МЕТОДЫ ЭКОЛОГИЧЕСКИХ ИССЛЕДОВАНИЙ

УДК 502

USING REMOTE SENSING AND GIS-TECHNIQUES IN SOUTH EAST CASPIAN COASTAL CHANGES DETECTION

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Remote sensing and GIS techniques have been used to detect the shoreline changes along Miankaleh peninsula promontory of the Gorgan Bay entrance over the last three decades (1975-2002). For this purpose satellite data including LANDSAT ETM$^+$, TM, SPOT, ASTER L1A and RADARSAT have been analyzed. SPOT-Pan data were georeferenced with respect to 1 : 50 000 topographic maps using a Universal Transverse Mercator (UTM) projection, then all the needed data sets were registered to the SPOT-Pan image. The hydrological data showed a rapid rise of the Caspian Sea level by 2.6 m between "1975-1996".

В статье рассматриваются изменения береговой линии Иранского побережья Каспийского моря за прошлые три десятилетия (1975-2002 гг.). Работа проводилась с использованием геоинформационных технологий. Для этого были проанализированы спутниковые данные, привязанные к топографическим картам масштаба 1: 50 000. Полученные гидрологические данные показали повышение уровня Каспийского моря на 2,6 м во временном отрезке 1975-1996 гг.

Introduction. This investigation focuses on the use of various optical (SPOT, Landsat MSS, TM, ETM$^+$, ASTER L1A) and RADARSAT data for mapping shoreline changes of Miankaleh peninsula promontory in the south-eastern Caspian Sea coast of Iran during the period of 1975-2002. The hydrological data showed a rapid rise in the level of the Caspian Sea by 2.6 m between 1977 and 1996 (Figure 6). Most GIS software packages allow all remotely sensed data to be imported and analysed. Change detection involves the ability to quantify temporal effects using multi-temporal and multi-sensor data sets.

The Landsat TM provides digital data in infrared spectral bands where Land/Water interface is well defined (Ellis et al. 1989; Tao et al., 1993; and Tittley et al., 1994). Landsat TM and other types of remote sensing imagery used for coastal related research such as (Hesselmans et al., 1994; Welch et al., 1993; Donoghue et al., 1994; koopmans et al., 1994; Dwivedi and Sankar 1992; EL Raey et al., 1999; Frihy et al., 1998; Loughlin, 1991; and Dewidar and Frihy 2003).

The 'waterline' is defined as the boundary between a water body and an exposed land mass in a remotely sensed image (Mason et al. 1997). Waterline extraction is potentially one of the most effective satellite remote sensing tools for studying changes in tidal flat environments and coastlines (Ryu et al. 2002). Frazier and Page (2000) reported that a simple density slicing method using Landsat TM Band 5 is effective in detecting clear water boundaries. Kevin and El Asmar (1999) exploited TM Band 7 in the Nile Delta region for this purpose.

The rapid sea-level rise of the Caspian Sea by 2,5m (about 15 cm/year) between "1977-1996" caused significant changes in coastal morphology and dynamics especially on the Gorgan Bay entrance.

The wetland of Gorgan Bay is an outstanding example of a natural sand spit/coastal lagoon system characteristic of the south Caspian Sea.

The study area extends from the west (Miankaleh Peninsula promontory) with longitude 36° 54` to 36° 59`N at Ashoradeh area, and latitude 54° 01` to 54° 04` E (Figure 1). The study area represents a sensitive district of erosion along the Miankaleh Peninsula coast of Iran. Moreover, it is characterized by highly diverse categories of morphodynamic boundaries.

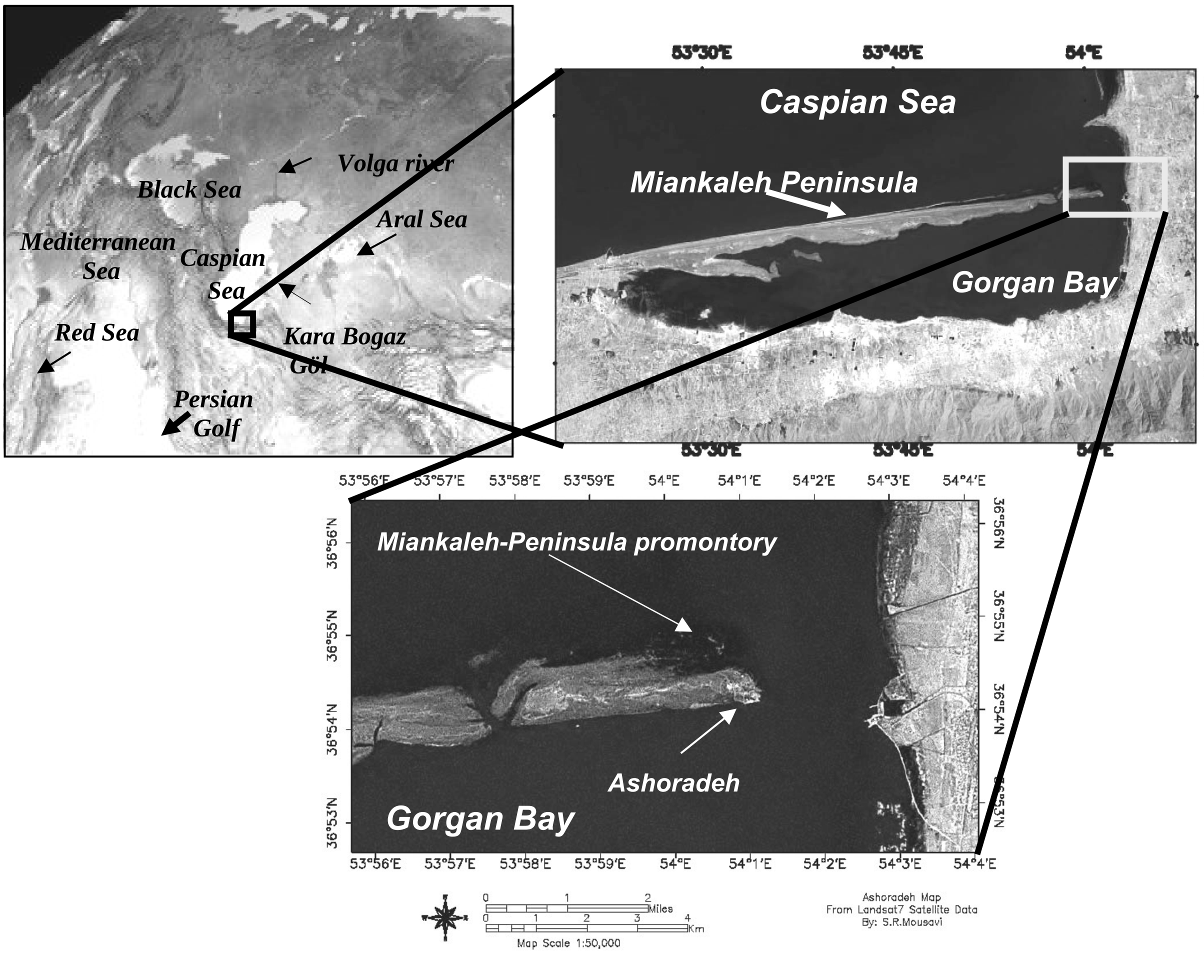

Figure 1. Location of the Miankaleh Peninsula promontory superimposed on regional MODIS and LANDSAT ETM+ Imagery

The present study aims to indicate the presence of multi-temporal conflict between different interests of various environmental, economic and related specialists along the Miankaleh Peninsula coastal zone and decision makers, as well as the absence of long term monitoring plans for the coastal dynamic systems of the Caspian Sea in Iran. This conflict is highlighted by detecting the historical shoreline change at Gorgan Bay entrance coastal zone during the last three decades. We will introduce the study area and data in the next section, followed by the waterline extraction method and demonstrate in the results section that selection of the proper band or combination of bands is the key to the proper output, and that the flood condition should be considered.

Study Area and Data Sourses. Gorgan Bay and Miankaleh Peninsula are situated in the Provinces of Mazandaran and Golestan, in northern part of Iran. They are located at the Southeastern Caspian Sea, about 2 km west of Bandar-e-Turkmen and lie between 36˚45′ N to 37˚1′ N latitude and 53 ˚ 30′ E to 54 ˚ 7′ E longitude. Miankaleh Peninsula promontory and Gorgan Bay entrance are situated at Golestan

Province, in north Iran (Figure 1). It is located at the Southeastern Caspian Sea, about 2km west of Bandar-e-Turkmen as lie between 36° 54′ N to 36° 59′ N latitude and 54 ° 01′ E to 54 ° 04′ E longitude (Figure 1). Gorgan Bay is the largest coastal wetland in the southern coastal Caspian Sea. The average dimension of Gorgan Bay are 12500 m in the North-South direction, and 60000 m in the East-West direction, an area of 583 km² and the average dimension of Miankaleh peninsula are 2000m in the North-South direction, and 58000m in East-West direction, an area of 116 km² (Figure 1).

Multi-date satellite images from Landsat MSS, TM, ETM, ASTER L1A, SPOT PAN, RADARSAT sensors were used to detect the changes of Gorgan Bay entrance shorelines. Since the shape of Miankaleh Peninsula promontory shoreline is a result of the advance and retreat in historical times, the present study is largely based on the analysis of recent multi-dates satellite images during 1975 to 2002.

Table 1

Satellite data for Miankaleh Peninsula and Gorgan Bay

Satellite	Sensor	Path/Row	Scene	Date
ASTER-L1A	Full Mode	–	Full	11.05.2002
LANDSAT2	MSS	176/34	Full	07.04.1975
LANDSAT2	MSS	176/34	Full	06.06.1977
LANDSAT5	TM	163/34	Full	17.071987
LANDSAT5	TM	163/34	Full	13.10.1990
LANDSAT5	TM	163/34	Full	16.07.1998
LANDSAT7	ETM	163/34	Full	30.07.2001
LANDSAT7	ETM	163/34	Full	25.04.2001
SPOT	HRV2-Pan	154/276	Full	28.091993
SPOT	HRV1-Pan	153/276	Full	28.09.1993
RADARSAT	ScanSar Narrow.B	Lat 34º30', 37º00'	Full	17.5.1999

Methodology. The different kinds of optical and radar data were acquired over Miankaleh Peninsula and Gorgan Bay (Table 1). First, from each one of the Landsat MSS, TM, ETM$^+$, a false colour composite (742, RGB) were plotted in colour and from SPOT and RADARSAT in grey colour as well. These hardcopies were used for fieldwork and identify the existing main coastal features. In the field, with these images were recorded more than 30 locations by GPS receiver. Second, SPOT-PAN data was geometrically corrected with respect to 1 : 50 000 topographic sheets in a UTM projection. Third, all Landsat MSS, TM, ETM$^+$ and RADARSAT data were registered to this SPOT-PAN 10 meter georeferenced image. Fourth, these mentioned data were analysed using various image processing techniques including, spectral enhancement (PCAand NDVI), level slicing, spatial image enhancement (convolution filtering), TM band ratios, spectral classification and 3D Analysis with DEM. Fifth, all these geocoded data were imported to GIS environments and changes detection were extracted manually by visual interpretation and updated features were digitised on screen as vector layers. Sixth, GIS analysis (overlay and summary) was used to evaluate and visualize the outcome (figure 2).

Georeferencing images. When we are using with various satellite data which are different dates and sensors for a changing territory we should use topographic maps for defining ground control points coordinates. Geometric rectification was carried out using the ERDAS 8,5 and ENVI 3,6 software. Therefore, SPOT-PAN data were georeferenced with respect to 1 : 50 000 topographic maps using a Universal Transverse Mercator (UTM) Projection and all radar and optical (SPOT, Landsat MSS, TM, ETM$^+$) data sets were then registered to this SPOT-PAN image.

We have had requested various radar and optical data of different dates and sources for the most important time periods, e.g. Landsat MSS of 1975 for a Caspian Sea level lowest state, SPOT of 1993 for a middle of the last sea transgression period, RADARSAT of 1999 for the highest sea level after the last transgression and so on (Table 1).

Principal Component Analysis (PCA). PCA is used in various purposes, such as geological mapping and remote sensing terrain features (Loughlin, 1991; Yousef, 1991; Dwivedi and Sankar, 1992). Principal components reduce input data to axes of primary variation and least correlation. PCA of the six non-thermal Landsat TM bands were calculated to determine if one of the rotated axes be applied as a land/water difference signal. None of the components appeared to serve this function directly, however, PCA band 1 was evaluated because it did have a strong water component. This accounts for the primary in the image to extract of shoreline.

Normalized Difference Vegetation Index (NDVI) and Water Index (WI). NDVI is a normalized ratio of TM bands 3 and 4 expressed as (B3-B4) / (B3+B4). NDVI value range is from -1 to +1 with higher values characteristic of the high vegetation C a result of the high vegetation reflectance of near-infrared band 4 and low vegetation reflectance in red visible band 3 (chlorophyll absorption band) (Figure 3 and Figure 4).

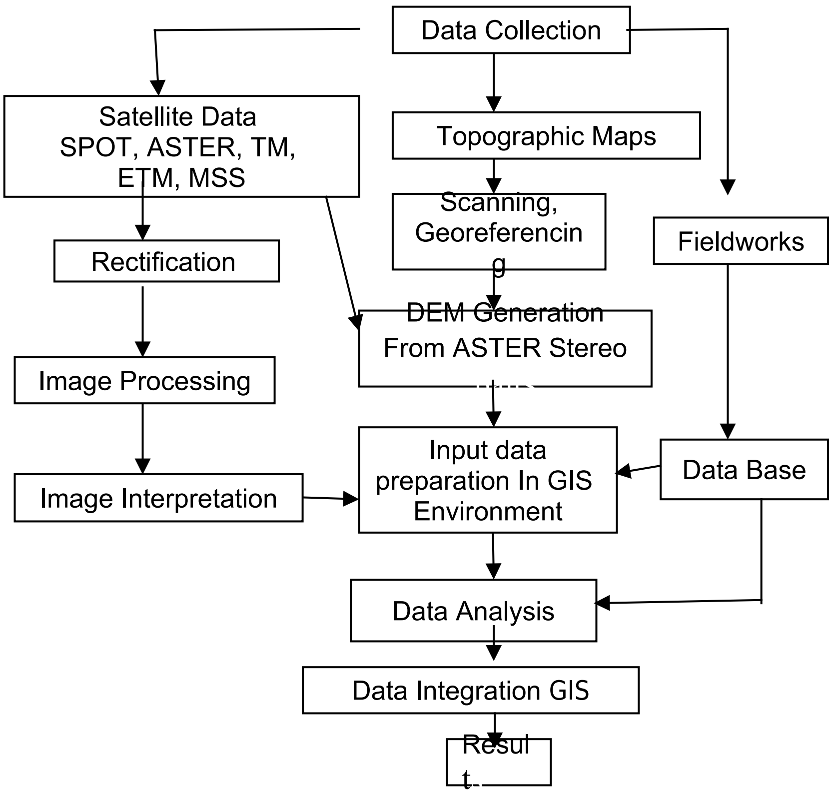

Figure 2. Diagram of methodology for this study

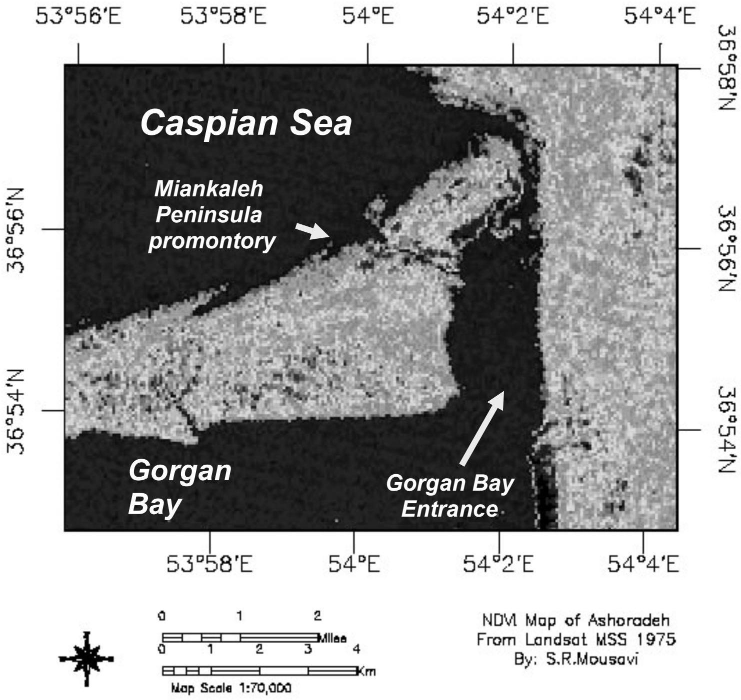

Figure 3. Normalized Difference Vegetation Index (NDVI) of Landsat MSS from 1975 over Gorgan Bay entrance

Results and discussion. The hydrological data showed a rapid rise of the Caspian Sea level by 2,6 m between 1977 and 1996 (Figure 6). The method of georeference and mutual coordination of images has been successfully used for images adjustment and studying of territory changes at large and small scales.

Six unsupervised classified images of 1975, 1977, 1987, 1990, 1998 and 2001 were obtained using Recode Module, six reclassified images were obtained as binary images (0 for water and 1 for else). In order to map the shoreline of the area, in GIS environment, six vector layers were extracted. These vectors derived from satellite images were superimposed to detect the differences between them and other different data sources (Figure 7). Mapping results of the measured erosion of areas in different data and sources have been shown in (Figure 7). The Caspian Sea level rise affected on whole part of the Gorgan Bay and Miankaleh Peninsula coast but the greatest erosion occurred in the mouth and Westside of Gorgan Bay (Figure 7). By 1997, Gorgan bay waters had transgressed westward, parallel to the Alborz Mountains, increasing the area of the bay by roughly one-half; the spit that defines the northern Bay Shore is narrower owing to the westward flooding (arrow). Sea level rise also encroached upon the eastern shore, widening the channel into the bay and changing the shape of the promontory and Figure 14).

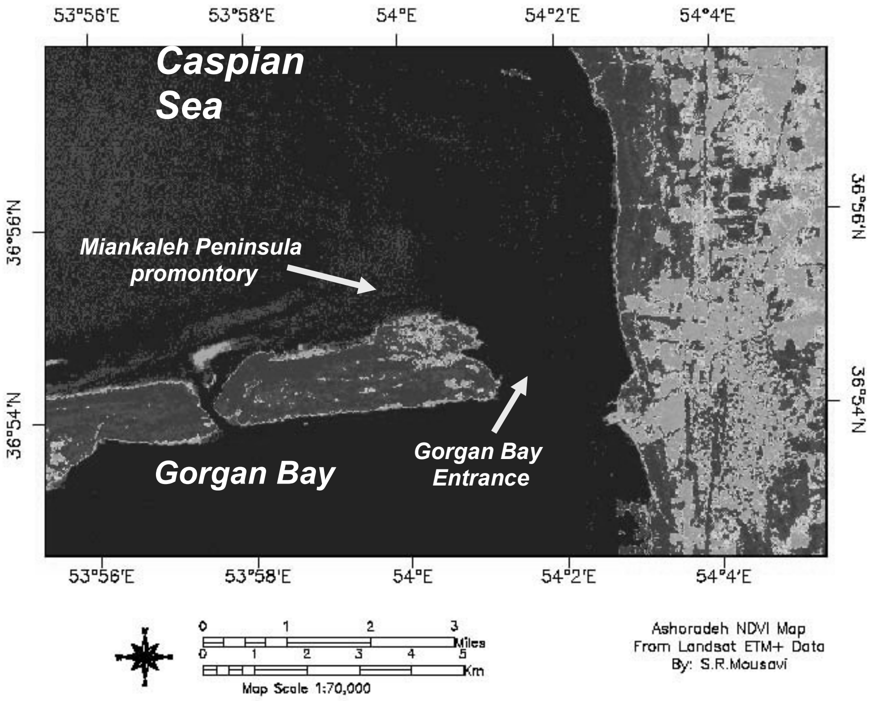

Figure 4. Normalized Difference Vegetation Index (NDVI) of Landsat ETM+ from 2001 over Gorgan Bay entrance

The data processing procedures identified in the methodology section have produced two digital spatial files as:

a) Classified Land/Water Raster File:

It is necessary to classify the first file for land/water categories because it is the first step in producing the raster and vector interfaces. This is a binary file in which the pixels have all been classified as either land or water (Figure 9 and Figure 10). An interface can be calculated from this file. It can be used for planning, or response purposes as well as serve as the basis for calculating land/water acreage for specific sites. The land/water raster file could also be used for change detection and analysis to document trends and make predictions. Other analytic procedures could be performed on the file to calculate land/water shoreline density and to indicate areas of complex land/water such as areas that are more vulnerable.

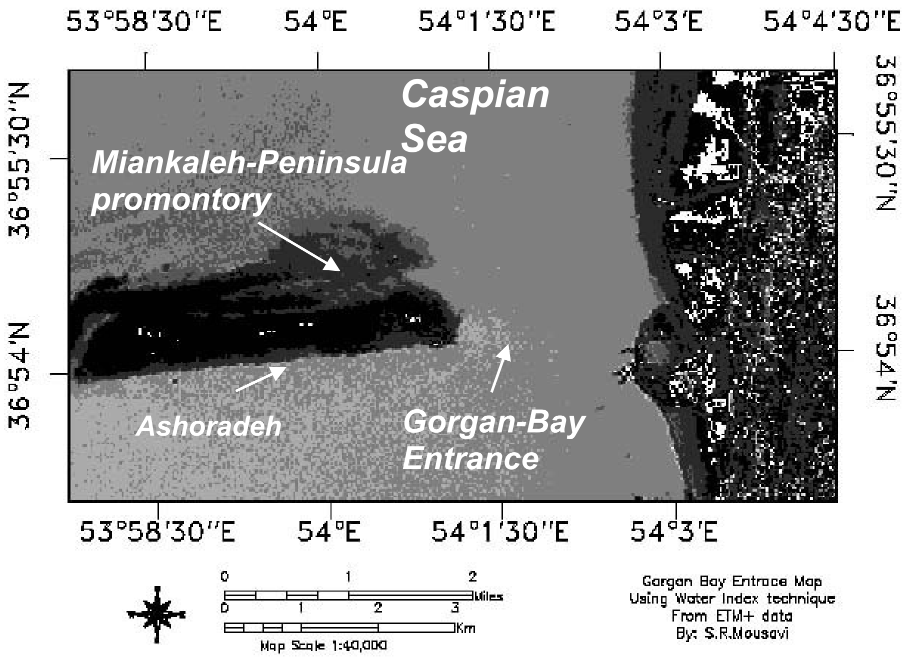

Figure 5. The Water Index (WI) over Gorgan Bay entrance which is the sum of visible bands divided by the sum of infrared bands (B1+B2+B3) / (B4+B5+B7) from Landsat ETM+ from 2001 after the Caspian Sea level rise

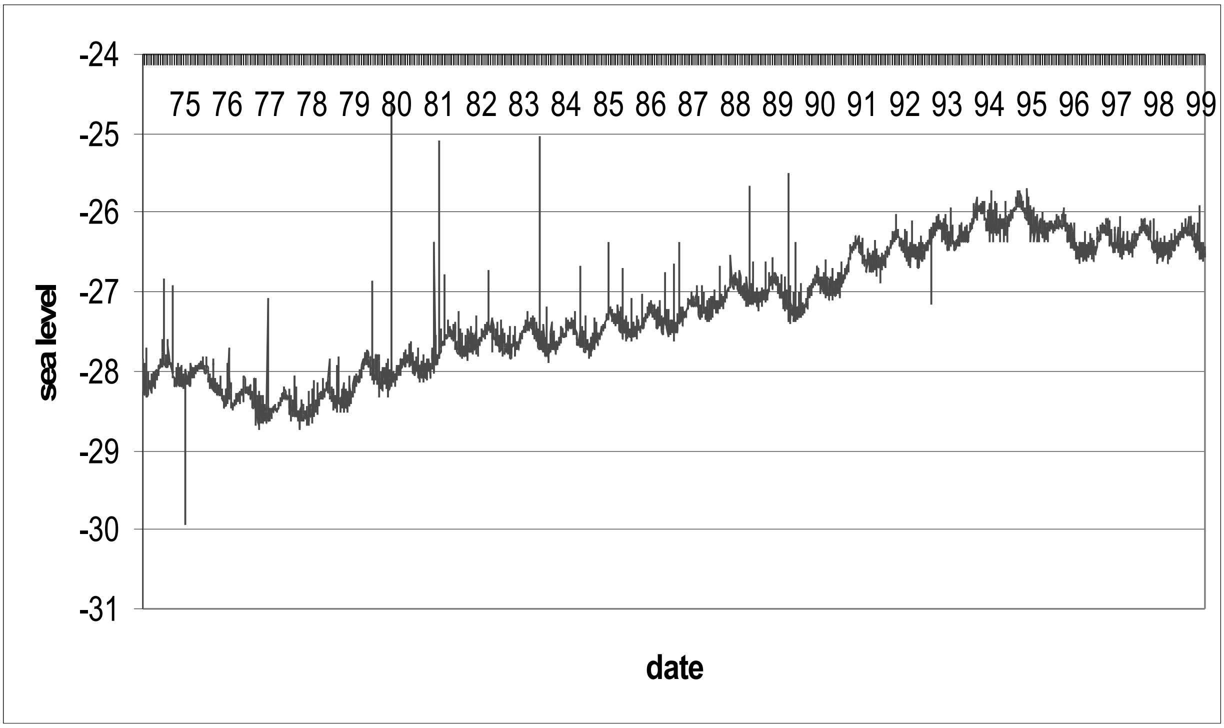

Figure 6. The Caspian Sea level changes (1974-1999) from Anzali's Station in the Southern Caspian Sea

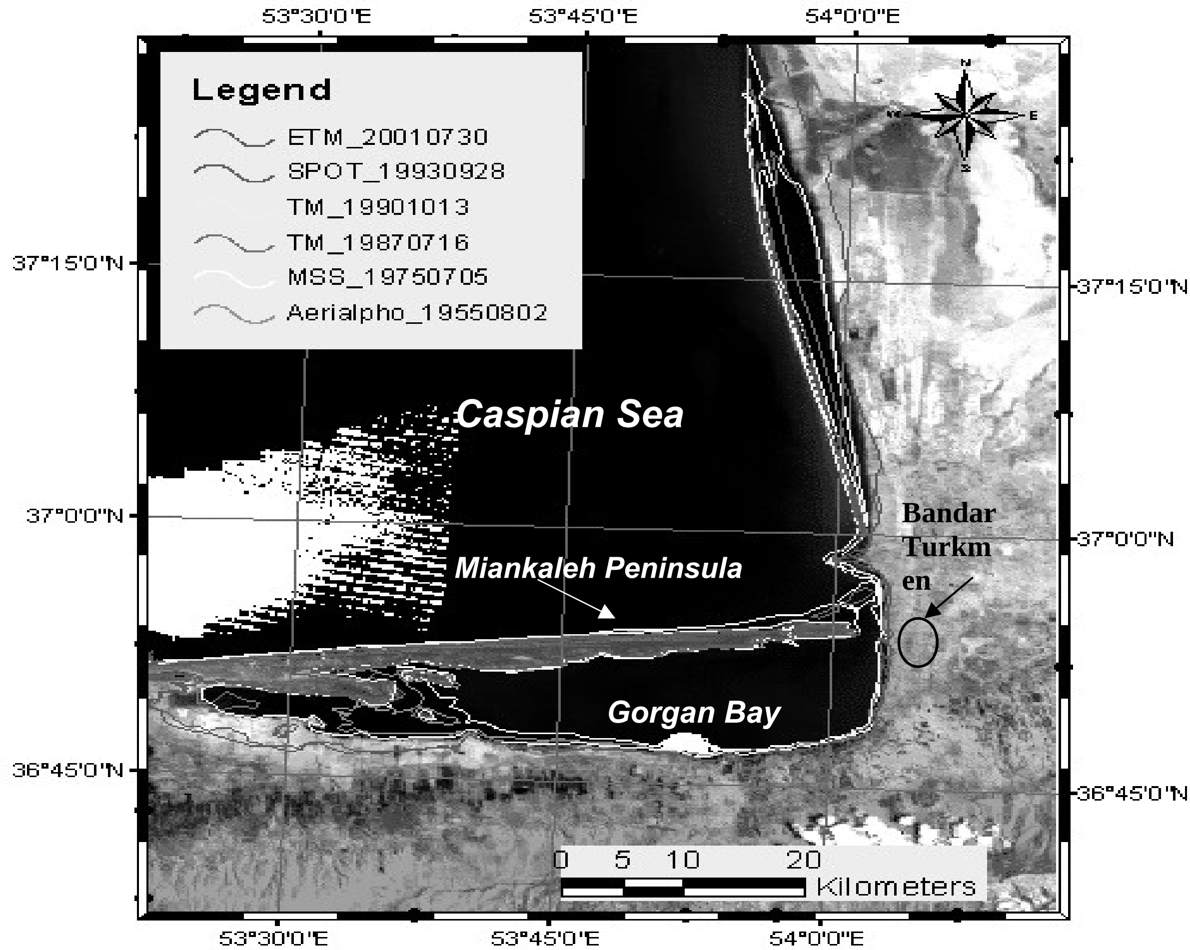

Figure 7. Landsat TM imagery from composite of bands 742 (RGB), with overlay showing shorelines in before and after the Caspian Sea level rise in Gorgan Bay

b) Land/Water Interface Vector File:

The land/water interface vector file is calculated from the raster land/water classified file and represents the shoreline with lines and polygons rather than with groups of pixels. It has numerous applications to planning and response. It can be used to calculate shoreline length, distance, perimeter, area measurements, and proximity buffering, as well as depict shoreline types with line attributes. It can be displayed with other GIS layers and features to illustrate relative location, change, proximity, and type. The vector shoreline can also be independently plotted, displayed, or measured without interference from other features. It will be a tool for oil spill contingency planning that allows planners to work directly with the shoreline either as a separate entity or in association with other environmental, cultural, or physical features. As a GIS spatial entity, the shoreline can be attributed with characteristics essential to planning and response. The attributes can be queried with Structured Query Language statements or otherwise manipulated with database functions. Thus, shoreline segments with specific criteria can be identified or selected. In a response scenario, the shoreline can be measured, and shoreline type and sensitivity codes accessed. Or the shoreline could be extracted for close examination, plotting, buffering, location query, and attribute assessment. The vector shoreline may also serve as input to certain dispersion models using vectors instead of raster. The shoreline type of potential landfall could be easily identified. Since the Miankaleh Peninsula promontory coast is so large, complex and dynamic, such a digital spatial resource is extremely valuable for response, planning and damage assessment.

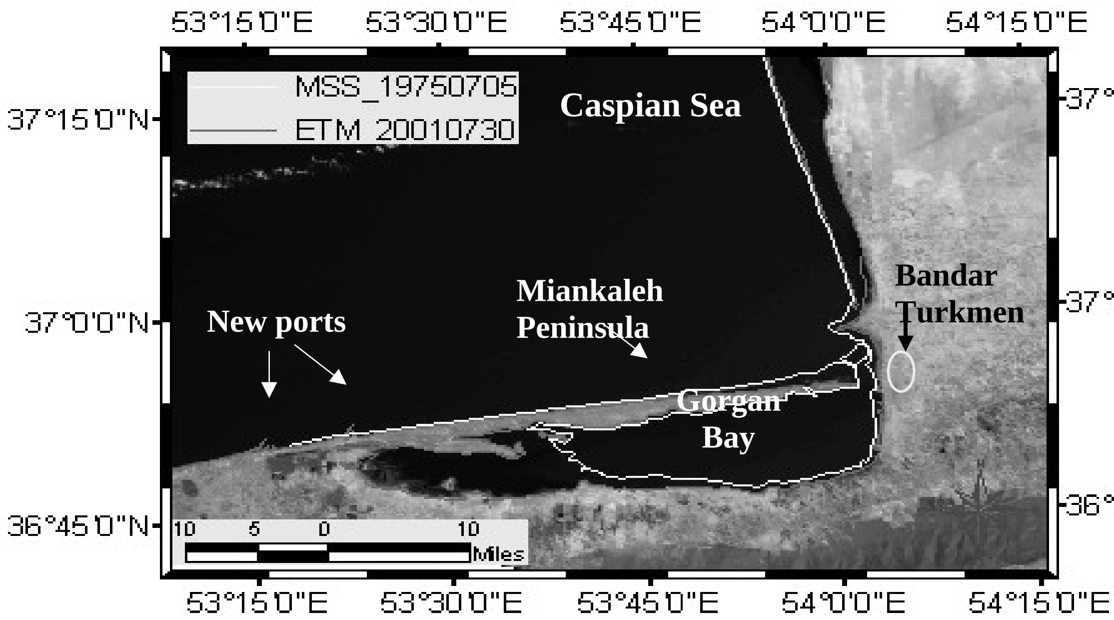

Figure 8. Landsat ETM+ band 7, with overlay showing shorelines before and after the Caspian Sea level rise

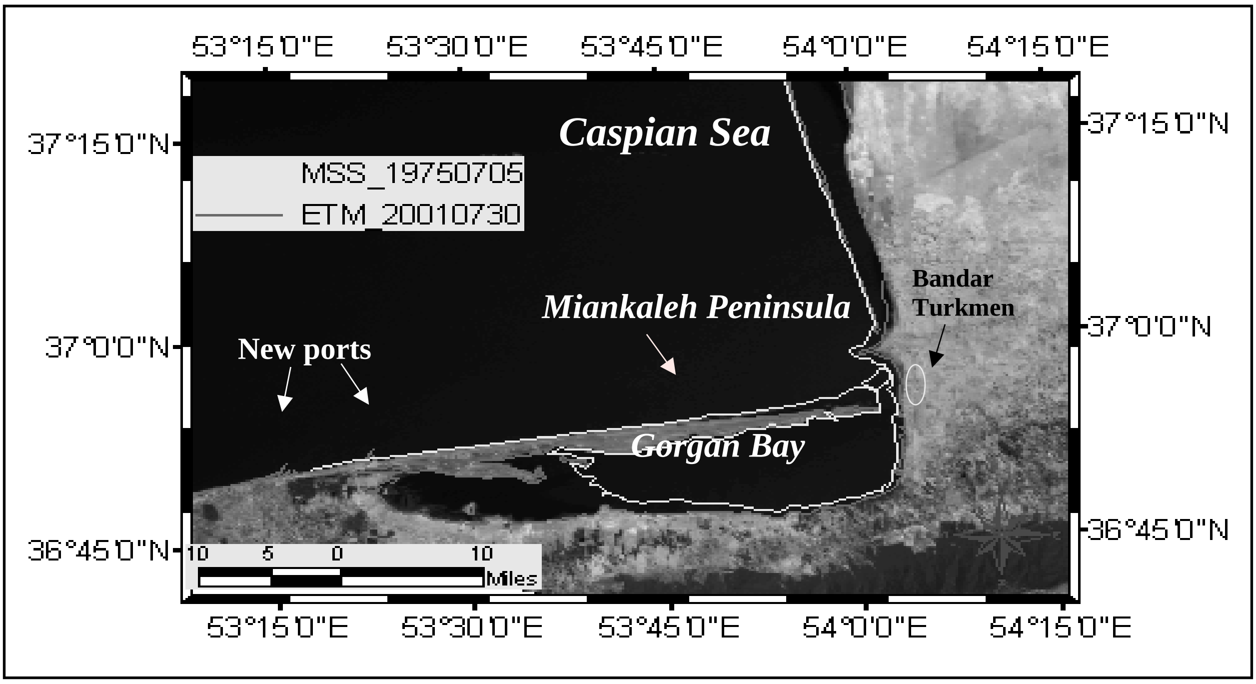

Figure 9. Landsat TM band 5, with overlay showing shorelines before and after the Caspian Sea level rise

Conclusion. This investigation showed that the employment of radar and optical (SPOT, Landsat MSS, TM, ETM^+, ASTER L1A and Aerial photographs) data with GIS software packages are useful for mapping, updating and documenting changes in coastal shoreline configuration between different dates and data sources. The SPOT-PAN satellite data is suitable for detecting shoreline configuration greater than 10m (the minimum resolution of the data) and registering of data in different dates and sources (Table 1).

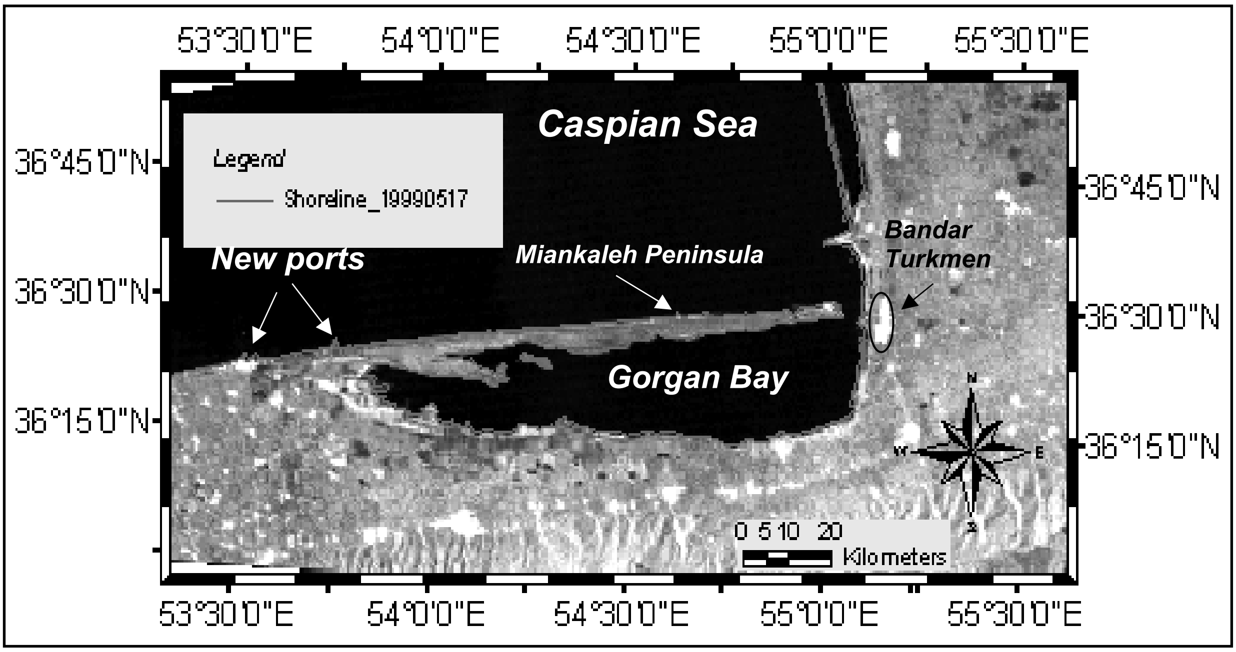

Figure 10. RADARSAT imagery to extract shoreline of the Gorgan Bay 1999

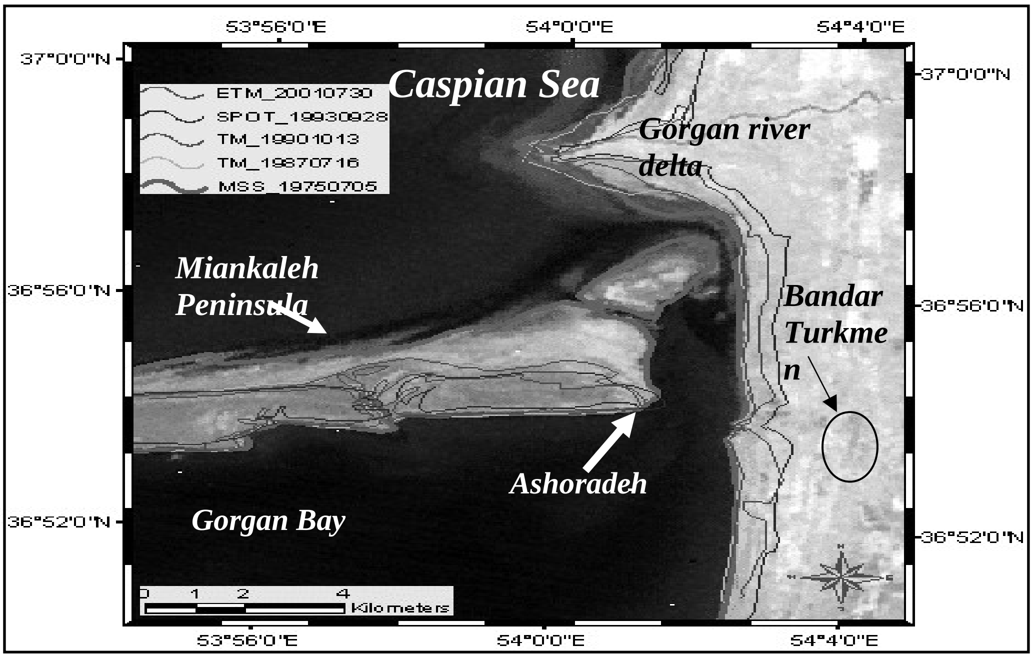

Figure 11. Landsat MSS, with overlay showing shorelines in before and after the Caspian Sea level rise
in Entrance of Gorgan Bay area

A. Mid-infrared Band 5 was subset from each of the Landsat Thematic Mapper satellite images of the coast of Miankaleh Peninsula promontory (Figure 9).

B. A moderate 3 x 3 convolution edge filter was executed on each band to slightly sharpen the land/water boundary for further processing. The filter had a kernel center of 14.

C. The land/water threshold was independently found in the transition zone for each Band scenes using interactive contrast histogram tools to determine the optimum position of the land/water boundary. Land/water features were corroborated with aerial photography.

D. The threshold value derived for each scene was used as the breakpoint for recoding values less than or equal to the threshold to water (value 1) and those above to land (value 2).

E. The edge enhanced, classified, cleaned and subset land/water files were converted to vector polygon files using raster to vector conversion software that created connected points (lines) along cell boundaries, (i.e. the land/water edge). The imagery files were processed using ERDAS Imagine software and the raster to vector conversion created vector polygon files as Arc-Info coverage.

F. Vector files were cleaned and polygon topology established. The land/water polygons were given land/water designations and colors.

G. The final vector files were examined for accuracy by overlaying them over the MSS ETM+, TM, and SPOT composite images (Figure 11, Figure 12 and Figure 14) of the area to ensure that they correctly represented the raster land/water interface as visually observed. The Gorgan Bay entrance shoreline changes map by final vector files was finalized (Figure 15).

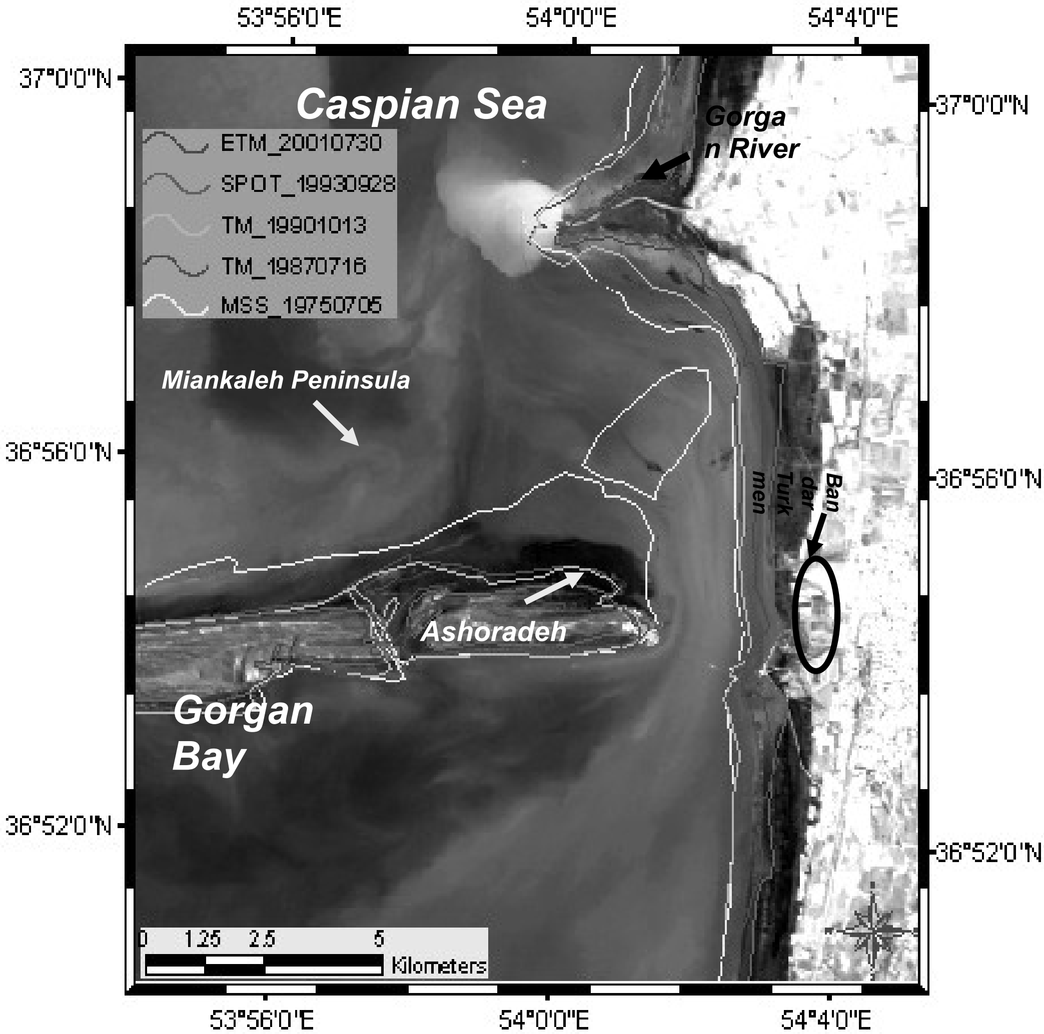

Figure 12. SPOT-PAN Imagery 10meters with overlay showing shorelines in before and after the Caspian Sea
level rise in Entrance of Gorgan Bay area

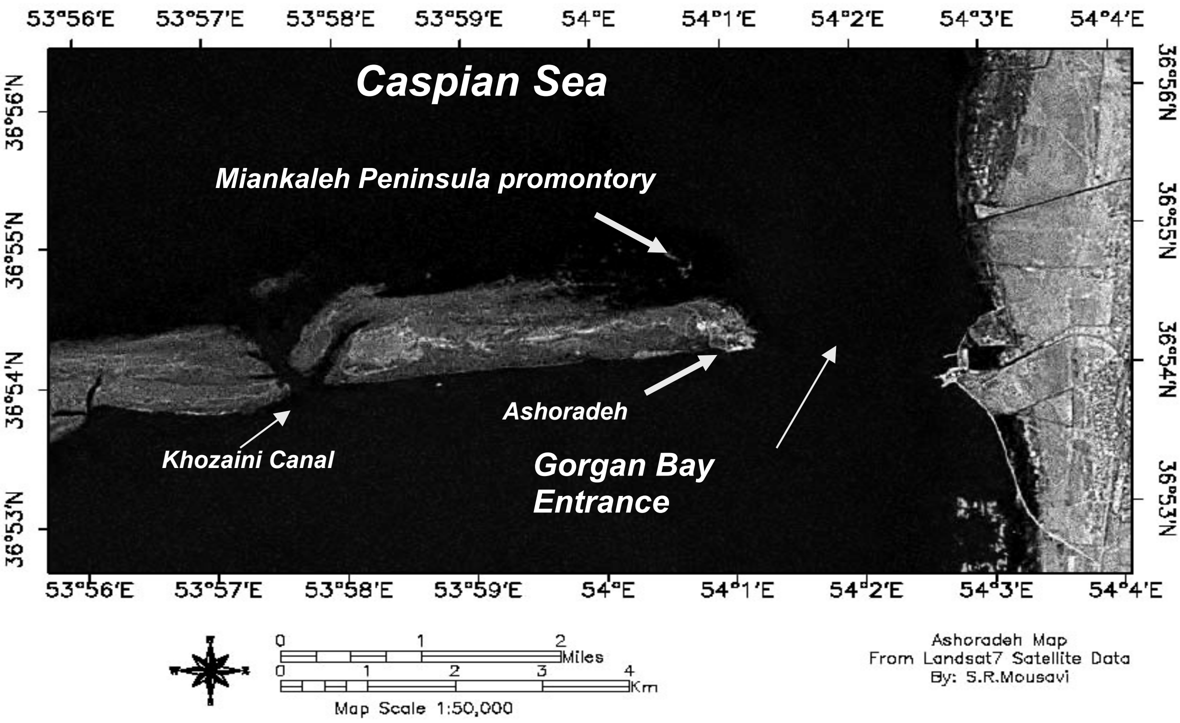

Figure 13. Landsat ETM+ imagery with resolution 14m using after the Caspian Sea level rise
in Entrance of Gorgan Bay

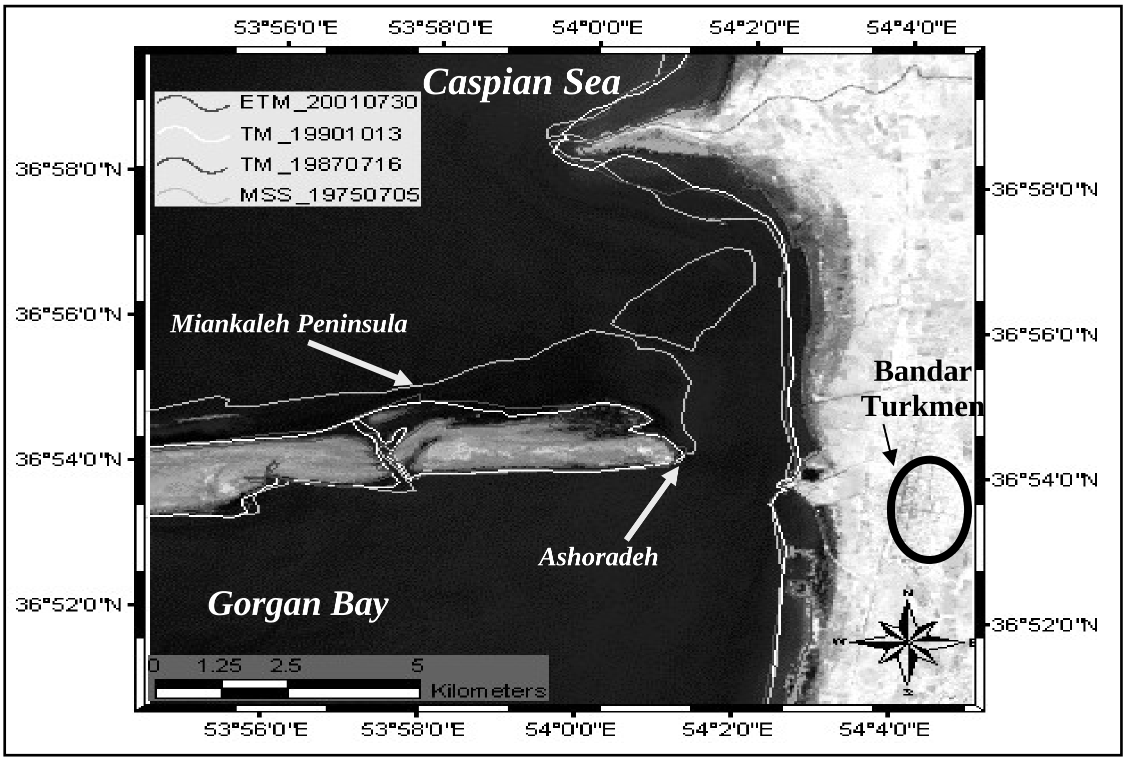

Figure 14. Landsat ETM, with overlay showing shorelines in before and after the Caspian Sea level rise
in Entrance of Gorgan Bay

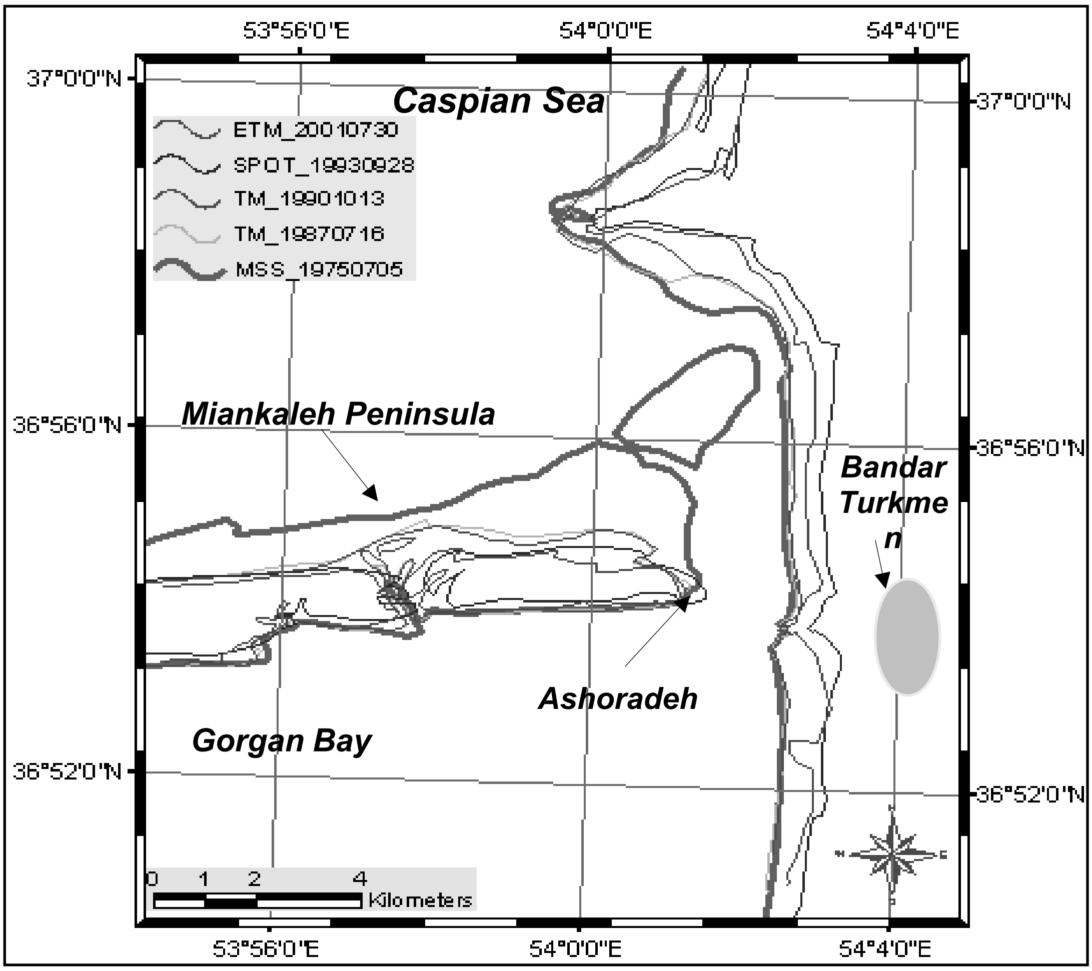

Figure 15. Shoreline changes map, with overlay showing shorelines in before and after the Caspian sea level rise
in Entrance of Gorgan Bay

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УДК 556.18:504.06:556.51

ОСНОВЫ МЕТОДОЛОГИИ ОЦЕНКИ ВОЗДЕЙСТВИЯ НА ОКРУЖАЮЩУЮ СРЕДУ (ОВОС) ВОДОХОЗЯЙСТВЕННЫХ ОБЪЕКТОВ

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В статье рассматриваются основы методологических подходов оценки воздействия на окружающую среду (ОВОС) водохозяйственных объектов.

Methodological bases of the estimation of the influence on the environment (EIE) of the water resources formation are considered in the article.

Природная среда является важнейшей составляющей в окружающей человека среде и основой жизни на Земле. Хозяйственная деятельность человека, обуславливающая собой субъективные