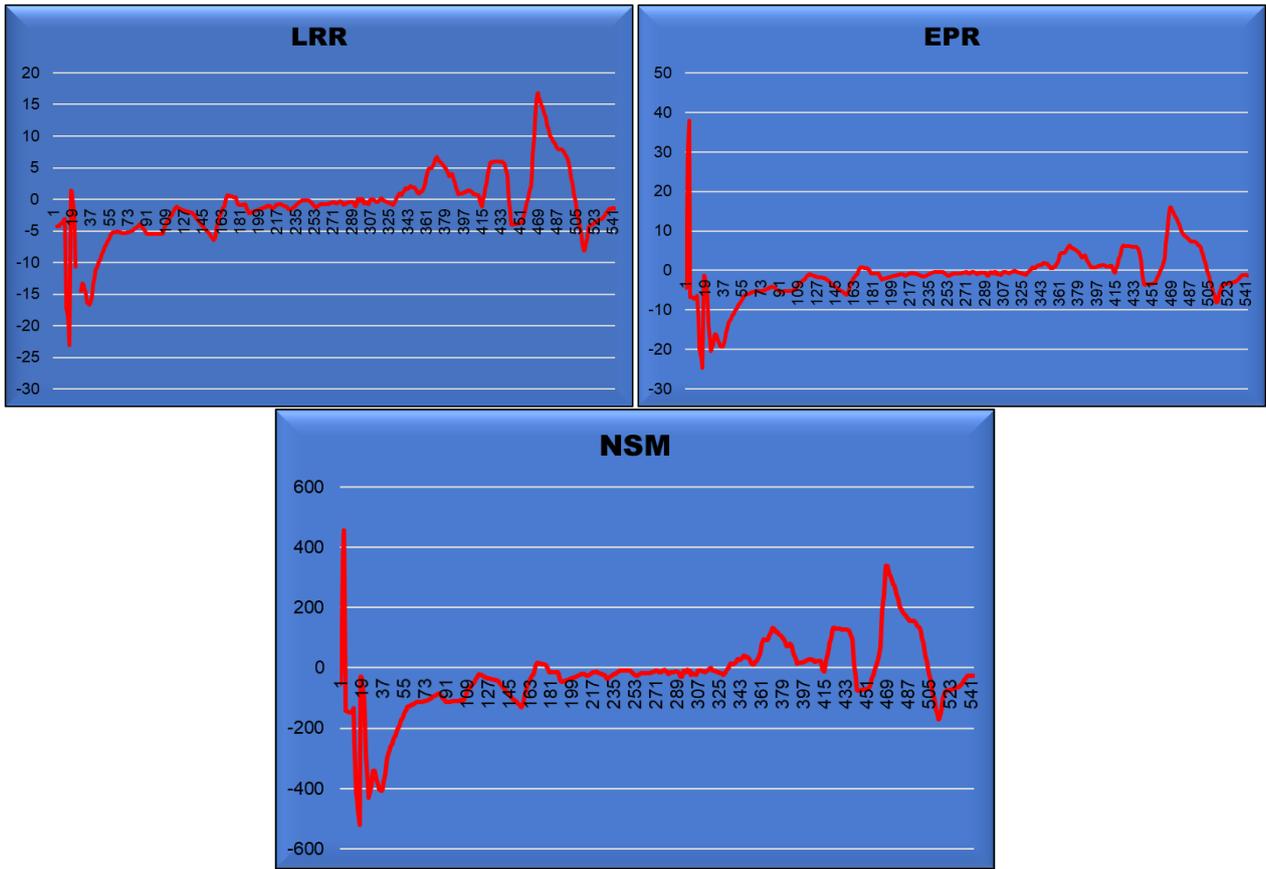
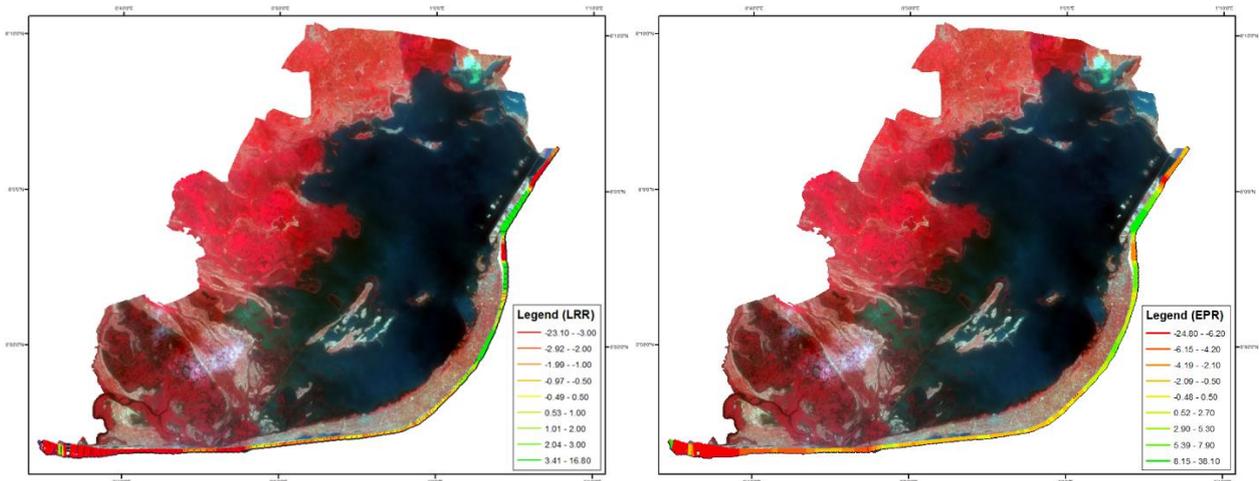


Figure 3. Graphical representation of the shoreline changes from 2000-2021 in Linear Regression Rate (LRR, m/year), End Point Rate (EPR, m/year), Net Shoreline Movement (NSM, m/period). Most of the areas falling below the line indicate shoreline erosion.



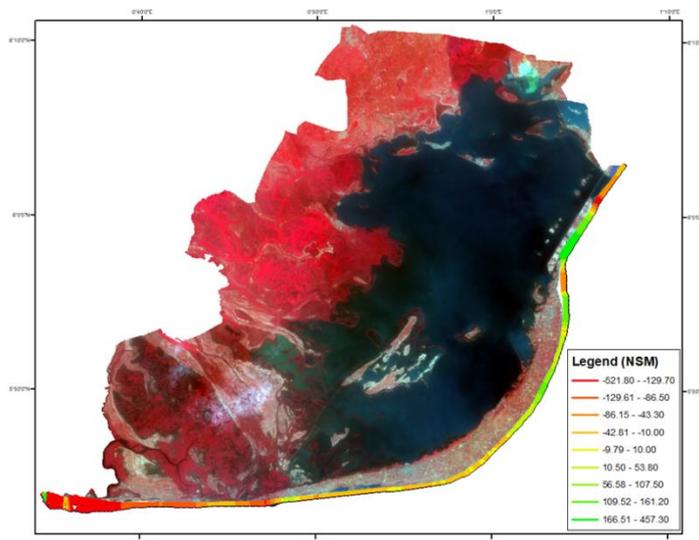


Figure 4. Rate of shoreline change from 2000-2021 (Negative values in red and yellow indicates erosion whereas the positive values in green colours indicate accretion).

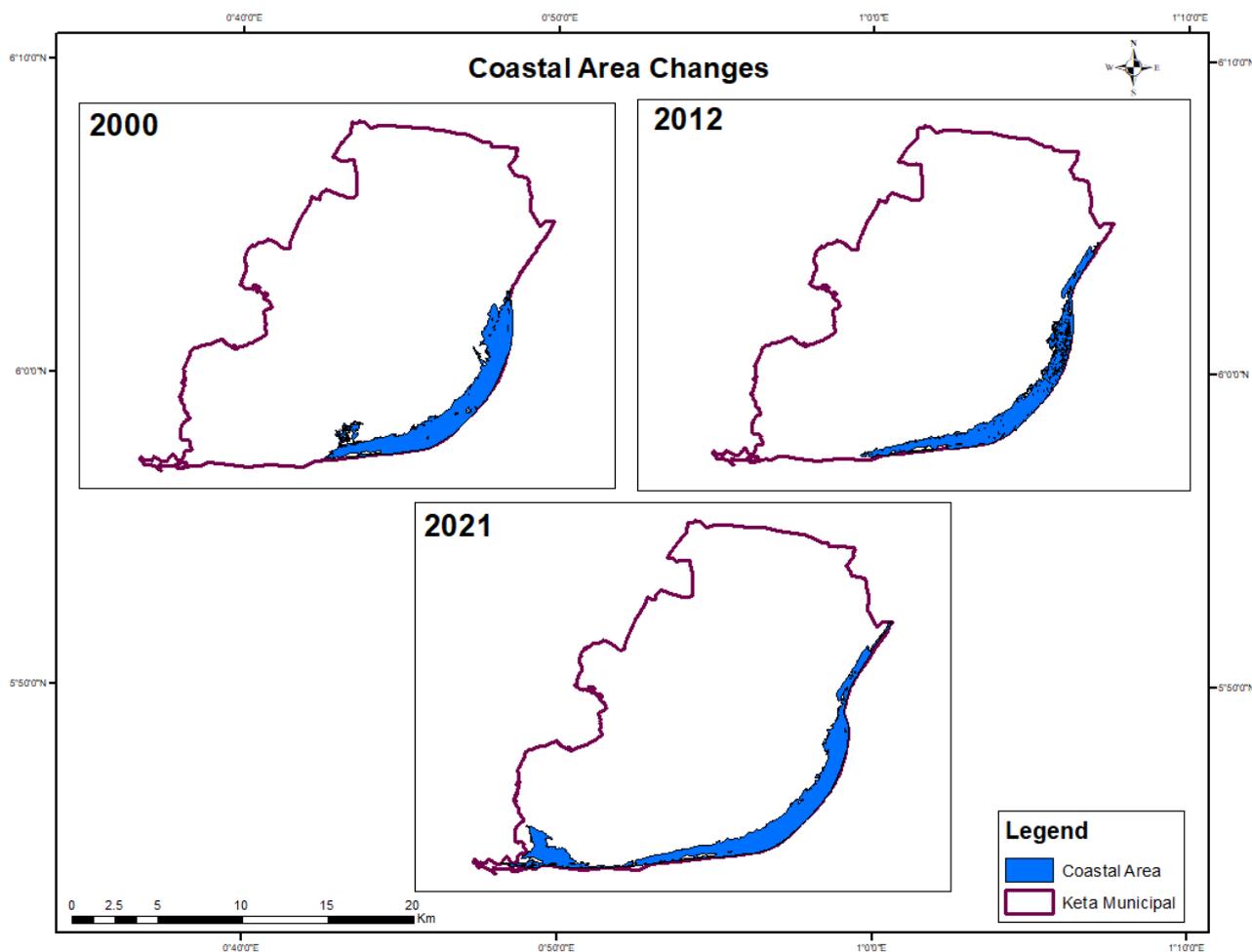


Figure 5. Digitized Coastal Areas in hectares (ha) from 2000 to 2021

## 5. CONCLUSION

The study was an effort to understand the dynamics of Keta's shoreline changes and assess the Land Use Land Cover Changes from 2000 to 2021. The study also demonstrated the

importance of integrating GIS and remote sensing techniques in monitoring and assessing the long-term shoreline changes and the Land Use Land Cover Changes. The Digital Shoreline Analysis System (DSAS) within the Geographic Information System (GIS) proved useful for calculating the shoreline

change. The findings showed that the Keta coastline has experienced more erosion than accretion from 2000 to 2021. The End Point Rate of -1.19m/year highlights the eroding trend of Keta's shoreline. This shows the need for immediate action to halt the immense erosion occurring and to ensure the resources along the coastline are protected and preserved.

The Land Use Land Cover assessed also indicates the municipal's fragile ecosystem made up of 70% water, hence the normal functioning of the municipal's ecosystem could be disrupted if further environmental degradation along these coasts continues. It is therefore recommended that sustainable land use management strategies are put in these coastal areas. In addition, the integration of GIS and remote sensing techniques together with numerical modelling and field surveys could enable a better understanding of these shoreline changes. This will aid in devising restoration and conservation measures to ensure the preservation of the natural resources

along the coastal area. Furthermore, this research will enable decision-makers to identify the susceptible areas along the Keta's municipality to devise better solutions to existing coastal problems in these locations. This will also aid in achieving most of the Sustainable Development Goals (i.e., 1, 2, 3, 4, 6, 11, 13, 14, and 15) in the municipal.

## 6. ACKNOWLEDGEMENTS

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