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Due to the drop in the level of the Caspian Sea evaluation of the geomorphologic properties of the coastal region based on the processing of satellite images

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Abstract

The fall in the level of the Caspian Sea in recent years has a serious impact on the infrastructure of the coastal zone. In this work, based on the processing of images taken from the Sentinel 2 satellite, the influence of the level drop on the morphometric characteristics of the coastal zone from the cape Bandovan to Astarachay river of the Azerbaijan water area of the Caspian Sea is estimated. The images were processed using the Tasseled Cap and DSAS-Digital Shoreline Analysis System software. The results are presented in the form of maps and tables, graphically showing the changes occurring in the coastal zone as a result of falling sea level.

1. Introduction

The coastal zones are environmentally and economically important regions. Monitoring of the coastal zone and, in particular, the precise demarcation of the coastline is important as a fundamental research object in solving problems such as environmental protection in the context of *global* climate change. Shorelines are important particular qualities for land/water resources management, geographical mapping, safe navigation and coastal monitoring.

The coastal zone is located in the zone of contact of the atmospheric system, hydrosphere, lithosphere and biosphere. Coastal zones formed as a result of geomorphological processes, such as abrasion and accumulation, have different characteristics from the points of view of the landscape structure, geomorphological process, relief and its constituents (Yamamoto and Finn 2012).

2. Method

The most common methods for shoreline extraction involve visual interpretation from conventional ground surveys or aerial photographs (Boak and Turner 2005, GENS 2010). These methods are, by definition, subjective and depend on the interpreter's individual abilities, often requiring the operator to be familiar with the locale (Boak and Turner 2005). Using tidal datum indicators is a better method to identify the shoreline, but it's limited when determining the historical shoreline (GENS 2010). In recent years, there has been an increase in the use of remote sensing data using

Accuracy plays a crucial role in determining the shoreline using satellite imagery, and several factors make it difficult: sea level changes, coastline movement due to swells and surges, the presence of waves, the presence of watts and swamps along the coast (is incorrectly classified as a part of water).

In this research work, the pre-processing steps are applied for the automatic extraction of coastline by using the ArcGis 10.5 software. The shoreline change analysis was performed using ArcGIS 10.5 and DSAS 5.0. Furthermore, the erase tool of ArcGIS practiced for the calculation of erosion-accretion of the study area. The database used in this study to determine the coastline is the 2016-2021 Sentinel 2A satellite imagery.

Sentinel-2A MS image, covering an area of 100 km x 100 km, were used for a shoreline extraction. The high-resolution MSI data include 13 spectral bands from Visible and Near-Infrared (VNIR) to Short-wave infrared (SWIR) region, fine spatial resolution (10, 20 and 60 m), and 12 bit (Drusch, Del, Carlier, Colin, Fernandez, Gascon, Hoersch, Isola, Laberinti and Martimort 2012). For extract of the shoreline, we used the Tasseled cap transformation method and NDVI (Normalized

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Difference Vegetation Index). Determining the Normalized Difference Vegetation Index (NDVI) in this technique uses a composite Red band and Near Infrared (NIR) to determine the level of greenness and classification of vegetation areas. The next step uses Tasseled Cap to convert band channel into a new band set with clear interpretation for vegetation mapping, this transformation already proven fit for shoreline extraction (Safyanov 1996). Tasseled cap transformation (TCT) is a usually used remote-sensing technique and has been successfully used in various remote sensing-related applications. However, the TCT coefficient set is sensor-specific, and therefore, in this article, we developed the TCT coefficients specifically for Sentinel-2 multispectral instrument at-sensor reflectance data (Thieler, Himmelstoss, Zichichi and Ergul 2009). Tasseled Cap process are using composite bands of red, green, blue, NIR, short wave infrared-1 (SWIR-1) and short wave infrared-2 (SWIR-2) to find out the level of brightness, greenness and wetness of an object. Brightness, a measurement value for the ground; greeness, a measured value for the vegetation; wetness, a measured value for interactions of soil and canopy moisture (Wang 2018). After this analysis shoreline was extracted (Figure 1).

Figure 1. Shoreline extraction results for 2016 to 2021

2.1. Study area

The study area is located coastal zone from the Cape Bandovan to Astarachay river of the Azerbaijan water area of the Caspian Sea. The coastline is approximately 300 km.

2.2. Data

The Sentinel-2A product has radiometric and geometric corrections. An atmospheric correction operation was performed by applying a Sen2Cor processor to the satellite image in the SNAP software package provided by ESA (European Space Agency). Satellite imagery was analyzed on two different dates (19/08/2016 and 20/05/2021).

Optical and synthetic aperture radar (SAR) satellites to extract and mapping the shoreline automatically or semi-automatically (DI 2003). Several methods have been proposed to accurately locate the positionof the shoreline and are based on the use of supervised and unsupervised classification or thresholding techniques (Garcia-Rubio, Huntley and Russell 2015, GENS 2010, Tingting and Hanqiu 2019). Regardless of the method the classification of the pixels in water or land will depend, among other factors, on the resolution of the input data used.

In the study, various semi-automated methods such as Tasseled Cap (Brightness, Greenneess, Wetness) and DSAS (Digital Shoreline Analysis System) were used to identify and dynamic the coastal zone and coastline, the areas of impact and quantitative indicators of geomorphological processes were determined. For this study, used high-resolution Sentinel 2 satellite images for 2016–2021.

3. Results

The shoreline is constantly influenced by sea level variations, climate and ecosystems that occur over a wide range of time-scales. The combination of natural and manmade activities often exacerbates the shoreline change and increases the risk factors to coastal community. According to the results, in period form, 2016 to 2021 the rates of shoreline position changes indicate that all transects are accretional and less erosion was observed.

Study area shoreline is changing over time because of accretion and erosion process. However, the whole area of the coastline is almost gone through the accretion process whereas the erosion also occurred but not like the accretion through the entire period. From 2016-2021 most of the accretion took place having 8052 ha of the net gain of the area although in this period coastline has lost about 71.47 ha of the land. Kura island gain of the area 623.66 ha lost of 220 ha.

The assessment of the coastline variation was accomplished in present research work for the from the Bandovan to river of Astarachay coastline integrating GIS. Total 2 years (2016 to 2021) data was evaluated coastline, using the DSAS application and satellite data. For the automatic extraction of the study area, TCT and NDVI is proposed in this research work. This metod outperforms by providing accurate and finer edges of the coastline. The coastline change rates were measured based on EPR and NSM statistical techniques to evaluate the short term trends. The results obtained indicate that there is a change in shoreline from 2016-2021 it shows an mean accretion of 230 m. mean of erosion 23,14 m.

4. Discussion

In Caspian Sea, the minimum sea level for the past years was registered in 1977 by a ground station at -29 m. Since 1978, the sea level has risen, and in 1995 it was registered at -26.66 m and whereupon the sea level was almost stable with slight decrease. In 2016-2020, a 0.2-meter descent was observed in the Caspian Sea (Figure 2).

Figure 2. Sea level changes in the Caspian Sea (1837-2019)

The Digital Shoreline Analysis System (DSAS) is a GIS-based system established by the USGS. DSAS5.0 has six statistical methods to measure variations. In this study, Net Shore Movement (NSM), End Point Rate (EPR) approaches were used. NSM measuring net shoreline change according to distance rather than mean value. NSM relates to date and only two shorelines requires, i.e. total distance among the earliest and the latest of coastline in each transect. The End Point Rate (EPR) was selected as the statistical parameter describing the spatial patterns of shoreline change (Scott, Moore, Harris and Reed 2003). EPR measures shoreline change by dividing the distance of the coastline among its initial and the most current position of coastline. Where, the EPR and NSM positive and negative value shows seaward and landward movement of the coastline respectively (Figure 3; 4). Baseline, historical seashores and coastlines uncertainty are input data delivered in the model for during simulation phase. The spaces among transects alongside the baseline and transects length were demarcated based on the coastline pattern. DSAS creates transects that are cast perpendicular to the baseline at a user definite spacing along the coast. The transect coastline intersections along this baseline are then used to compute the rate of change statistics. Based on the logical conditions in DSAS, 2446 transects has been created that are oriented perpendicular to the baseline at each 500 m spacing along from Cape Bandovan to Astarachay river.

Four scenes of Sentinel 2 sensors, covering the periodsentinel between 2016 and 2021, were used to demarcate shoreline positions and estimate shoreline change rates from the Bandovan to Astarachay river of Azerbaijan. The method relies on image processing techniques using the IDRISI software, and the Digital Shoreline Analysis System for ArcGIS software, which provides a set of tools permitting transects-based calculation of shoreline displacement. First, the Sentinel images were radiometrically and geometrically corrected. Second, band ratioing, reclassification, raster to vector conversion, and smoothing techniques are applied successively to detect and extract the multi-temporal shoreline data. Third, these data are overlaid and the changes are calculated using the end points and net shoreline movement and end point rate methods. The results indicate significant shoreline changes ranging from 1559.6 to −41.7 m/year, while some parts remained unchanged.

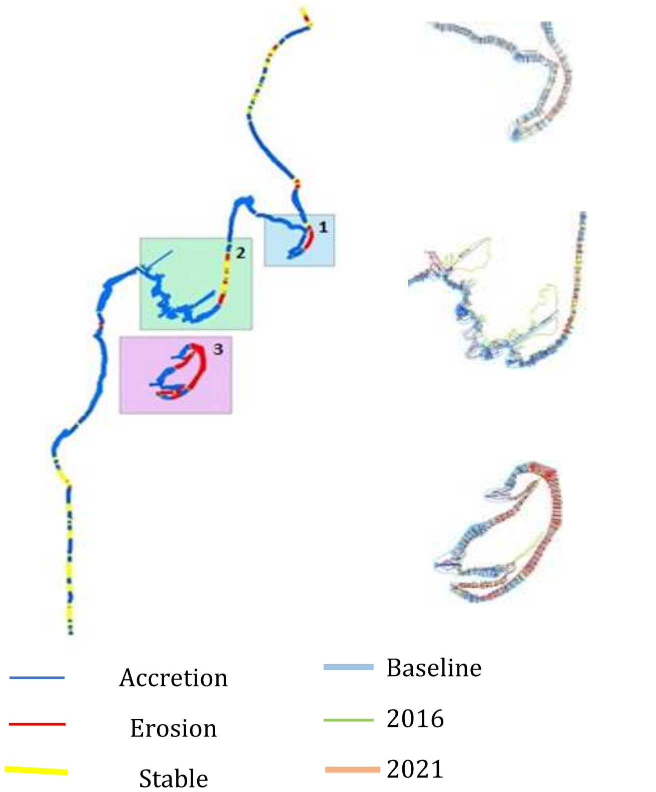

Figure 3. Areas where the coastline is subject to maximum erosion (1) and accretion (2) and result of Kura language island (3).

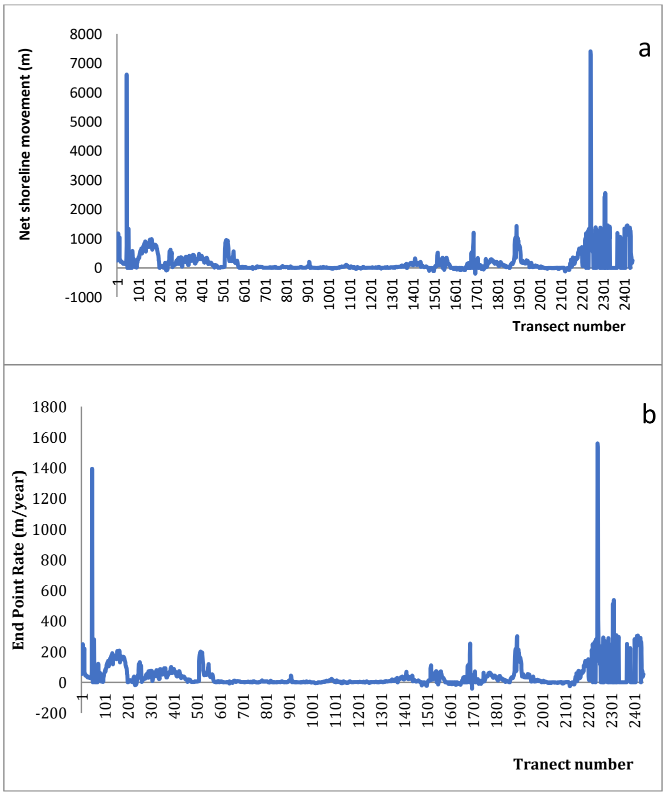

Figure 4. Rate of shoreline change a (NSM in m), b)(EPR in m/yr) for the year 2016 to 2021.

5. Conclusion

The presented results are clearly indicative of a coastline shift. This was particularly noticeable between 2016 and 2021 when the shoreline moved on average 197.12 m towards the Caspian sea. As the coastline moves away from the land, a continuous increase in the beach surface in from the Bandovan to river of Astarachay was observed. Based on conducted analyses, the sandy area increased by 7980.53 ha. The area of the Kura language island has expanded by 403.66 hectares (Figure 5).

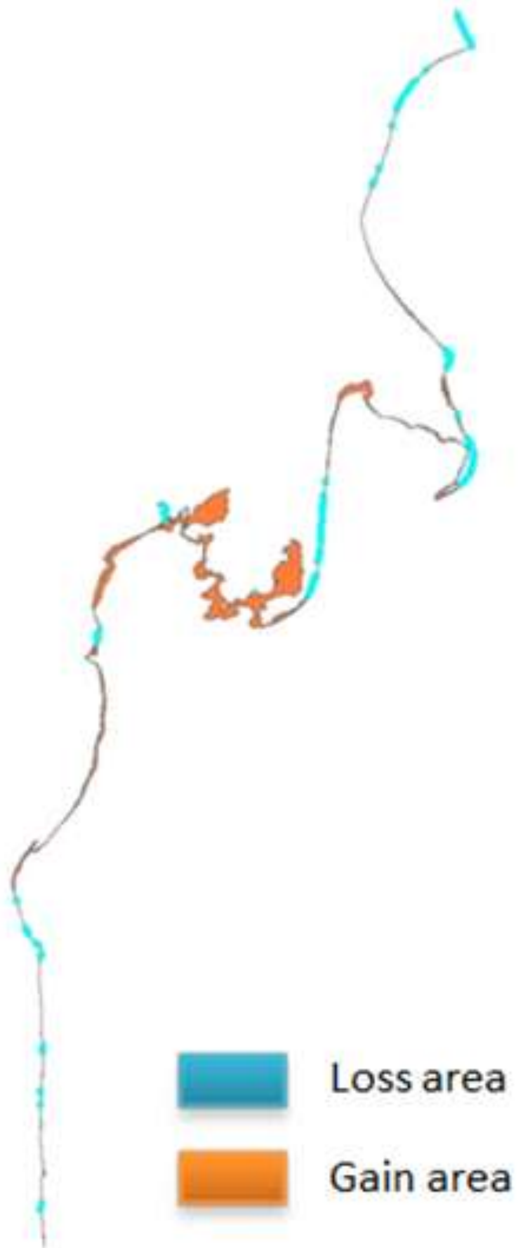

Figure 5. Fragments showing land gain and loss

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