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Monitoring long term shoreline changes along Caspian Sea, Azerbaijan using geospatial techniques

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Abstract
Since the Caspian Sea has no access to the ocean, its level changes cover a wide range. Thus, the change of the level affects the coastal zone and leads to a change in its geomorphological structure. In the study, the displacement dynamics of the coastline of Azerbaijan for the years 2005 and 2021 were determined using the Sentinel 2A and Landsat 7 satellite images and remote sensing data. Tasseled Cap Transformation (TCT) and different Normalized Difference Water Index, Normalized Difference Vegetation Index have been used to demarcate the shorelines. According to the established coastline, the increasing and decreasing land areas were calculated.The main objectives of the study are to demarcate the shorelines of 2005 and 2021 from the different sensor satellite images, to identify the quantitative and qualitative shoreline changes for above mentioned periods.

1. Introduction

The coastal zone is one of the most dynamic areas on Earth, with changes occurring at a wide range of time and spatial scales. Shoreline is defined as the line of contact between land and water body (Kajichang, et al. 2013). They are continuously modified by natural and human made process. This fact, makes systematic mapping of this type of regions a challenge. Coastal zones is of particular importance for the presence of availability of settlements and economic activities, most of which are related to tourism. Accurate demarcation and monitoring of shorelines necessary for understanding various coastal process. Shoreline delineation is difficult, time consuming and sometimes impossible for entire coastal system when using traditional grand survey in techniques. The coastline is not a straight line to all locations; it has many modulations and undulations because some geomorphological features are easily washed out by wave energy, like limestone. Shoreline changes resulting from natural and anthropogenic activities are interrelated. International Geographic Data Committee (IGDC) is recognized the shoreline as the one of the 27 most important features-to be mapped and monitored (Kajichang et al. 2010). The shoreline change studies help in the different application fields such as shoreline erosion monitoring, coastal zone management, flood prediction, and evaluation of water resources (Yashon et al. 2006). In this study, coastline demarcation is an important and challenging task as it forms the basis for further research such as coastline changes, forecasting and detection of vulnerabilities, etc. Understanding coastal dynamics requires a broader temporal and spatial scale approach that time-limited and localized research cannot provide. Over the past several decades, remote sensing and geographic information systems techniques have led to improvements in coastal geomorphological research. Currently, the development of remote sensing and GIS technologies has established itself as the most powerful and reliable tools for mapping coastline changes.

Tasseled Cap Transformation (TCT) and different Normalized Difference Water Index, Normalized Difference Vegetation Index have been used to demarcate the shorelines and vector change detection method has been employed to access the changes of coastal zone Caspian Sea territory of Azerbaijan by using Sentinel 2A and Landsat 7 (ETM+) sensor data (Thieler et al. 2009).

The main objectives of the study are to demarcate the shorelines of 2005 and 2021 from the different sensor satellite images, to identify the quantitative and qualitative shoreline changes for above mentioned periods.

By using these methods, the study aims to provide valuable insights into the dynamics of the coastal zone in the study area. The results of the analysis can be used to develop effective coastal management strategies and to promote the sustainable development of the coastal ecosystem.

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2. Method

In this study for to identify occur changes in the coastal zone for sixteen years was used ortho rectified and geodetic dataset of Landsat Enhanced Thematic Mapper plus (+ETM 2005) and Sentinel 2A (2021) data. Based on accessible databases, some pre-preprocessing methods were first involved for correction of atmospheric inaccuracy using dark object subtraction. Dark object subtraction (DOS) is perhaps the simplest and most widely used image based relative atmospheric correction approach for classification and change detection applications (Markhamet al. 2000). In the second stage, the process of geometric correction which is known as orthorectification was applied to the Landsat images. During this process, data is corrected according to the user's ground reference system. 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) (Mamishova, 2022).

2.1. Determination coastline

For extract of the shoreline, we used the Tasseled Cap Transformation method and NDVI (Normalized 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. 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 [4]. 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 (Figure 1) (Yamamoto and Finn, 2012).

After this analysis shoreline of the river from Samurchay to the Astarachay coastal of the Caspian Sea was extracted (Figure 1).

The extracted shoreline can provide valuable information for further analysis and management of the coastal zone. It can help to identify areas that are prone to erosion or accretion, track changes in the shoreline over time, and support the development of coastal management strategies.

Overall, the extraction of the shoreline from Samurchay to the Astarachay coastal of the Caspian Sea represents an important step in understanding the dynamics of the coastal zone in the study area. The extracted data can provide a valuable resource for researchers, policymakers, and other stakeholders interested in the sustainable management of coastal ecosystems.

Figure 1. Shoreline extraction results for 2005 to 2021

2.2. Caspian Sea level

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 3).

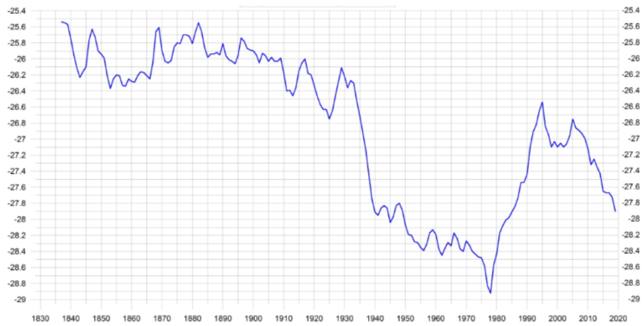


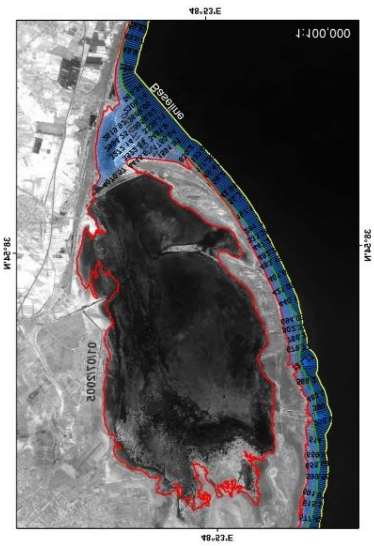
Figure 3. Sea level changes in the Caspian Sea (1837-2019)

3. Results

The Digital Shoreline Analysis System (DSAS) is a GIS-based system established by the USGS. DSAS 5.0 has six statistical methods to measure variations. In this study, Net shore Movement (NSM) was used. NSM measuring net shoreline change according to distance rather than mean value. NSM relates to date and only two shorelines require, i.e. total distance among the earliest and the latest of coastline in each transect (Thieler et al. 2009). Where, the NSM positive and negative value shows seaward and landward movement of the coastline respectively. 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, 6758 transects has been created that are oriented perpendicular to the baseline at each 100 m spacing along from river of Samurchay to the Astarachay coastline.

The results of coastline analysis show that the NSM distance positive values follow the 0,02 m between 10804 m, negative values follow (-907.54 m) between (-0.02 m). The maximum accretion distance 10804 m, maximum erosion distance -907.54 m (Figure 4).

a



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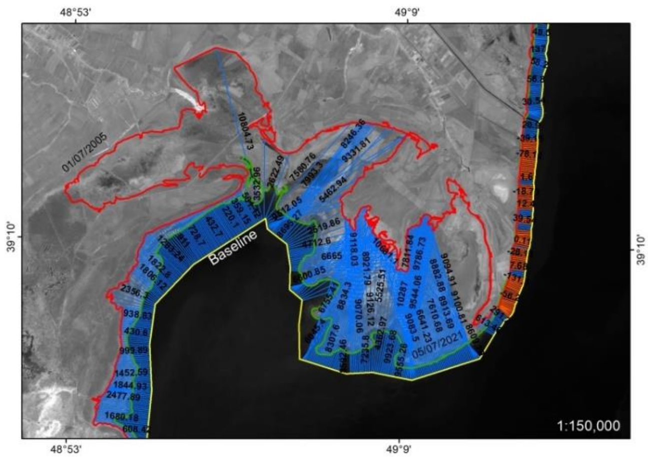

c

Figure 4. Net Shoreline Movement (NSM) Change Rate 2016 to 2021 (same areas)

The rates of shoreline position variations measured by the NSM method during this period show that the coastline is principally subjected to accretion (Figure 5).

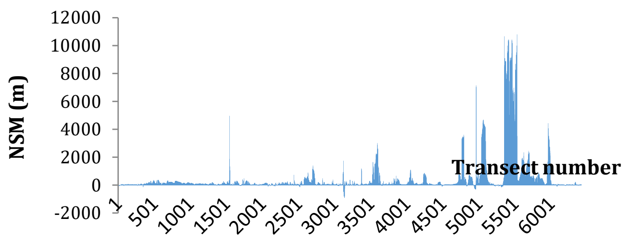

Figure 5. Net Shoreline Movement (NSM) Change Rate 2016 to 2021

4. Discussion

It is worth noting that while the overall trend indicates a net gain in the area due to accretion, there have been some losses of land due to erosion. These losses of land could have significant implications for the ecosystem of the study area, including changes in the habitat and biodiversity of the shoreline.

Therefore, it is essential to monitor and manage the coastline to. The findings of this study can provide valuable information for coastal management planning, including the implementation of measures such as beach nourishment, sediment management, and shoreline stabilization.

Overall, the results of this study provide important insights into the dynamics of the study area's shoreline and highlight the need for continued monitoring and management of the coastline to ensure its sustainability and resilience.

5. Conclusion

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 2005-2021 most of the accretion took place having 16.85473.41 sq. km of the net gain of the area although in this period coastline has lost about 0.12 31.15 sq. km of the land.

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