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Climate Induced Coastline Changes: A Case Study In Togo (West Africa)

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Changing climate is a global distress these days. Global warming is one of the men driven outcome of climate change which causes the glaciers to melt, shoreline regression and raises the level of sea. The regression of shoreline in Togo resulted in vandalization of human habitat and infrastructure. This research aims to monitor the coastal erosion utilizing the geospatial techniques in Togo from 1988 to 2020. The process of extraction and existence of change in shoreline is analyzed. Scientific problems regarding the precision of classification algorithms methods utilized for shoreline extraction using various satellite images are also considered. Thus, NDWI index derived from multisource satellite images were used in this research paper. The performance of Iso Cluster Unsupervised Classification, Otsu threshold segmentation and Support Vector Machine (SVM) Supervised Classification techniques are monitored for the shoreline extraction. This study also takes into account the topographic morphology including non-linear and linear coastal surfaces. The rate of change of shoreline was estimated through the statistical linear regression method (LRR). The results demonstrated that the SVM Supervised Classification method worked accurately for topographic morphology than other methods.

Keywords: Landsat Images, Coastal Erosion, Remote Sensing, NDWI, Shoreline, Sentinel Images, SVM

Author's Contribution
All authors have contributed equally

Conflict of interest
The authors declare no conflict of interest in publishing this manuscript in IJIST.

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Introduction

The changing climate is now an active area of research because of its adverse effects globally. Global warming is one of the outcomes of climate change which results in melting of glaciers, regression of shoreline and rising sea levels. Shoreline is actually the line where land and sea meets [1]. The shoreline regression results in coastal erosion causing destruction of natural ecosystem, human habitat and the socio economic infrastructure [2].

One of the consequences of global warming is coastal erosion and increased induction. Increased global temperature has caused the reduction of ice caps which in turned has raised the level of oceans causing ocean expansion and changing wind patterns. Consequently, it results in coastal flooding and rapid regression of coastline [4, 5, 6].

Coastal regions or shorelines constitute less than 20% of surface of earth. Coastal regions host nearly 45% of population for agriculture, transportation and fishing [7]. Shorelines are one of the major energy sources utilizing tides and waves. These anthropogenic activities have posed a threat to coastlines by raising the probability of coastal erosion and shoreline regression [8].

Climate change has affected 70% of the world's coastal regions raising the risks of flood outbursts. Moreover this flooding has affected more than 200million people around the globe. Population increase and infrastructure development has raised the need of monitoring and assessment of coastal regions. Moreover effective management and planning is required for coastline development [9].

Shoreline is primary benchmark for the measurement of any kind of climate changes. Anthropogenic activities as well as natural activities cause changes in shoreline. Industrial and residential area development has caused massive changes in shorelines. Shorelines are globally being eroded due to extensive tides and storms [10].

Moreover the extensive flooding which results in extensive sediment supply to coastal regions causes erosion and disrupts the sediment transport system. The phenomena of coastal erosion severely affected the West African coast but Togolese coast is the main concern of this study. The Togolese coast has to face challenges including coastal erosion and urban expansion because of its configuration.

Konko et al. (2018) [2] observed that the Togo coast shoreline has experienced recession which ranges from 1.66 to 5.25 m per year while urbanization has increased up to 7.84 ha per year. These average ranges predicted that the 82.724 inhabitants of the local population are at a continual risk of inundation caused by regression of shoreline which might affect 7% or more surface area until 2070s. The induction near the beach could vandalize the infrastructure and rural exodus phenomena.

The Togolese coast is monitored to plan and define hazard zones and to predict erosion. This research paper focuses on western Togolese coast utilizing remote sensing techniques. Remote sensing technique is an accurate tool to obtain reliable information regarding shoreline. The landscape features are monitored and discriminated utilizing the preferred means which include satellite images.

The Normalized difference water index (NDWI) along modified normalized difference water index is developed to enhance the discrimination of terrestrial and aquatic zones of coastal areas using various methods of water index derived from satellite imagery.

The classification algorithms utilized for the shoreline extraction from water index has major scientific concerns regarding precision regardless that the discrimination of aquatic and terrestrial zones can be done through satellite images.

Issues related to the extraction of shoreline can be resolved using reliable tools such as image processing techniques. Some other methods including Iterative Self Organized Data Analysis (ISODATA)_[11],Support Vector Ma- chine (SVM) [2] [12], thresholding and morphological filtering [13], object-oriented fuzzy classification approaches [14], Random forest method [15], genetic algorithm based methods [16] and mean-shift segmentation [17] have been proposed for extraction of shoreline.

This research paper focuses on assessment of performance of different methods for the shoreline extraction on topographic surfaces and on the shoreline kinematics from the year 2009 to 2020.

Materials and Methods

Study Area

The study area Togo lies in West Africa bounded by Ghana. The area under study is characterized by subequatorial climate having four seasons including a dry, a rainy, a short dry and a short rainy. This area contains irregular precipitation at the rate of 1000 to 1400 mm/year. The mean temperature is usually high, about 27°C. Togo covers nearly 57000km^2 area having population of about 8 million people.

Data Used

The required data for this study was obtained from Sentinel (https://sentinel.esa.int/) and Landsat (https://landsat.usgs.gov/) platform.

Figure 1. Map of Togolese Coast West Africa for the year 2020.

Satellite imagery

The satellite images come from different sensors, including Enhanced Thematic Mapper Plus (ETM+), including Thematic Mapper (TM), and Multi Spectral Instrument (MSI) were used to obtain satellite images. The image breakdowns are as follows: ETM+ image of 13 December 2009 at 09:59:54 am, TM image of 12 February 2019 at 09:34:08 am, MSI image of 04 January 2020 at 11:18:13 am. The dates were chosen in the long dry season in order to use images that were sensed in similar conditions and similar time for a coherent data analysis [18].

Optical images

ENVI software was used to preprocess the acquired optical images. The images are first geo referenced with the help JICA topographic data and GPS field surveys in accordance with the World Geodetic System the UTM projection. Subsequently the images are processed for radiometric and geometric correction and then for re sampling. The atmospheric effects were reduced using radiometric correction, while the geometric correction removed the geometric distortion [19].

NDWI technology

In order to enhance the terrestrial and aquatic zone discrimination various water index methods have been developed including modified normalized difference water index and Normalized difference water index. In this research NDWI is used due to its accuracy, convenience and efficiency [20].

Shoreline Extraction Methods

The line joining land and sea is called the shoreline [20]. The shoreline is basically line connecting a sea with land. Changes on shoreline can be detected using various methods including Image enhancement which processes satellite images, write function memory insertion, manual method and density. Manual method, write function memory insertion, density slice using single or multiple bands and multi-spectral classification, image enhancement, Multi-date data classification, Images digitization, and comparison of two independent land cover classifications and various other methods are used for detection of satellite images and shoreline extraction. [21] [22] [23] [24] [25]. The shoreline has also been extracted automatically with satellite images various algorithms used for processing of images including segmentation, pre and post segmentation.

Three distinct methods are more accurate and commonly used for shoreline extraction on NDWI indices including Otsu threshold segmentation, SVM supervised Classification methods and Iso Cluster Unsupervised Classification.

Otsu Threshold Segmentation Method

Ostu proposed a dynamic method for the partition of input raster images into water regions and homogeneous land with by reducing intra class variance. The method is known as Otsu's method.

The Otsu threshold segmentation method is the most referenced method which provides dynamic variety of thresholds on the basis of different regions in different sectors. It automatically sets the value in accordance to the local features for the achievement of a good partition between sea water and land. For the calculation of thresholding level value it highly depends upon the discriminate analysis which utilizes the cumulative moments recorded in first order of the histogram.

Iso Cluster Unsupervised Classification Method

The aquatic and terrestrial environments are separated using the Iso Cluster Unsupervised Classification method. The migrating means technique is also used as a tool for modified iterative optimization clustering procedure in the Iso Cluster Unsupervised Classification. The cells are separated into user specified number having distinct uni modal groups using the algorithm in the multidimensional space of the input bands. This method is mostly used for unsupervised classification.

The SVM Supervised Classification Method

The aquatic and terrestrial areas are also separated using SVM Supervised Classification method. It is a statistical non parametric technique which is in general used to maximize the margins and to separate observations on the basis of search for hyper-plane. The original formulation of the algorithm was dev3eloped by Vapnik (1982) [37]. SVM also minimizes the risk of error during classification and it has high performance during separation of pixels.

Shoreline Kinematics

Shoreline kinematics provides better knowledge of consequences of coastal erosion phenomenon on human habitats.

Results and Discussions

Coastal erosion due to anthropogenic activities has reached at an alarming position in Togo coast of West Africa. Aneho and Lome are the two major cities at higher risk of erosion and accretion. The changing wind patterns and tidal waves have eroded nearly 5-10 meters coastline per year.

In Togo the coastal erosion was intervened through the construction of autonomous deep sea port of Lome in the year 1968. This port can accommodate nearly nine meter depth requiring cargo ships. The process of sediment accumulation has been disrupted due to the construction of this port. Thus, this caused a loss of beaches through erosion. The construction of port effected the direction of currents which triggered sand drift off the shoreline.

Figure 2. Map of coast subdivided into seven sectors on sentinel-2 Satellite image.

Figure 3. Lome Sea port constructed at the Togolese coast.

Figure 4. Shoreline regression for the years 2009 and 2019

Table 1. The average rate of erosion per year in these sectors

Sectors Low value(meter/year)	**a** −3.88	**b** -3.49	**c** +1.85	d −4.16	**e** −6.64	**f** −5.46	**g** −6.35
High value (meter/year)	-1.1	-1.01	+2.18	−1.84	−1.66	−2.8	−3.78
Average value	-2.49	-2.25	+2.06	−3.00	−4.15	−4.13	−5.07

Figure 5. Division of Togo coastline into sections

The average rate of erosion in the region surrounding the port is nearly 3 meters per year. The Figure 4 shows the regression of shoreline for the year 2009 and 2019. LRR method is used for extraction of shoreline changes for the years 2009 and 2019. The southwest of the Togolese coast show average rate of erosion ranging from 2.49 to 5.07 m/year for the shoreline kinematics.

The average rate of erosion is 3.00 m/year, 4.15 m/year and 4.13 m/year for d, e and f sectors respectively. The sector b records both erosion and an accretion phenomenon as the asphalt road is close to the sea which causes erosion in sector b. The sector d which is port zone indicated accretion phenomena.

For the better understanding of rate of erosion on the coastline of Togo, it is divided into seven sectors through shoreline kinematics. The average rate of erosion per year in these sectors is given in the table below.

Conclusions

The coastal region of Togo is monitored from 1988 to 2019 in this research paper to investigate erosion phenomena. In this study Iso Cluster Unsupervised Classification method, Otsu threshold segmentation method, and SVM Supervised Classification methods are assessed to analyze the performance for the shoreline extraction from NDWI indices on both nonlinear and linear surfaces. This research also takes into account the kinematics of shoreline.

According to results the SVM Supervised Classification method performed accurately on linear and non-linear coastal surface as compared to the other methods. The southwest of the Togolese coast show average rate of erosion ranging from 2.49 to 5.07 m/year for the shoreline kinematics. Sector a showed the lowest rate of erosion.

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