Detection of Caspian Sea Coastline Changes by Fuzzy-based Object-Oriented Image Analysis

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ABSTRACT

Coastal zone detection is an important task in national development and environmental protection, in which, extraction of shorelines should be regarded a fundamental research of necessity. Very dynamic coastlines such as the Caspian Sea coasts could pose considerable risk to the surrounding countries future economic-social developments. Due to the rapid advances in remote sensing technology, modern and reliable techniques are required to detect and update coastline geodatabase of these areas to explore rates of physical and ecological retreats. Accordingly, the main aim of the present study is to monitor the Caspian Sea coastline swings over a possible maximum period from 1975 to 2020. For this purpose, Landsat TM, ETM+ and OLI and Sentinel 2A-B imageries, were progressively processed to generate most of the thematic models in a tempo-spatial context. All data-sets were sampled from the Khazar Islands Port (south of Baku city) to Neftchala Peninsula and precisely preprocessed by ERDAS Imagine software, referenced to the accurate DEM and TOPEX/Jason satellites data. Two classification procedures were subsequently implemented based on preprocessed satellite imageries, primary, by applying Interactive Supervise (IS) and Maximum Likelihood (ML) classifications to extract water surface changes. To improve processing accuracy, all images have been segmented to derive water surfaces and coastlines objects, by applying a Fuzzy-based Object-Oriented Image Analysis (F-OBIA) inside an eCognition software. Revealed models demonstrate several long-term meaningful persuaded fluctuations and considerable periodical changes on the western part of the Caspian Sea coastline, even the emergence of new or enlarging the existing islands and changes in the location of oil-rigs, mostly observed during the resent years. Implementations of such significant changes signify that at the present time the majority of Azerbaijan coastal natural components and oil exploration industry are undoubtedly in crucial hazards.

Introduction. Natural and artificial land features are very dynamic, changing somewhat rapidly in our lifetime (Lunetta and Elvidge, 1999). It is important that such changes could be inventoried accurately so that the physical and human processes at work can be more fully understood. During the last decade, change detection has been regarded as a trustable technique in remote sensing to determine the changes in a particular object of study between two or more time-periods (Singh, 1989; Donnay et al., 2001). Water surface is accordingly regarded as unique environment and its monitoring could be an important task national development and resources management (Jensen, 1996). For coastal zone monitoring, water surface extraction in various times is considered a fundamental work because coastlines have a dynamic nature around the Caspian Sea. Moreover, coastal zone management requires the information about coastline changes over time intervals (Rasouli, et al., 2008). As the world's largest closed body of water, considerable changes in the Caspian Sea water level make it an unique laboratory to study all aspects of coastal zones Sea (Mammadov, 2007). Currently an advance image processing plays a unique role for data acquisition as an economical method and optical images have advantages such as easier interpretation and easier availability

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(Rasouli, et al., 2010). Thus, a combination of trustworthy traditional and advance image processing techniques could be applied in the Caspian Sea investigations.

Study area. The Caspian Sea ranks as the largest inland body of water in the world (Herdendorf, 1982). It is surrounded by different countries such as Russia, Azerbaijan, Turkmenistan, Kazakhstan and Iran. Generally speaking, the Caspian Sea could be recognized as an endorheic and terminal lake, meaning that its water does not reach the ocean. At present, the countries of the region are relatively major world oil and natural gas producers, experiencing new economic and political transitions. It is also believed that about 90 percent of all the world's sturgeons continue living in the Caspian Sea (Mammadov, 2002). Additionally the sea is a well-known location where the world famous Caviar is mainly produced and supplied by neighbor countries. Fluctuations of the sea level causes significant changes in the nature of sampled study area shores (nearly about 110 km on the straight direction) from south to north, connecting two parts of the sea belong to the coastal city of Neftchala and Khazar Islands Port. This part of the Caspian Sea is always very important evidence for the potential of becoming the greatest oil industry, tourist resorts and fishery industry centers. The sampled area has a identical morphology, relatively non-urbanized part which is located alongside of the Caspian Sea, with its natural national parks, agricultural activities and rural communities whom majority have been localized in the western side Rayon's.

Data processed. The dataset used in the present research for the extraction of coastline is composed of:

- Landsat MSS, TM, ETM+ and OLI images sampled from 1975 to 2020,
- Sentinel 2A & B images, sampled from 2015 to 2020, with 10 meter resolution,
- TOPEX & JASON/OSTM Altimetry and ALOS-Palsar DEM digital data, with 12.5 meter resolution.

Techniques applied and results found:

- creation of an unique geodatabases and introducing required pre-preprocessing methods,
- approaching traditional image classification methods, such as ISC and MLC,
- modeling a F-OBIA inside the eCognition software,
- extracting segmented objects, necessary to interpret meaningful image objects,
- getting information on pixel shapes, textures and spectral into account simultaneously,
- grouping neighboring pixels into meaningful landuse maps,
- setting an ArcGIS in creating of long-term database and mapping of the Caspian Sea coastal changes.

Concluded remarks:

- Landsat images are the finest dataset in detection of coastal changes over a longer-time period.
- F-OBIA inside a eCognition software could be well-applied on Landsat and Sentinel imageries in order to map accurate changes of the Caspian Sea dynamic shorelines, even the emergence of new islands and changes in the location of oil-rigs.
- The synoptic capabilities of advance image processing provide a useful reconnaissance tool to target more detailed field surveys to neighborhoods of change.
- This technique produces all well-referenced files of the coastline which can be analyzed inside a ArcGIS setting to estimate rates of changes over relatively longer periods being used for change detection modeling.
- In the future investigations, the Caspian Sea vulnerable shorelines have to be targeted by introducing of a real-time monitoring system for more detailed trustable information in Azerbaijan future sustainable developments.

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