The impact of human activities on the mangrove forests of the Qeshm Island, Iran

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ABSTRACT

This article investigates the human impact on the mangrove forest in the Qeshm Geopark on the Qeshm Island in the south of Iran from 1986 to 2020. The area of mangrove forests increased by 14% from 5,131 hectares in 1986 to 5,472 hectares in 2000, and to 5,967 hectares in 2020. The mangrove forest is threatened by oil and gas facilities and a zinc smelter located on the island. The average concentration of nickel in sediment (97.2 µg/g) and in leaves (3.1 µg/g) was higher than the average concentration of vanadium in sediment (38.7 µg/g) and in leaves (0.5 µg/g). The results showed that the transfer coefficient of nickel and vanadium from root to leaf on the dry side of the Qeshm habitat (r = 0.597 and r = 0.516, respectively) was positively correlated with pH. Therefore, increasing the pH leads to an increased metal transfer from the root to the leaf, which endangers the mangrove habitat on the island. The mangrove forest in the vicinity of the zinc factory is threatened by high concentrations of lead (244.2 ppm), zinc (3172.8 ppm), arsenic, and cadmium found in the soil sample.

KEYWORDS

geopark; mangrove change; Google Earth Engine; bio pollution; Qeshm; Iran

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1. Introduction

Geosite and geomorphosite are two new concepts in tourism studies that have entered the geographical and tourism literature with an emphasis on determining special and valuable places of tourism (Ielenicz 2009). Today, geotourism has a special place among the disciplines and types of tourism that emphasize the responsibility of tourism activities. Geotourism, which has been less studied in comparison with living nature, emphasizes that the use of geological and geomorphological forms and capabilities should be centered on the protection of these forms and features and their sustainable use (Sabokkhiz et al. 2012).

Geomorphosites are systems that are the result of external and internal active factors in an area and are of great importance in understanding the geological history and geological evolution of an area. The value of a geomorphosite is very high because of its focus on conservation for the future and the accumulation of tourism capital (Comănescu 2011). In this situation, the first step in geotourism should be to recognize and introduce the scientific and intrinsic values of a geomorphosite in order to be known to tourists and, while considering the issue of protection, to provide infrastructure and tourism services for geomorphosites. In fact, it should be said that geotourism attaches great importance to recognizing the scientific and conservation value of a landform and considers the values of tourism to be conditional on the improvement of scientific and conservation values. Geotourism can provide a desirable experience for the tourist and at the same time maintain the unique quality of tourism destinations in an integrated way, so it can be considered useful for both groups of tourists and indigenous people (Boley et al. 2011). In addition to emphasizing the forms, features and geological and geomorphological capabilities, geotourism emphasizes the issue of indigenous society as well as cultural and ecological values, which in a way as value-added, reinforces and complements geotourism. Qeshm Island can be considered a gateway for Iranian geotourism. Qeshm Geopark as one of the most important natural attractions, despite the existence of many potentials in the supply of nature tourism, due to the lack of facilities and infrastructure services is not growing much. Based on this, the capacity of Qeshm Geopark has not been evaluated so far. Therefore, to solve these problems, it is possible to plan to select the best geosites for Qeshm Geopark by applying the desired criteria. Qeshm Island, along with some shortcomings, has very significant opportunities, facilities and potentials. Qeshm Island, due to its privileged nature tourism areas such as mangrove forests and unique tourism and beautiful coastal shores and ancient history and unique cultural heritage, as well as the special culture of indigenous peoples, has many capabilities to attract tourists. Overall, it can have a significant impact on the region's economy. However, due to negligence and lack of proper management of tourism in the lowest levels of tourist attraction with the aim of nature tourism and consequently economic stagnation in the region is facing. Lack of public awareness and lack of facilities to introduce the island's attractions can each be a factor in the lack of tourism in Qeshm Island. Next to Qeshm Geopark are mangrove forests, which are a unique example in southwestern Asia. This forest is a unique example on Qeshm Island. Therefore, due to the establishment of oil and gas facilities and zinc factory, it is necessary to take the necessary measures to protect it. Many mangrove forests have been destroyed by human activities or natural causes. Today, the world's mangrove forests with an area of about 137.760 square kilometers (Giri et al. 2011), are the source of more than 21 ecological services and 45 natural products and play an important role in providing human welfare (Eggert and Olsson 2009; Duke et al. 2007). Despite the great importance of these ecosystem services in meeting human needs, the destruction and extinction of these unique coastal habitats has intensified over the past three decades around the world. So far, more than 50% of the world's mangrove forests have been destroyed (FAO 2016). Different coastal ecosystems, especially mangroves, are exposed to multiple environmental stresses and disturbances (geological, physical, chemical and biological) almost constantly and simultaneously, and vary in their characteristics over time and space (Venter et al. 2006; Halpern et al. 2007). The direct result of these disturbances will be a reduction in the size and health of mangroves, an intensification of global warming and other climate change, a decline in coastal water quality, a reduction in biodiversity, the destruction of coastal habitats and the destruction of much of society's resources (Walters et al. 2008). Given that mangrove ecosystems are always exposed to threats from natural and human hazards, planning and providing appropriate tools to mitigate their effects is inevitable (Allen et al. 2001). Achieving the above goal and helping to prioritize management actions and provide the desired infrastructure to reduce risks or their consequences, depends on sufficient and accurate knowledge and information about the process of change in these ecosystems over time (Allen et al. 2001). Examining changes in the mangrove area over time will enable responsible organizations and managers to select appropriate adaptive options and solutions that play an important role in the efficiency and success of mangrove forest conservation and development programs and as part of Integrated coastal zone management ensures a balance between economic exploitation and cultural values and prioritizes existing threats and helps meet managerial, organizational and legal needs (Eslami-Andargoli et al. 2009; Alongi et al. 2015). Therefore, in this study, changes in the level of Qeshm mangrove forest in a period of 30 years from 1986 to 2016 were examined and plotted through NDVI images. Deforestation can be identified and investigated with data obtained from various sensors and GIS. Meanwhile, the assessment of forest changes by satellites provides a comprehensive and clear view to quantify how and how quickly they are destroyed (Myers 1988). In addition to studying the changes in mangrove forests, changes in various climatic elements in the study period can be studied and evaluated. This data can be stored in a database and provide basic information and visual maps to decision makers. Reconstruction of the area damaged, destroyed or abandoned by human actions should also be among the management priorities of these forests. In addition, improving the living conditions of indigenous communities can also play an effective role in this regard, thus the need for these communities to harvest timber, demolition to increase land under cultivation of agricultural products, shrimp farming, use of branches as Forage should be provided. It is necessary to carry out all these measures, to know the level of these forests and their quantitative and qualitative changes, and to pay attention to climatic elements and human activities simultaneously. In this regard, the use of remote sensing data and the use of valuable tools of GIS is very important and effective. Extensive studies have been conducted on mangrove forests. Kjerfve and Donald (1997) in their study examined factors such as temperature, hydrology, water level, tides, carbon dioxide and tropical storms. Alongi (2002) stated that despite the tremendous value of mangrove ecosystems for coastal communities and their associated species, these forests have been extinct at an alarming rate. About a third of the world's mangrove forests have been lost in the last 50 years. Manson et al. (2003) evaluated changes in the distribution and spread of mangroves in Moreton Bay and southeastern Queensland, Australia, using two methods: spatial and temporal analysis model and change detection analysis. The findings show that over the past 25 years, about 3,800 hectares have been lost as a result of natural losses and mangrove clearing for urban development, aquaculture, industrial and agricultural development, and currently only about 15,000 hectares of mangroves remain in the bay remained. Mahdavi et al. (2003) in a study examined the trend of quantitative and qualitative changes in mangrove forests in the mangrove protected area between Qeshm and Bandar Khamir. In this research, aerial photographs of 1967 and 1994 were used. Based on the results, the area of mangrove forests in the Qeshm habitat area in 1967 was estimated at 8026 hectares and in 1994, 8016 hectares, which shows a decreasing trend in the area of mangroves in this habitat over a period of 27 years. In a study by Karen (2004), the effects of climate change on mangrove ecosystems were investigated and the role of increasing water levels and atmospheric carbon dioxide was investigated. In another study, the effects of climate change and rising sea levels on mangroves in the oceanic islands were investigated (Gilman et al. 2006). Virk and King (2006) examined changes in mangrove forests in the Indian state of Kartaka using Landsat images from 1986 and 2003 and two change determination techniques. Finally, by analyzing the results of their work, they concluded that deforestation is mainly the result of the development of hydropower, while reforestation is mainly due to afforestation projects. Armenteros et al. (2006) studied temporal and spatial changes in mangrove systems communities in the Cuban Bay of Cuba and concluded that seasonal changes in tropical mangroves occur due to changes in factors such as temperature, dissolved oxygen, and water pH. Hajjarian (2006) investigated quantitative changes in mangrove forests in Qeshm region using aerial photographs and satellite data over a period of 40 years. The results of this study show the rate of different changes in the level of mangrove forests in this period. In the years 1957 to 1966 had a decreasing trend, in the period 1966 to 1998 had an increasing trend, in the period 1998 to 2001 had a decreasing trend and finally from 2001 to 2005 had an increasing trend. In this study, the existence of regional and global changes caused by artificial stimuli has been expressed as a factor in changes in the area values of mangroves in different time periods. Another study in which the relationship between environmental factors and their effects on mangroves was discussed in more detail is related to the study of Catherine et al. (2007) in which the effects of factors such as atmospheric carbon dioxide, sea level, precipitation and Temperatures were studied and the effect of each of them was predicted to predict the possible situation affected by the impact of these factors on the forests of Australia in 2030 and 2100. Giri et al (2007) measured the rate of change of Bangladeshi mangroves over a 23-year period (1977–2000) using Landsat satellite imagery. In this study, images of three time periods related to 1977, 1989 and 2000 were processed and changes in the size of mangroves in these three time periods were identified. As in other parts of the world, in Iran, studies have been conducted on changes in the size of mangroves in different habitats. Giri et al. (2008) examined the degradation of mangrove forests in Madagascar. In their studies, they used satellite data from the years 1975–1990 and 2005 and considered both supervised and unsupervised classification methods for evaluation. The results of their research showed that the main reason for the destruction and reduction of the mentioned forests is their conversion into agricultural lands and aquaculture lands and urban development. Liu et al. (2010) in a study examined the changes in the spatial distribution of mangroves in the southern Chinese province of Guangdong from 1977 to 2010. In this study, a set of land use and land cover data was monitored through classification and produced using Landsat satellite images over a period of time. Thus, changes in mangrove cover and its relationship with changes in the size of shrimp farms were investigated. Taghizadeh et al. (2009) in a study examined the distribution of mangrove forest communities in the Sirik habitat of Hormozgan province. The results of studying the distribution of mangrove communities in this habitat showed that from the east to the west of the habitat, the establishment of Rhizophora mucronate masses increases and with approaching large Rhizophora mucronate, Rhizophora mucronate masses become more dominant. Pure mangrove, pure Rhizophora mucronate and mixed masses have an area of 272.6, 43.9 and 326.7 hectares, respectively, and the total area of Sirik habitat in this study is 643.2 hectares. Yáñez-Espinosa and Flores (2011) discuss the effects of rising water levels on the morphological and anatomical properties of mangrove species and believe that mangroves can adapt to these changes if the water level changes slowly. Sirajuddin et al. (2012) in a study investigated the effect of climatic element fluctuations on the area of Iranian mangrove forests in Gwadar Bay. The results showed that the quantitative status of Gwadar Bay mangrove forests during the statistical period (1987–2008) has an upward trend and the area of forests has increased from 384 hectares in 1987 to 607 hectares in 2008. In a study conducted by Nguyen et al. (2013), spatial and temporal changes in mangrove area as well as land use changes around mangroves over a 20-year period (1989–2009) were evaluated. In this study, using the supervised classification method, a map of mangrove cover changes was prepared and its relationship with other surrounding uses was investigated. Khorani et al. (2016) investigated the changes in the level of mangrove forests due to climatic fluctuations in the habitat zones of Khamir and Qeshm. The results of this study showed that the level of mangrove forest cover between 1984 to 1998 has an increasing trend (with an average area increase of 33.92 hectares per year) and in the period between 2001 to 2009 has an increasing trend (with increasing amount Equal to 450 hectares per year). Salehipour and Lak (2014) examined changes in the size of Iranian mangroves over a 35-year period from 1973 to 2008. The results of this study showed that all mangrove habitats in the country had an increasing trend during the period. According to the results of this study, all mangrove habitats in Iran in the period 1975 to 1989 have an increasing trend and only the size of Jask habitat zone has been reduced in the same period. Qeshm mangroves also had the highest increase among all habitat zones in the country in the same period. Finally, the size of all mangrove habitats in the country until 2008 has been increasing. The size of the country's mangroves has increased by 37.8% from 1975 to 2008. In a study conducted by Bazrafshan et al. (2016), the effect of runoff and sediment upstream watershed on changes in the size of mangrove Gabrik forests in Hormozgan province was investigated. In this study, Landsat satellite images over a period of 7 years (1993 to 2010) were used to study the area of mangroves. According to the results of this study, the amount of increase in the area of Gabrik mangroves in a period of 7 years was equal to 0.22 hectares per year. In addition to this research, the dangers facing mangrove forests should also be considered. Mangrove forests are in increasing danger. One of the problems that threatens the life of mangrove ecosystems today is the accumulation of heavy metals in their habitats (Alongi 2002). Due to the fact that plants show different sensitivities to chemicals and especially to increasing the concentration of heavy metals in the reaction environment, some of them disappear from the environment and some increase their tolerance to metals, so their study is essential (Smical et al. 2008). Due to their physical and chemical properties, mangroves are able to accumulate large amounts of metals in the effluent of their environment (Defew et al. 2005). In the bed of mangrove habitats, contaminants are transferred to adjacent waters, including groundwater, through runoff and urban, agricultural and industrial effluents, and as a result are easily available to mangrove trees. On the other hand, pollution from fossil fuels, factories and surrounding industries helps to increase the transfer and absorption of pollutants through mangrove forests. Extensive studies have been performed on the concentration and distribution of metals including nickel and vanadium in mangrove habitats. In this research, the capabilities of Qeshm Island such as geopark and mangrove forest are introduced and changes in the size of these forests over a period of 30 years from 1986 to 2016 are investigated and finally the threatening factors of these forests in terms of heavy metals are introduced and the status of 7 toxic elements was expressed. In this regard, the information of Qeshm Geopark site (qeshmgeopark.ir) and the research of Mafi Gholami et al. (2017), Moradi et al. (2014) and Moore et al. (2013) have been used. The results of their findings were used to understand the current situation of Qeshm Island.

2. Study area

Qeshm Island is located between 55 degrees and 15 minutes and 38 seconds to 56 degrees and 16 minutes and 52 seconds east longitude and 26 degrees and 32 minutes and 20 seconds to 27 degrees north latitude. The height of the island is about 10 meters above sea level. The island leads from the north to Bandar Abbas and part of Bandar Lengeh, from the northeast to Hormuz Island, from the east to Larak Island, from the south to Hengam Island and from the southwest to Greater and Lesser Tunbs and Abu Musa (Figs. 1–3). The length of the island is about 115 km and the width from the ridge of Bandar e Laft in the northern part to the ridge of Shib Deraz in the southern part of the island is about 35 km and in the narrowest place

Basaidu is about 10 km and the total area of the island is 1628 km^2. Qeshm is one of the hot and dry lands and the relative humidity in Qeshm is high. The first and most important plant community of the island in the mangrove forests is a species of mangrove called Avicennia marina and they occupy a large area of the island. Qeshm plants are drought tolerant and need high humidity in summer and are mostly visible in the form of short semi-desert shrubs. Rainfall is rare on Qeshm Island, so the southern coastal climate should be considered hot and dry. The climatic situation and the calcareous lands of the island have deprived the soil of Qeshm from having proper vegetation. The island's lands have little vegetation. The vegetation of the North, Northeast and Tourian lands is more impressive than the lands of other parts of the island. The most important vegetation of the island is the trees and shrubs of tropical areas such as dates.

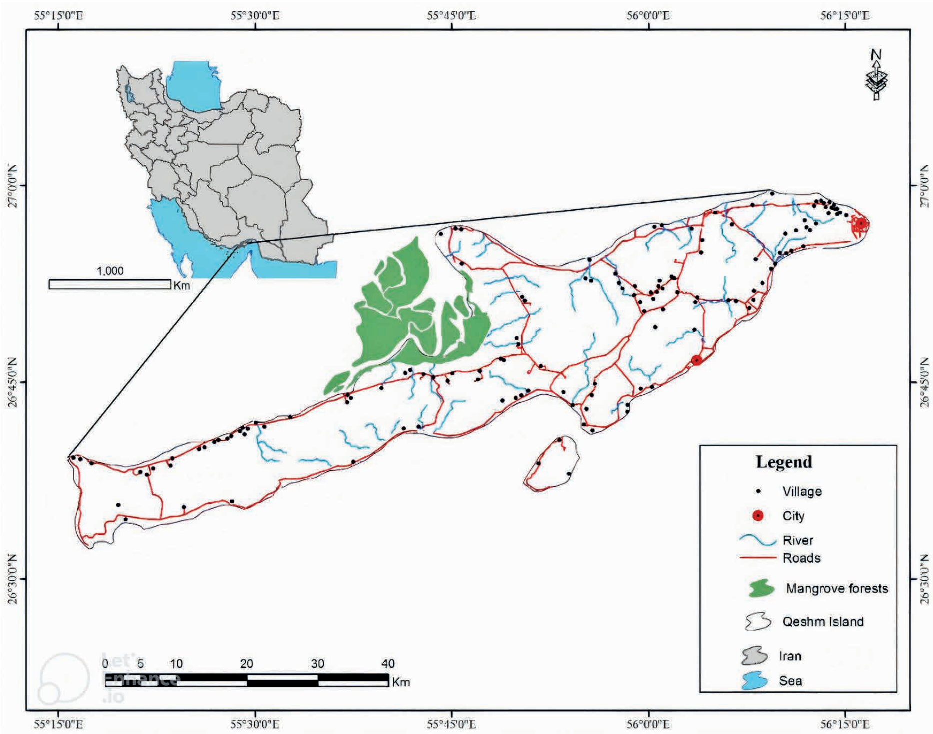

Fig. 1 Location of Qeshm Island.

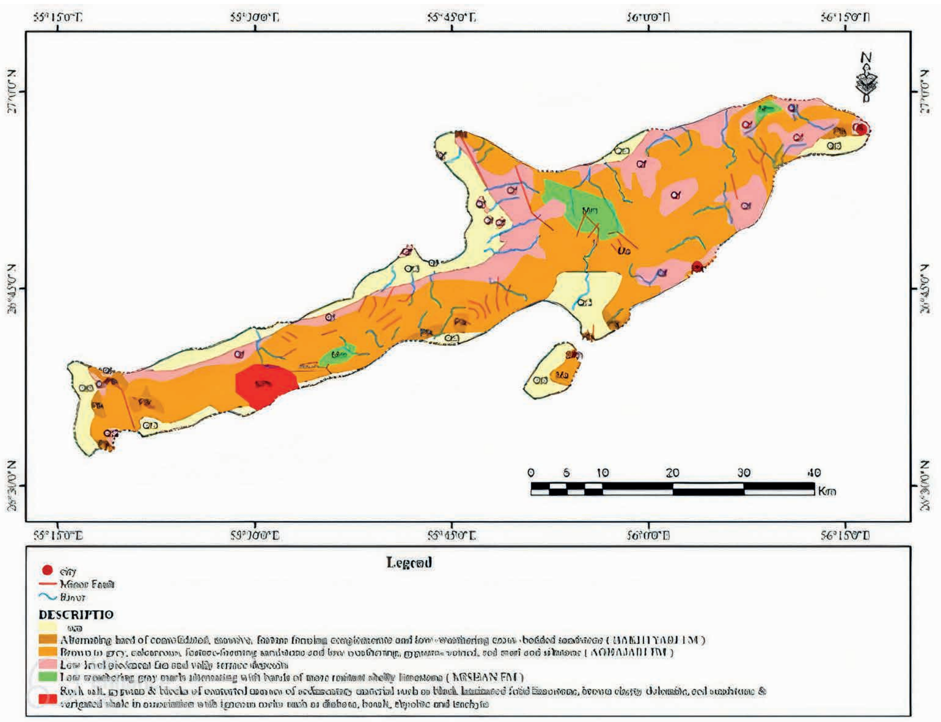

Fig. 2 Geological map of Qeshm Island.

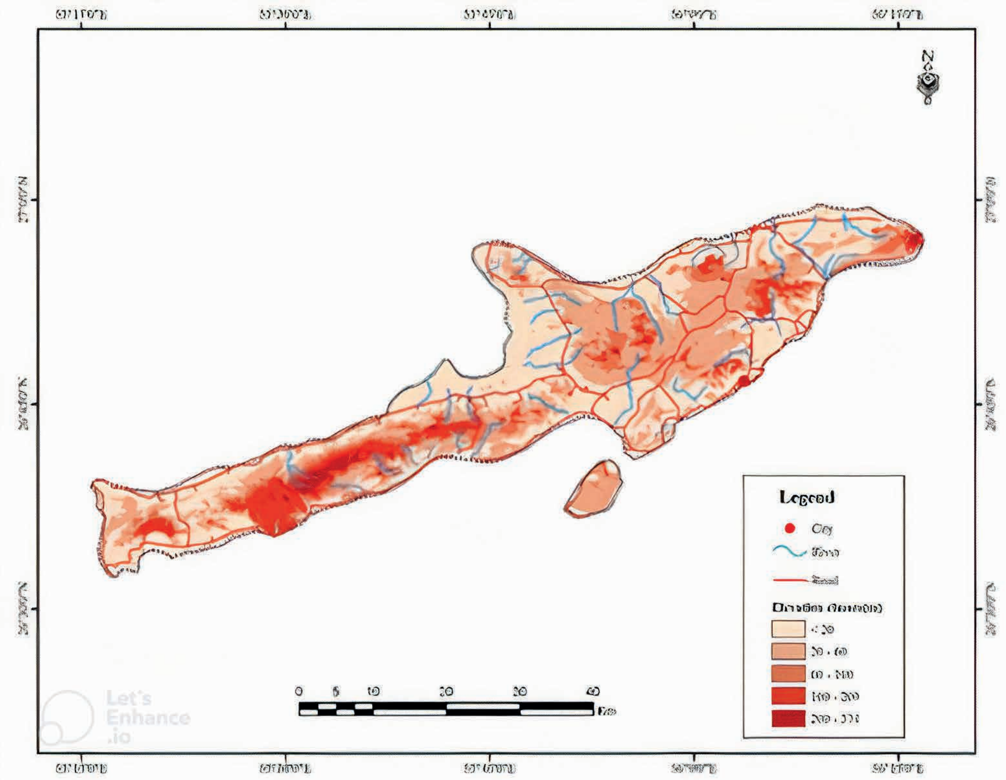

Fig. 3 Topographic map of Qeshm Island.

3. Material and method

In this study, the geotourism and ecotourism status of Qeshm Island was investigated and then the threats to Qeshm nature were investigated. For this purpose, Qeshm Geopark was first introduced through the information mentioned in Qeshm Geopark website (qeshmgeopark.ir). In the meantime, special emphasis was placed on the geosites of Chakavir Gorge, Awli Gorge, Namakdan salt complex, Chahkuh Gorge, Shur Valley, Tandisha Valley, Setarehgan Valley, Star's valley, Roof of Qeshm and Korkora kooh Gorge and their location was drawn on the map. Then the mangrove forest on Qeshm Island was studied. This forest is one of the unique examples of Avicennia marina mangrove forest in southwest Asia. In this study, to identify changes in the 34-year period and to estimate the area of mangrove forests, the Landsat Surface Reflectance images of 1986, 2000 and 2020 were used in the Google Earth Engine software. Annual climate change in the study area leads to the submergence of forests and other lands in the area. Therefore, in order to cover such a problem and create a cloudless image for each year, the average seasonal images (spring, summer, autumn and winter) were calculated and selected separately. The NDVI index was also used to identify changes and better differentiate mangrove cover from other lands. Then, in order to study the hazards threatening the nature of Qeshm, the role of pollutants caused by oil and gas facilities along with the zinc plant was investigated. For this purpose, the findings Moradi et al. (2014) in the field of nickel and vanadium accumulation in the sediment, mangrove roots and leaves were used. The findings of Moore et al. (2013) were used to analyze the role of zinc Factory in soil pollution of Qeshm Island. Then the amount of 7 toxic elements, arsenic, cadmium, lead, zinc, cobalt, selenium and antimony in the soil was determined. Finally, the status of pollutants on Qeshm Island as well as changes in mangrove forest area were investigated.

4. Result and discussion

There are unique geotourism and ecotourism attractions on Qeshm Island, including Qeshm Geopark and Mangrove Forest. In this section, first Qeshm Geopark is introduced and then the factors that threaten Qeshm Geopark and mangrove forest are introduced and the extent of their effects is introduced.

4.1 Analysis of geotourism attractions of Qeshm Island

The Persian Gulf region has about 130 small and large islands that are scattered in different parts of it. Qeshm Island is the largest island in the country and the Persian Gulf in the province of Hormozgan and is located at the mouth of the Strait of Hormuz (Mostofi Almamaleki and Rostam Gourani 2009). Qeshm Island with its natural attractions is one of the tourism hubs of Iran. Beautiful nature, heights and mountains, antiquities, beaches and mangrove islands can make this island one of the most lucrative places in terms

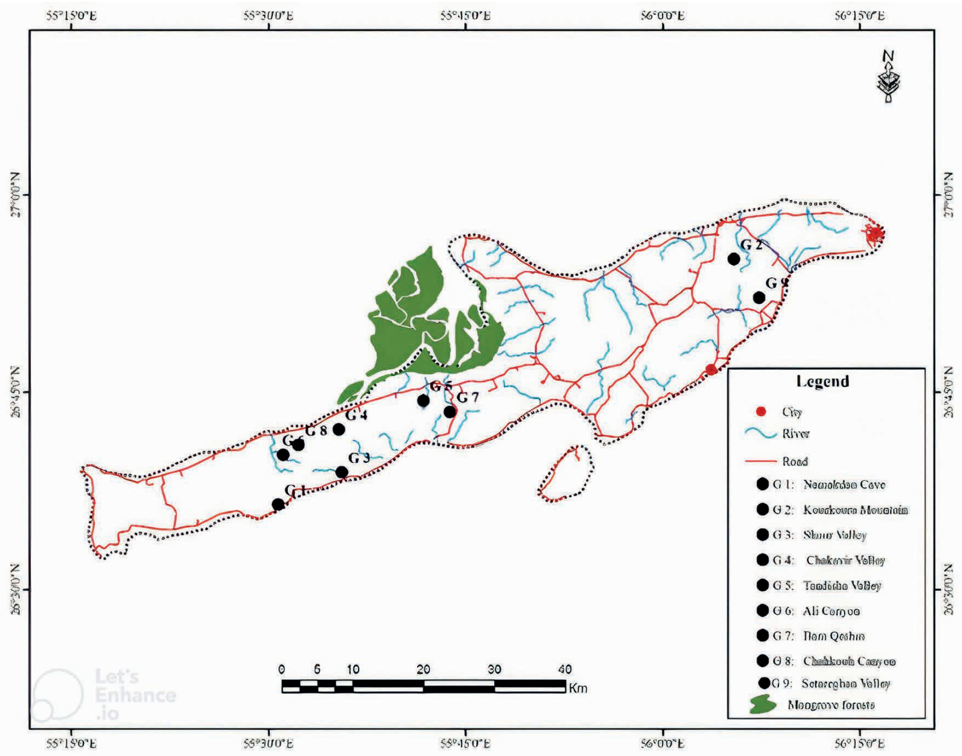

Fig. 4 Map of Qeshm Island Geopark.

of tourist attraction (Akbarpour and Nourbakhsh 2011). Qeshm Geopark with an area of 30,000 hectares is located in the west of the island. The geopark has a museum that displays the region's wildlife and photographs of the geopark's geological phenomena (Fig. 4).

Qeshm Island, as the largest island in the Persian Gulf, has a collection of tourist attractions and landscapes. But what has made the island more attractive in recent years is the island's geopark, which was inscribed on the UNESCO World Heritage List in 2006. This geopark has a set of geotourist and cultural attractions. Tandisha Valley, ChahKuh Gorge, Stars Valley, Korkorakooh, Roof of Qeshm, Shur Valley are among the important geomorphological features in Qeshm Island (Figs. 5–13).

Stars Valley geosite located near Borka Khalaf village is one of the most popular geosites in Qeshm World Geopark.This geosite is a unique example of geosites. The formation of this valley is due to the action of erosion factors such as water and wind and weight pressures on various parts of the earth. In the sections that had more resistant material, the erosion factors were less affected and as a result, these sections remained. But in the weaker parts, the erosion performance is more severe and has destroyed these parts. In the walls of this valley, two completely different genders can be seen from a thick and relatively soft layer of yellow to light gray below and a thin, hard layer of white to dark gray above. The substrate is loose and wears out and degrades rapidly against erosion agents. However, the top layer is resistant due to the presence of a natural cement made of lime and protects the bottom layer against erosion like a shield. Wherever the top layer is lost or has seams and cracks, erosion has acted more intensely and rapidly, causing small valleys and various cracks to open in the area. In some parts of this valley, columns can be seen, some of which are needle-shaped and narrow. One of the reasons for the formation of these shapes is the rotational movement and flooding of seasonal rainwater around the column or the remnants of old walls. Also, a strong part of the upper layer on a small part of the lower layer, has preserved this part as a column. The layers of this valley are very sensitive and fragile due to the mentioned features, and even the weight of a human being on its floors can cause their sudden collapse.

Fig. 5 Stars Valley Geosite.

Fig. 6 Korkorakooh Geosite.

Fig. 7 Roof of Qeshm.

Fig. 8 Tandisha Valley.

Fig. 9 Namakdan Salt complex.

Fig. 10 Chahkuh Gorge.

Fig. 11 Namakdan Cave.

Fig. 12 Awli Gorge Geosite.

Fig. 13 Chakavir Gorge.

To the east of Giahdan village is Korkorakooh geosite. Due to the beauty of the area, it has been introduced as another main site of the geopark. The construction of the area was mostly made of marl. Due to erosion by running water, the limestone layer placed on the marl has eroded and valleys have formed in the marl layer. In the central part of Qeshm Island, there is a beautiful plain, from which a wonderful view is located on the north and south coast of the island and is known as the roof of Qeshm. This roughness is a wide plateau with a height of more than 120 meters, which is located in the central part of Qeshm Island. Alternating layers of marl and sandstone can be seen on its wall. roof of Qeshm is a beautiful attraction. From the roof of Qeshm, you can see the mangrove forest, the Tandisha valley and the Persian Gulf from the north and south of Qeshm Island, which has a very beautiful and unique view. Tandisha Valley is another geopark site whose surface is often covered with cracks. It is structurally relatively similar to the Valley of the Stars, except that it is larger. It is located on the south coast of the island and near of Namakdan salt complex, the Shur valley geosite. The oldest sedimentary layers of the island can be seen in this valley. Also, the highest peak of the island with a height of nearly 400 meters overlooks this valley. On the other hand, due to the location of this area in the center of the anticline, rich gas resources are located in this site. Chahkuh Gorge is located in the southwest of Qeshm Island. Chahkuh Gorge is a special and unique example of erosive performance of running water. The rapid and powerful movement of water in heavy rains has been the main factor in the formation of this Gorge. However, water erosion is a secondary factor in the formation of this Gorge. The floors surrounding this gorge are part of the north-west ridge of the anticline where Namakdan Mountain is exposed. Due to lateral pressures and stretching of the anticline layers, seams, cracks and fractures appear in the anticline wall. These joints and fractures are the weak points of the wall and various erosive factors have stronger and more effective performance in those points. Chahkuh gorge is one of these primary fractures caused by erosive factors. One of the features of the geological formation of Chahkuh Strait is its impermeability to water. This causes water to flow into it and erode its cracks. The Namakdan salt complex is located in the southwest of Qeshm Island. The 6 km long Namkadan salt complex is the longest salt cave in the world, which is formed inside the Namakdan salt dome. One of the sights around the salt domes and salt caves is the presence of colorful layers of minerals and various stones. Great care is needed when visiting different parts of the salt dome. On the surface of salt domes, there are many dissolution holes that the risk of falling into them is very serious. Some of these holes are hidden and may be covered by a thin layer that may not be obvious at first glance. The Awli Gorge geosite is located in the western part of the island in the south of Chahu Sharghi village. This geological phenomenon is composed of thin layers of marl at the bottom of the gorge. The entrance to the gorge is wide at first, but after 50 meters it becomes very narrow. This gorge is very similar to Chahkuh gorge. Adjacent to Guran village, the Chakavir Strait geosite is located 92 km from Qeshm city. This strait is caused by water erosion. The concave cavities of the walls of this gorge have created an amazing view. This strait is one of the most beautiful geopark geosites.

4.2 Analysis of mangrove forest in Qeshm Island

Another attraction of Qeshm Island is the mangrove forest. Mangrove forests are tropical ecosystems that grow on the margins of two different environments, sea and land (Saleh 2007). The growing environment of mangroves is very dynamic and the water level in these habitats has daily and seasonal flows (Iftekhar et al. 2008). The main goal of sustainable management in mangrove forests is to create the necessary conditions for the protection, improvement and proper use of mangrove forests. Access to mangrove forests is in some cases impossible. For this reason, ground studies are not sufficient to determine the location of phenomena, and the use of telemetry information can provide users with the necessary information. One of the suitable methods to achieve this goal is to use satellite images during different periods and compare the trend of changes during this period. Detection of change is a process that shows changes in the state of different phenomena at different times (Singh, 1989). Correct detection of changes in surface features can be a good model for a better understanding of the relationship between humans and natural phenomena. The three main stages of change detection include initial image processing including geometric correction, radiometric and atmospheric corrections and topographic corrections, selection of appropriate techniques for change detection analysis and evaluation of the results. Qeshm Island mangrove forests are located in the geographical range of 26 degrees and 45 minutes to 27 degrees north latitude and 55 degrees and 20 minutes to 55 degrees and 51 minutes east longitude in the northern part of Qeshm Island (Fig. 14).

Most of the forest communities of Qeshm Island are spread in Laft and Tabl and cover a large area. Mangrove forests in Iran are among the conservation tree communities and the exploitation of these communities is in the form of harvesting branches for livestock, beekeeping, aquaculture and recreational use. Iran’s mangrove forests are exposed to degradation due to various natural and human hazards such as over-harvesting of branches, illegal hunting, unplanned tourism, development of some industries, entry of urban and industrial wastewater and oil pollution. In addition to these factors, the presence of some environmental stresses such as drought, high summer heat, lack of annual rainfall and even

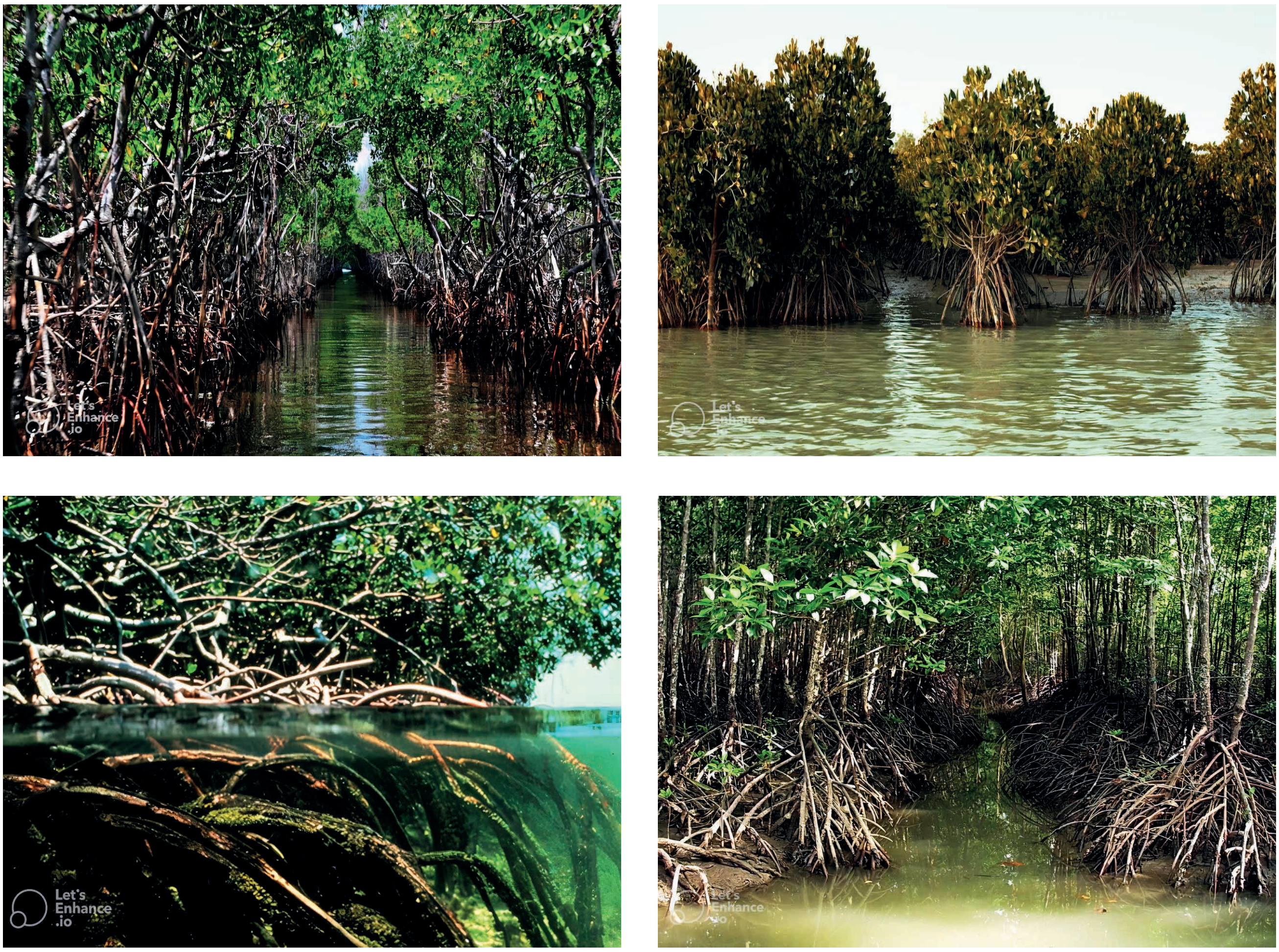

Fig. 14 View of mangrove forests on Qeshm Island.

the impact of tropical storms, has made mangroves a sensitive ecosystem. Therefore, these areas are in dire need of protection (Danehkar et al. 2007). Therefore, in this section, the condition of Qeshm mangrove forests has been studied. To identify changes over the 34-year period and to estimate the area of mangrove forests, the Landsat Surface Multi-spectrum images of 1986, 2000 and 2020 were used in the Google Earth Engine software. Annual climate change in the study area is such that it leads to the submergence of forests and other lands in the area. Therefore, in order to cover such a problem and create a cloudless image for each year, the average seasonal images (spring, summer, autumn and winter) were calculated and selected separately. The NDVI index on all images (12 Landsat images) was also used to help accurately identify changes and better distinguish mangrove cover from other areas (Viana et al. 2019; Vo et al. 2013; Seto and Fragkias 2007). Previous studies have used the NDVI index to identify changes in mangrove forests (Adi et al. 2016; Bihamta et al. 2019; Bihamta et al. 2020). Then, the supervised classification method was used. In these methods, it is first necessary for the user to enter values into the algorithm. For this purpose, 155 mangrove samples, 121 mud samples from tidal areas and 110 water samples were collected for each study year. Finally, these samples were placed at the input of the SVM (Support vector machine) algorithm to classify annual NDVI images. It can also be used to classify mangroves using pixel reflectance (Mahendra et al. 2019). A total of 50 samples were taken from Google Earth images to validate the vegetation maps of 1986, 2000 and 2020. Then, the maps were evaluated using the Confusion matrix, which includes the statistical parameters of overall accuracy, kappa coefficient. Overall accuracy and kappa coefficient are calculated from the following equations (Jensen 2015). Finally, to estimate the percentage of decrease and increase of vegetation, especially mangrove, the classification maps of 1985, 2000 and 2020 were reviewed.

$$\frac{N\sum_{i=1}^{r} xii-\sum_{i=1}^{r}(x_{i+}\times x_{+1})}{N^2-\sum_{i=1}^{r}(x_{i+}\times x_{+1})} \quad (1)$$

Where k is the number of rows (e.g., land-cover classes) in the error matrix, xii is the number of observations in row i and column i, and x_{i+} and x_{+j} are the marginal totals for row i and column j, respectively, and N is the total number of samples.

$$\frac{1}{N}\sum Pii \quad (2)$$

Where OA defines the total accuracy of the model, test pixels are described by *N*, and *P pii* represents the total number of correctly classified pixels.

Tab. 1 shows the results of the Confusion matrix of land cover maps of 1986, 2000 and 2020. As can be seen in Tab. 1, the accuracy of User Accuracy in every 3 years of study is more than 93.33%, which indicates the high accuracy of extracting mangrove cover class from other lands. The overall accuracy of the maps in the studied years is 97.77, 91.11 and 93.33%, respectively. Also, the kappa coefficient of the maps is equal to 0.96, 0.86 and 0.90, respectively. In general, the results of overall accuracy and kappa coefficient indicate the high accuracy of the prepared maps, which can be used to identify mangrove changes.

Tab. 2 shows the area of vegetation in 1986, 2000 and 2020, as well as the rate of change over the 34-year period of mangrove cover. According to this table, mangrove forests in 1986 increased from 5130.78 hectares to 5471.87 hectares in 2000, which indicates a 6.23% increase in mangrove area. In 2020, the area of mangrove has reached about 5967.13 hectares, which is an increase of about 8.30% compared to the area of mangrove cover in 2000. Overall, mangrove levels have increased by about 14.02 percent over the 34-year period from 1986 to 2020. Fig. 15 and Fig. 16 show the vegetation map by years and the time series map of changes in the mangrove forests of Qeshm Island over a period of 34 years, respectively.

4.3 Threatening factors of mangrove forests in Qeshm Island

All residents and experts of the Hormozgan Province Natural Resources Department who participated in the interview blamed the excessive exploitation of mangrove forests for the destruction of these habitats because the natives of the areas cut down trees to provide livestock feed. One of the problems that threatens the life of mangrove ecosystems today is the accumulation of heavy metals in their habitats (Alongi 2002). Due to their physical and chemical properties, mangroves are able to accumulate large amounts of metals in the surrounding effluent (Defew et al. 2005). One of

Tab. 1 Results of Confusion matrix parameters of mangrove forest maps in 1986, 2000, 2020.

Land Cover 1986					
Classes	Mangrove	Mud and Tidal	Sea	User Accuracy	Producer Accuracy
Mangrove	100	0	0	100	100
Mud and Tidal	0	100	6.67	100	93.75
Sea	0	0	93.33	93.33	100
Overall Accuracy: 97.77					
Kappa Coefficient: 0.96					
Land Cover 2000					
Classes	Mangrove	Mud and Tidal	Sea	User Accuracy	Producer Accuracy
Mangrove	93.33	0	6.67	93.33	93.33
Mud and Tidal	6.67	86.67	0	92.86	86.67
Sea	0	13.33	93.33	87.50	93.33
Overall Accuracy: 91.11					
Kappa Coefficient: 0.86					
Land Cover 2020					
Classes	Mangrove	Mud and Tidal	Sea	User Accuracy	Producer Accuracy
Mangrove	93.33	6.67	0	93.33	93.33
Mud and Tidal	6.67	86.67	0	92.86	86.67
Sea	0	6.67	100	93.75	100
Overall Accuracy: 93.33					
Kappa Coefficient: 0.90					

Tab. 2 Area and extent of mangrove changes from 1986 to 2020.

Categories	**Extent (ha)**			**Change (%)**		
Classes	1986	2000	2020	1986-2000	2000-2020	1986-2020
Mangrove	5130.78	5471.87	5967.13	6.23	8.30	14.02
Mud and Tidal	17019.0	16971.7	16334.5	−0.28	−3.90	−4.19
sea	14079.6	13785.6	13927.3	−2.13	1.02	−1.09

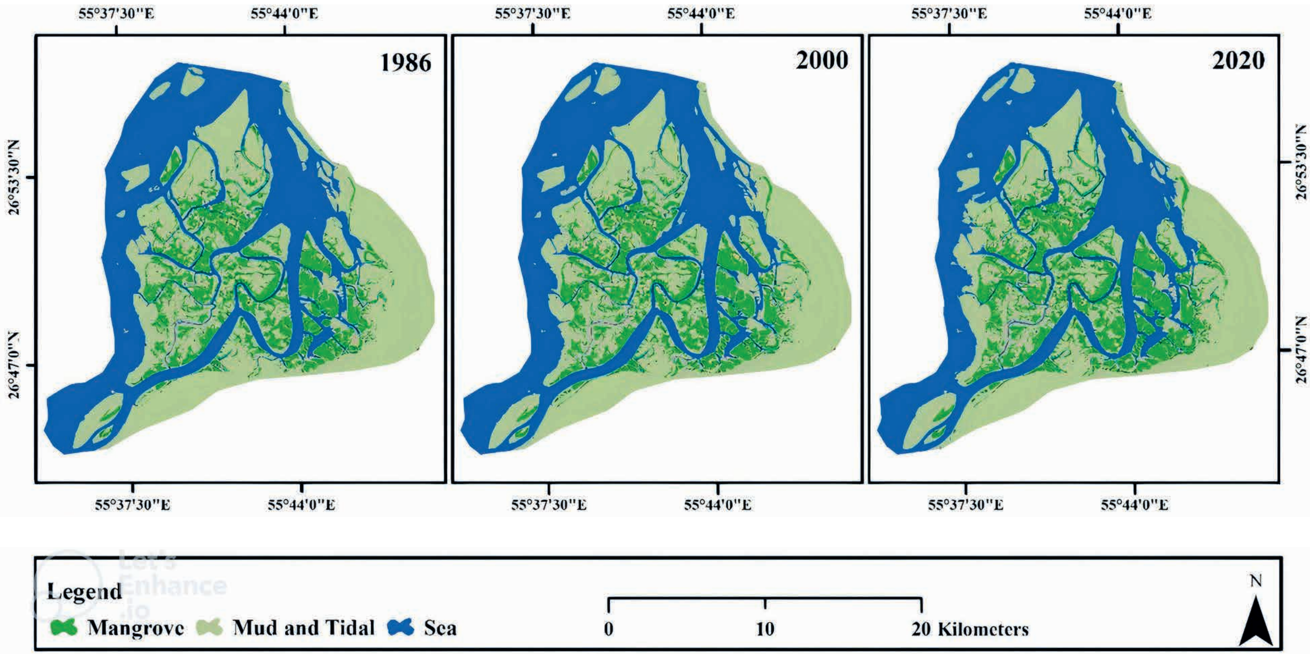

Fig. 15 Land cover map using SVM classification algorithm.

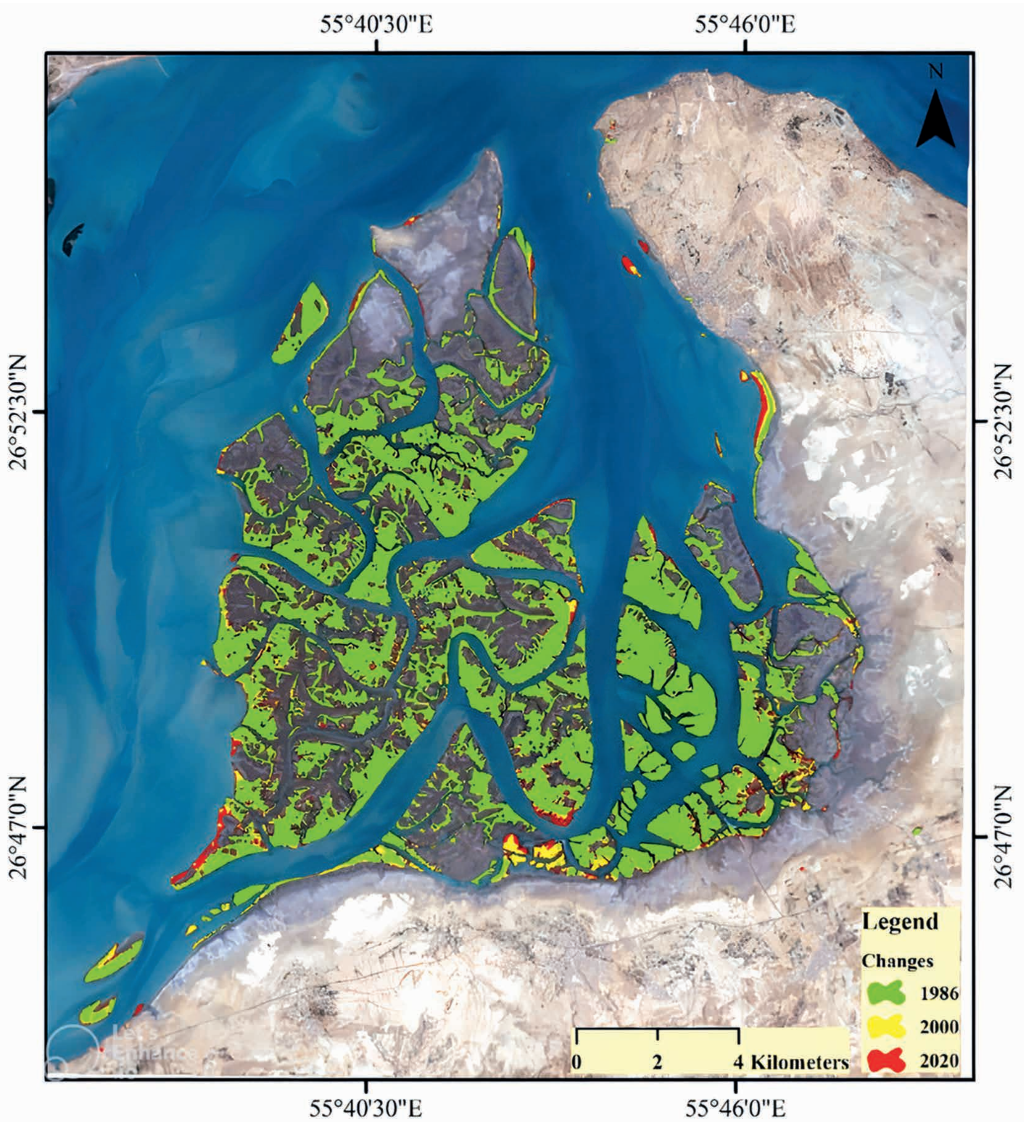

Fig. 16 Changes in mangrove levels over a 34-year period.

Tab. 3 Correlation of metal transfer from sediment to root with bed characteristics on land and sea in mangrove habitat in Qeshm. Source: Moradi et al. 2014.

Parameter	Statistical analysis	Qeshm			
		sea		land	
		nickel	vanadium	nickel	vanadium
PH	Correlation Coefficient	0.216	−0.302	−0.650	−0.451
	p-value	0.500	0.340	0.030	0.164
Organic Compound	Correlation Coefficient	0.389	−0.259	0.528	0.031
	p-value	0.106	0.416	0.095	0.928
EC	Correlation Coefficient	0.324	−0.252	−0.665	−0.715
	p value	0.152	0.429	0.013	0.013
Clay	Correlation Coefficient	−0.216	0.060	−0.216	0.302
	p-value	0.500	0.854	0.500	0.340
Silt	Correlation Coefficient	−0.518	0.475	0.183	0.763
	p-value	0.084	0.119	0.591	0.006
Gravel	Correlation Coefficient	0.216	−0.302	−0.442	−0.745
	p-value	0.500	0.340	0.087	0.008

the main sources of heavy metals entering mangrove trees occurs in oil-contaminated areas. The most important heavy metals in petroleum compounds are nickel and vanadium. The concentration of nickel in oil is in the range of more than 300–300 mg/l (Barceloux et al. 1999; Danzon 2000). Although very low concentrations of vanadium and nickel are beneficial for plant growth, high concentrations are toxic (Barceloux et al. 1999; Campel et al. 2006). The Persian Gulf is one of the most valuable aquatic ecosystems in the world, which has valuable resources from the huge mangrove forests. But in recent years, these ecosystems have become one of the most vulnerable areas of the Persian Gulf to a variety of environmental stresses, especially oil pollution and heavy metal emissions. In this part of the research, the findings of Moradi et al. (2014) on the accumulation and transfer rate of heavy metals in mangrove trees are presented. The texture of sediments in Qeshm habitats is mainly sandy. In Qeshm habitat, the average concentration of nickel in sediment (97.2 µg/g) and leaves (3.1 µg/g) was higher than the average concentration of vanadium in sediments (38.7 µg/g) and leaves (0.5 µg/g). In Qeshm habitat, the concentration of vanadium (19.8 µg/g) in the roots was higher than the concentration of nickel (14.7 µg/g). The results of the correlation of transfer coefficients from sediment to root are presented in Tab 3.

Most significant correlations were observed in the land section. The correlation of nickel and vanadium transfer coefficient from root to leaf with substrate characteristics is shown in Tab. 4.

Tab. 4 Correlation of metal transfer from root to leaf with bed characteristics on land and sea in mangrove habitat in Qeshm (Moradi et al. 2014).

Parameter	Statistical analysis	Qeshm			
		sea		land	
		nickel	vanadium	nickel	vanadium
PH	Correlation Coefficient	−0.301	−0.400	0.597	0.516
	p-value	0.341	0.198	0.40	0.086
Organic Compound	Correlation Coefficient	−0.173	0.365	−0.668	−0.535
	p-value	0.591	0.243	0.018	0.073
EC	Correlation Coefficient	−0.326	0.203	−0.175	−0.097
	p-value	0.301	0.526	0.587	0.765
Clay	Correlation Coefficient	0.376	0.248	−0.389	−0.087
	p-value	0.228	0.438	0.212	−0.789
Silt	Correlation Coefficient	0.648	−0.110	0.302	0.178
	p-value	0.011	0.367	0.340	0.580
Gravel	Correlation Coefficient	−0.418	−0.130	−0.251	−0.150
	p value	0.176	0.686	0.432	0.643

The results showed that the transfer coefficient of nickel and vanadium from root to leaf on the dry side of Qeshm habitat (with $r = 0.597$ and $r = 0.516$, respectively) was positively correlated with pH. Therefore, increasing the pH leads to increased metal transfer from root to leaf. In addition, nickel and vanadium transfer coefficients in Qeshm habitat (r = −0.668 and r = −0.535, respectively) showed a negative correlation with substrate organic matter. Therefore, with the increase of organic matter, the transfer of nickel and vanadium metals from root to leaf decreases. In Qeshm habitat, nickel transfer coefficient on the sea side has a positive correlation with silty texture (r = 0.648). The above study showed that the proximity of this habitat to oil and gas extraction facilities has caused the vulnerability of these trees. Another source of pollution on Qeshm Island that threatens the island's habitats is the zinc factory. The zinc factory on Qeshm is located on the Dargahan-Laft road in NFCQ. The altitude of this area is 8.84 meters above sea level and the distance of this factory to Laft village is 10 km. This factory was established in 1998 by NFC China. The output of this company is zinc ingots. The results of research by Farid Moore et al. (2013) were used to investigate zinc pollution in Qeshm Island. The material presented in this section is the result of the research of these researchers. The results for the seven toxic metals arsenic, cadmium, lead, zinc, cobalt, selenium and antimony are given in the table below. According to the results, it is clear that the concentration of metals such as arsenic, cadmium, lead and zinc in soil samples around the factory is very high and zinc metal has the highest average and medium. The mobility of elements in the soil largely depends on the physical and chemical properties of the soil. Meanwhile, pH and soil organic matter can change the mobility of metals (Denaix et al. 2001). PH and relatively high levels of organic matter limit the mobility of metals (Kapusta et al. 2011). According to Tab. 5, soil pH is in the range of neutral to alkaline and therefore metal mobility is expected to be limited. The percentage of organic matter in the soil is relatively low and therefore can be expected to play a lesser role in the mobility or immobility of metals. According to studies, arsenic is in the range of moderate to very high pollution, Cd, Pb, Sb and Zn are in the range of moderate to extremely high pollution, Se is in the range of no pollution to moderate pollution and Co is in the range of no pollution.

The distribution and dispersion of heavy metals in soil samples around the zinc factory shows that the amount of heavy metals in the soils adjacent to the factory increases in the direction of the prevailing wind (S-SW) and near the factory. By moving away from the plant, the concentration of these metals in the soil is significantly reduced. According to research conducted by Moore et al. (2013), the soil is contaminated with metals such as cadmium, lead, arsenic, zinc and antimony and the risk of cadmium and lead contamination in the study area is very high. Soil contamination with lead, cadmium and antimony metals is also high in samples contrary to wind direction. The reason for this is pollution caused by washing metals by rainwater runoff in the factory or passing vehicles on the road from Laft to Qeshm (about 100 meters north of the factory). According to the SDM index, the amount of metals in the area of 500 meters around the factory is very high and decreases with increasing distance from the amount of metals in the soil. The results of factor analysis test also confirm the origin of the studied metals. Although soils with neutral to alkaline pH limit the mobility of elements in the soil, sandy texture limits soil capacity and severe soil contamination with heavy metals as a result of metal leaching causes groundwater contamination. Given that surface runoff carries heavy metals and eventually enters the coastal environment, the possibility of coastal pollution in the long run will not be unexpected (Fig. 17).

5. Conclusion

The purpose of this study was to evaluate the capabilities of Qeshm Island with emphasis on Qeshm Geopark and mangrove forests as well as the threats to the island's ecosystem. Therefore, in the first stage, Qeshm Geopark was introduced using Qeshm Geopark website (qeshmgeopark.ir) and the location of Chakavir Gorge, Awli Gorge, Namakdan Salt Complex, Chahkuh Gorge, Shur Valley, Tandisha Valley, Roof of Qeshm and Korkora kooh Gorge on Qeshm Island it was shown. In the second phase, the mangrove forest on the island is introduced and using Landsat series Surface Reflectance images in 1986, 2000 and 2020 in Google Earth Engine software, land coverage area of 1986, 2000 and 2020 and the rate of change in the 34-year period of mangrove cover has also been estimated. Mangrove forests increased from 5130.78 hectares in 1986 to 5471.87 hectares in 2000, which indicates an increase in the mangrove area of about 6.23 percent. Also in 2020, the area of mangrove has reached about 5967.13 hectares, which is an increase of about 8.30% compared to the area of mangrove cover in 2000. Overall, the rate of change in mangrove land has increased by about 14.02% over the 34-year period from 1986 to 2020. In the next

Tab. 5 Descriptive statistics of heavy metal concentrations in soil samples (Moore et al. 2013).

Descriptive Statistics	As (ppm)	Cd (ppm)	Co (ppm)	Pb (ppm)	Sb (ppm)	Se (ppm)	Zn (ppm)
Mean	48.3	19.6	19.6	244.2	6.7	0.34	3172.8
Median	21.5	14.7	14.7	88.7	2.5	0.29	725
Minimum	6.20	11.6	11.6	6.3	0.3	0.05	62.8
Maximum	204	53.1	53.1	1620	37.8	0.88	34600

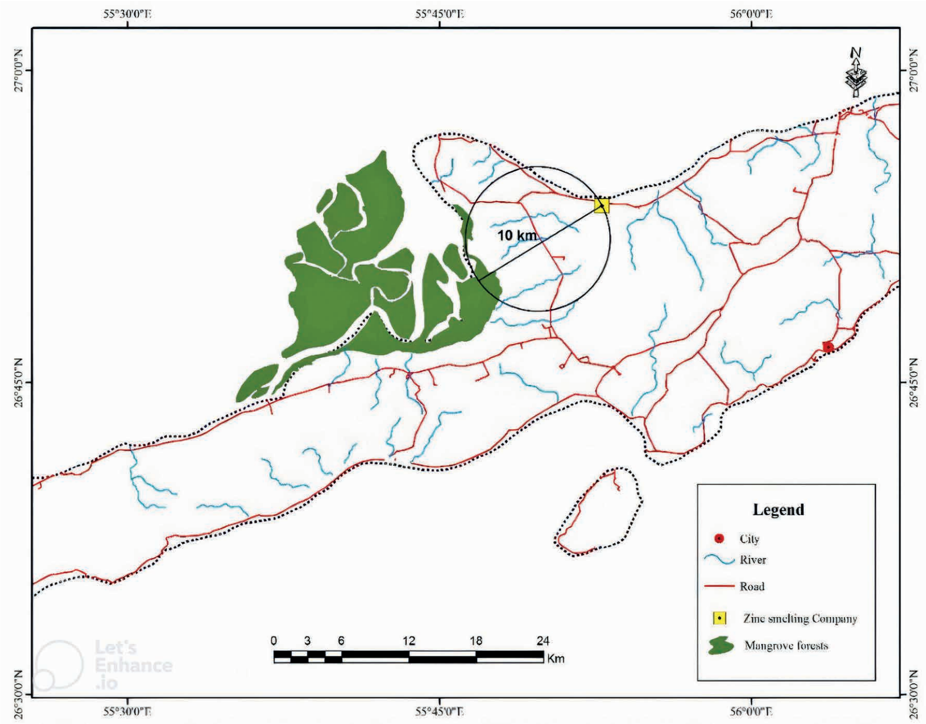

Fig. 17 Location of the zinc factory relative to the mangrove forest.

stage of the research, the threats to the ecosystem of Qeshm Island were investigated. For this purpose, using the research of Moradi et al. (2014), the accumulation status and transfer rate of heavy metals in mangrove trees of Qeshm Island were investigated. Accordingly, the average concentration of nickel in sediment (97.2 µg/g) and leaves of mangrove trees (3.1 µg/g) was higher than the average concentration of vanadium in sediments (38.7 µg/g) and leaves (0.5 µg/g). The results showed that the transfer coefficient of nickel and vanadium from root to leaf on the dry side of Qeshm habitat (with r = 0.597 and r = 0.516, respectively) was positively correlated with pH. Therefore, increasing the pH leads to increased metal transfer from root to leaf. The above study showed that the proximity of this habitat to oil and gas extraction facilities has caused the vulnerability of these trees. The polluting factor of Qeshm Island is not only allocated to oil and gas facilities, but also the zinc factory near the mangrove forest can be another threatening factor. Moore et al. (2013) investigated the status of seven toxic metals arsenic, cadmium, lead, zinc, cobalt, selenium and antimony in Qeshm Island. The results of their research are listed in this section. Studies have shown that the concentrations of metals such as arsenic, cadmium, lead and zinc in soil samples around the factory are very high and zinc metal has the highest average and medium. According to studies, arsenic is in the range of moderate to very high pollution, Cd, Pb, Sb and Zn are in the range of moderate to extremely high pollution, Se is in the range of no pollution to moderate pollution and Co is in the range of no pollution. Therefore, it can be argued that the zinc factory can damage the soil and ecosystem of Qeshm Island due to the significant volume of toxins. Considering the capabilities of Qeshm Island and the dangers threatening the island, it can be argued that mismanagement and neglect of the attractions of Qeshm Island has made this region face irreparable dangers.

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