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Long-term dynamic analysis based on Landsat imagery in the Gorgan Bay-Gomishan Wetland, Iran

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ABSTRACT

Coastal ecosystems are very dynamic and their changes occur relatively quickly due to the collision of two dynamic environments of land and sea. Gorgan Bay and Gomishan Wetland are unique ecosystems in the south-eastern part of the Caspian Sea. In this study periodic changes in the ecosystems of Gomishan Wetland and Gorgan Bay were evaluated over a period of 40 years using Landsat satellite imagery from 1978-2018. MSS, TM and OLI imagery along with NDWI index were used. The results show that the fluctuations in both ecosystems were consistent and the coastline changes were greater in the near-land areas. Based on the results, the highest area of water in both ecosystems was obtained in 1997 (210.43 and 528.97 km^2 for Gomishan Wetland and Gorgan Bay, respectively). These ecosystems also exhibited the lowest water area in 1978. In general, it can be conclude that remote sensing was an efficient tool in monitoring and managing coastal ecosystems.

Keywords: Landsat, Coastal Ecosystems, Change Detection, Dynamics.
Article type: Research Article.

INTRODUCTION

Shrinkage and degradation of aquatic environments such as bays and wetlands significantly reduce the performance of regional environmental protection and disrupt the habitat of rare aquatic animals and waterfowl, resulting in ecosystem degradation and biodiversity loss (Desta *et al.* 2012). These water bodies distributed around the world can act as indicators of global climate change in many different regions and geographical conditions and also climatic regions (Adrian *et al.* 2009). From the early 20th century, Coastal aquatic ecosystems, especially wetlands and bays faced with several challenges such as rapid economic development, increased agricultural land due to global growing demand for food supply, overuse of natural resources, excessive use of ecosystems water, sedimentation, water contamination, excessive development of tourism and habitat degradation (Cui & Yang 2002; Dahl 2011; Šabić *et al.* 2018). Hence, based on the Ramsar Convention, sustainable use of aquatic ecosystems is that they should not only be beneficial to the present generation but it could maintain its capacity to meet the needs of future generations (Agboola *et al.* 2016). Remote sensing is one of the best tools in improving the quality of knowledge and information about the current state of the aquatic ecosystems in order to adopt right management policies in them. Through this technique, it is possible to detect the desired changes in the region by using a set of multi-time images and processing them. By remote sensing data, it is possible to manage aquatic ecosystems in a scientific and efficient way (Gross *et al.* 2006; Rashidi Tazhan *et al.* 2019; Navabian *et al.* 2020; Soltaninejad *et al.* 2021). Detecting these changes is one of the basic needs in natural resources management and evaluation (Coppin *et al.* 2004; Lu *et al.* 2003; Sesnie *et al.* 2008). In recent decades, monitoring of coastal areas and extraction of water level changes at different time intervals have been considered, since coastlines are dynamic in nature and the management of such ecologically sensitive environments requires accurate information at various

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time intervals (Łabuz 2015). So, remote sensing technology has been widely used in obtaining information about these changes (Illesand *et al.* 2015). Gorgan Bay in the southern shores of the Caspian Sea were registered as a biosphere reserve in 1976 and therefore there is an international view to its protection (Darvishsefat 2006). Gorgan Bay in recent decades was encountered with problems such as reduced water quality through the entry of polluting effluents (Shahryari *et al.* 2008), increased sedimentation regime due to the destruction of riverbeds discharging to the bay and water level fluctuations in the Caspian Sea (Ghangherme, 2012). In the divisions made, Gorgan Bay along with Gomishan Wetland are considered as type A (Coastal Permanent Brackish Lagoon) and coastal wetlands (Bashari *et al.* 2015). Gomishan Wetland is located in the southeast of the Caspian Sea and is affected by the climate of the Caspian Sea and the arid and semi-desert climate of the Turkmen Sahra Plain (Omrani *et al.* 2019). Hence, the objectives of this study were to identify alterations in aquatic ecosystems in the southeast of the Caspian Sea (i.e. Gorgan Bay and Gomishan Wetland) over a period of 40 years (2018-1978) and in the next stage to analyze the results of coastline changes to get the better estimation of their conditions.

MATERIALS AND METHODS

Study area

Gorgan Bay (36 ° 48 'N, 53 ° 35'E and 36 ° 55'N, 54 ° 03'E) is connected to the protected area of Miankaleh Peninsula from the north and to Golestan and Mazandaran provinces from the south and to the Caspian Sea in the northeastern part through the Ashuradeh estuary of Turkmen Seaport (Sharbaty & Nasimi 2018). There are no tides in the Gorgan Bay. Gomishan Wetland is located in 37° 09´ to 37° 20´ N and 53° 54´ to 53° 58´E. In the form of a narrow strip, it borders the east coast of the Caspian Sea. Fig.1 illustrates the location of both ecosystems on the map.

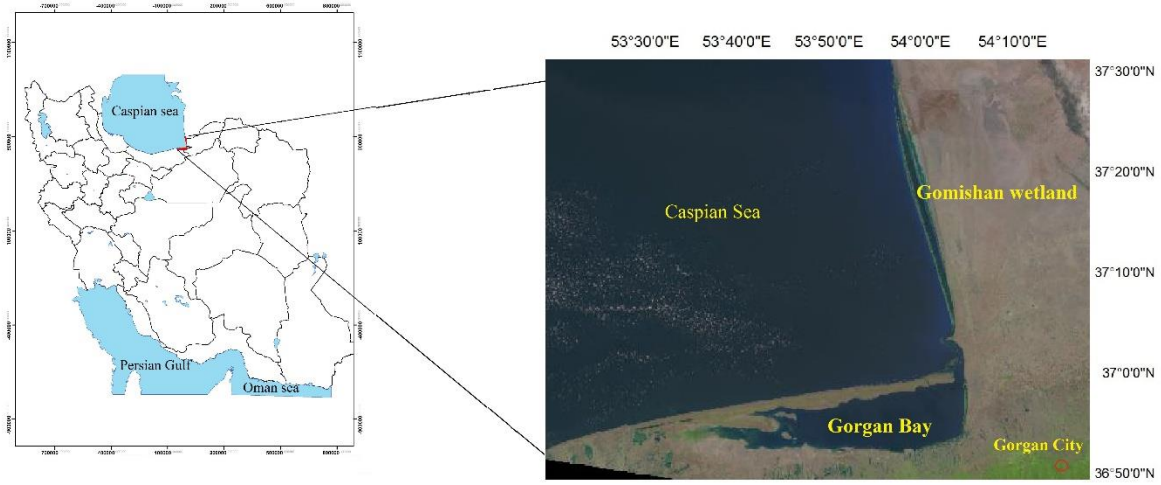

Fig. 1. Location of ecosystems on the map.

Methodology

Landsat satellite imagery was used in this study (https://earthexplorer.usgs.gov; Table 1). After the relevant reviews, the imageries of 1978, 1987, 1997, 2009 and 2018 were all selected with similar time conditions. The images that needed corrections were also processed.
In order to cut the water body area of the abovementioned images, the NDWI index (Equation 1) was used to identify and calculate the area (Ji *et al.*, 2009). The green bands of Landsat and NIR represent the near infrared band respectively.

$$\mathrm{NDWI} = \frac{\mathrm{G} - \mathrm{NIR}}{\mathrm{G} + \mathrm{NIR}}$$

All analyzes were performed on images in Arc GIS 10.5. Noteworthy, Gomishan Wetland continues after the border of Iran in the territory of Turkmenistan. In fact, the northern branch of Atrak River determines the northern border of this wetland (Kiabi *et al.* 1999). Therefore, in this study, these areas were also studied.

Table 1. Specifications of images selected for study.

Row	ID Image	Sensor	Date
1	LM02_L1TP_176034_19780708	MSS	8/7/1978
2	LT05_L1TP_163034_19870614	TM	14/6/1987
3	LT05_L1TP_163034_19970524	TM	24/5/1997
4	LT05_L1TP_163034_20090626	TM	26/6/2009
5	LC08_L1TP_163034_20180502	OLI	2/5/2018

RESULTS

A. Gomishan Wetland

The extracted area maps are separately presented in Fig. 2 during different years. Examination of the maps shows the growing trend of the wetland area compared to the early years (1978). According to Fig. 2, fluctuations can be observed both in the area of the wetland and along the coastline, especially in the near-land areas, in addition, by the construction of shrimp sites in later years, alterations in this area were more evident than in the wetland. Fig. 3 illustrates these alterations per km^2 in different years to better understanding of the events exhibiting that the highest area was obtained in 1997 (210.43 km^2). The smallest area was in 1978 with 16.3 km^2. This process is consistent with the maps obtained. In general, according to the dynamics of Gomishan Wetland, two stages can be imagined: the first period of the ascending period (1978-1997), and the descending period (1997-2018). The area of Gomishan Wetland is reported to be subjected to fluctuations in the Caspian Sea (Behrouzirad 2007). On the other hand, the rain gauge station was not established around the wetland and also availability to information of other stations was not feasible. So, we could not incorporate rainfall data in the same period.

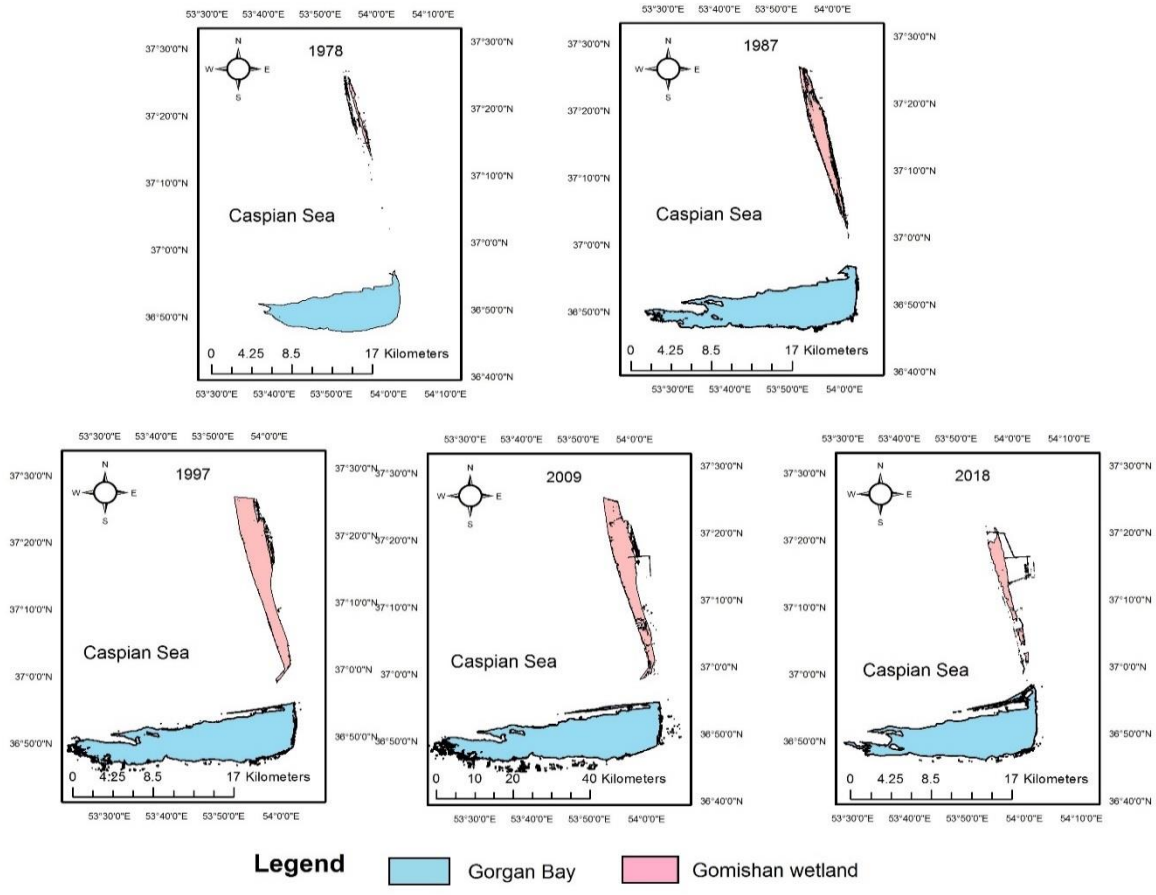

Fig. 2. Dynamic changes of ecosystems in different years.

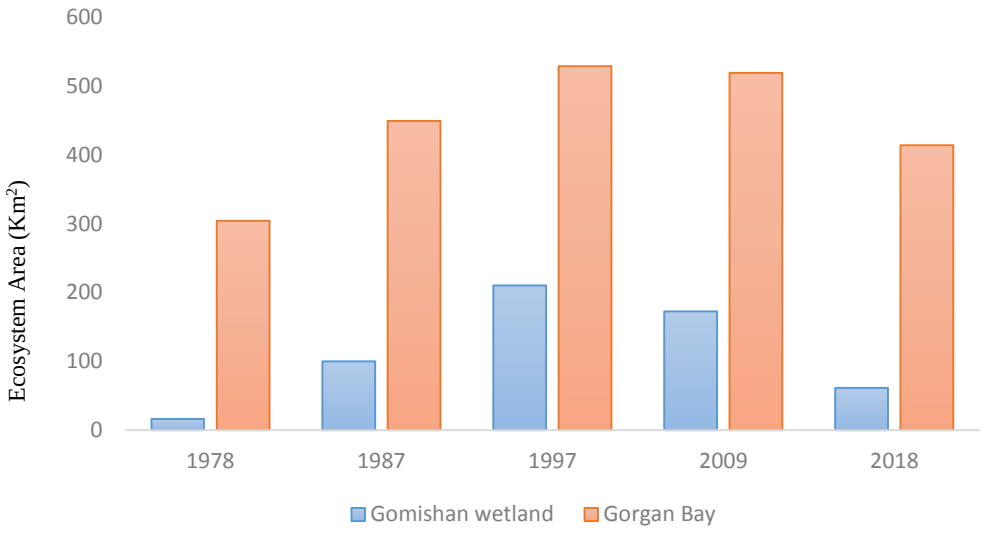

Fig. 3. Alterations in the area of ecosystems (Km^2).

B. Gorgan Bay

The extracted area maps are separately presented in Fig. 2 during different years. Despite the relative stability based on the maps of Gorgan Bay, alterations can be observed in the southern and southwestern parts of the bay. Therefore, for a more detailed study, the area of the studied years was obtained per km^2 (Fig.3). According to Fig. 3, an upward trend was observed until 1997 and to some extent 2009. The highest and lowest areas were obtained in 1997 with 528.97 km^2 and in 1978 with 309.44 km^2, respectively. Based on the Fig. until 1997 was the period of the bay water rise, while from 1997 to date, there has been a receding trend. The shores of Gorgan Bay are mainly swampy and the outflow of rivers such as Gorgan-rud and Qarehsoo in the region affect the conditions of the bay. The climate of the bay region with a sharp decrease in rainfall from west to east is evidence of an alteration from humid to desert. While in the west of the bay the vegetation of the wet areas can be observed, in the eastern areas the vegetation of the desert and salt-loving areas exhibited a dominant trend (Lahijani *et al.* 2010). In addition, for better estimation, Fig. 4 illustrates the alterations of the coastline between Gomishan Wetland and Gorgan Bay in 1978, 1997 and 2018. These years were selected based on the observed alterations.

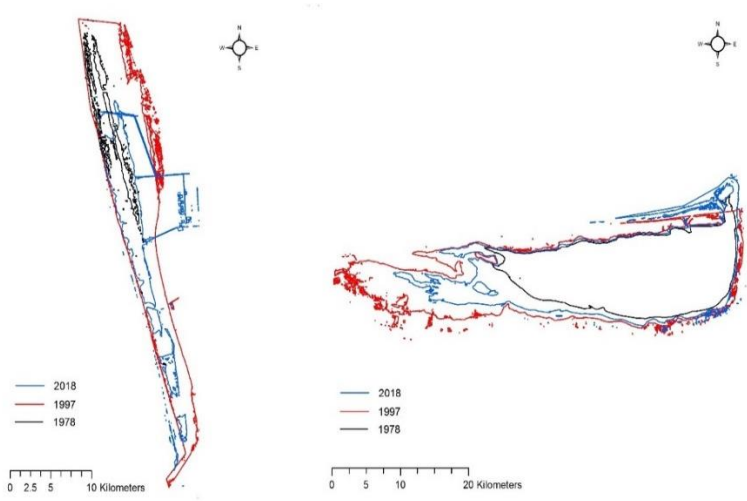

Fig. 4. Coastline changes of ecosystems in different years.

Accordingly, for both ecosystems, the most water-rise was observed in 1997 and the most receding water was observed in 2018. In addition, these fluctuations in the near-land areas were higher than other areas, which could be related to human activities in these areas.

DISCUSSION

A- Gomishan Wetland

The longevity of coastal environments and ecosystem processes is controlled by complex interactions including stressors and material flow between land, sea and atmosphere. As a result, coastal ecosystems are a variable and vulnerable part of the planet. Natural parameters that affect coastal ecosystems include sea level changes, rainfall, floods and hurricanes (Crossland *et al.* 2005; Eisenreich 2005). The ecosystems studied in this study are no exception to this rule. Based on studies of Gomishan Wetland and Gorgan Bay, the Caspian Sea is subjected to fluctuations **(**Ghangherme 2012). The water level of the Caspian Sea has two very important seasonal and annual alterations. Unlike regular perennial fluctuations, the Caspian Sea has relatively regular and distinct seasonal fluctuations, so that it starts to increase from March and continues until August. Then, until February and March, it decreases to its minimum level per year. These alterations depend on the amount of precipitation and melting snow along with other factors related to water and climate conditions (Shirood Mirzaei 2013). In our study, one of the factors that affect the results according to previous estimates is the fluctuations of the Caspian Sea. Studies show that climate change and tectonic activity have reduced the water level of the Caspian Sea in the southern region, although the effect of these earthquakes is not enough to explain the significant loss of seawater (Ozyavas and Khan 2012). In recent years, the shallow depth of Gomishan Wetland and the lack of water intake from the shrimp site have led to digging the new water supply canals directly from the sea, which has disrupted the hydrological relationship between the north-south of Gomishan Wetland and its dryness.

B- Gorgan Bay

Studies show that in addition to the fluctuations of the Caspian Sea, in the case of Gorgan Bay, the environmental and morphological conditions of the bay have been effective on making these alterations in the present study. The semi-closed water basin of Gorgan Bay has always been faced with the problem of reducing the volume of water due to its location in the sub-continental shelf region of the Caspian Sea with a gentle slope of the bed. The existential nature of this bay is mainly influenced by factors such as fluctuations in the sea level and high volume of sediment. In addition, the processes of erosion, sediment transport and sedimentation are determined by hydrodynamic parameters such as currents and water circulation regime, along with waves on the one hand and the flow of river sediments on the other hand (Jamshidi 2018). These factors cause adverse effects such as drying of shallow shores, shrinkage of the bay, and accumulation of organic and mineral sediments in this ecosystem. The abovementioned consequences can eventually cause morphological alterations in the coasts and coastline of the bay (Lahijani *et al.* 2010**;** Bagheri *et al.* 2012**;** Sharbaty and Ghanghermeh 2015). According to studies, Ghaz and Siah-Ab rivers have had a smaller share in the discharge of the Miankaleh Peninsula and the bay in recent years. The reason is the decrease in the irregular water withdrawal, raised pollution, destruction of forests along the abovementioned rivers, recent droughts, increase and development of urbanization. Furthermore, the decrease in the water level of the Caspian Sea and its receding water in recent years is very important in the changes in this area (Taghavi Kaljahi *et al.* 2014). The reason for the decline in the Caspian Sea water level can be attributed to overfishing and agricultural along with shipping activities in the northern countries of the Caspian Sea and the change in the Volga River in Kyrgyzstan in recent years. Moreover, the rotation of the Caspian Sea water, which is counter-clockwise from northwest to southeast, is also effective in these fluctuations (seasonal water circulation in Gorgan Bay is also based on counter-clockwise pattern; Sharbaty & Nasimi 2018). Of course, short-term and long-term factors have caused problems for this rotation. Meanwhile, by the alterations in the water level of the Caspian Sea, the water borders in the bay are disturbed by land, and as a result, the borders of these areas change leading to change in the using these areas for agriculture by local peoples. Another part of the change is related to the conversion of existing agricultural land into a water body. The reason is the low economic efficiency of these agricultural lands and the economic justification of fish farms in the villages of these areas along with the creation of dams. As a result, a large part of surface water is absorbed and prevented from entering the bay. Also, according to the Dashti *et al.* (2019) a large part of the water body of the bay has been turned into moisture lands (water-rise-receding water), especially in the western parts of the bay (Dashti *et al*. 2019). According to studies, the largest increase in moisture lands has been on the margins of the bay, which is due to the decline in the area of the bay and the transgression of moisture lands as well as its fertility for agriculture, which has increased its use and caused the fragmentation of the bay structure and Miankaleh Peninsula (Dashti *et al.* 2019).

CONCLUSION

In general, it can be conclude that the remote sensing, especially Landsat, has been effective in monitoring the alterations in the studied ecosystems. For proper management of coastal ecosystems as evaluated in this study, it is necessary to distinguish between anthropogenic effects and climate change on wetlands and bays. Dredging Ashuradeh mouth of Turkmen Seaport in the northeastern side of Gorgan Bay is the most important option to increase the life span of the bay and *its water renewal rate*. However, by the continuity of declining trend in the water level of the Caspian Sea, changes in the geometric structure of the Miankaleh Peninsula through the construction of new canals, can increase the connection between the bay and the Caspian Sea and consequently the potential for self-purification. In connection with Gomishan Wetland, we suggest that in addition to dredging, establish a buffer zone to prevent destructive human activities on the ecological functions of the wetland and also perform a continuous monitoring by the satellite.

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