The effects of Anthropogenic Induced geomorphological changes on mangrove forests in Tarut Bay, on the east coast of Saudi Arabia.

By

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Abstract:

Anthropogenic Induced geomorphological changes are considered one of the most significant changes in the natural environment. Human are an active geomorphological factor, as his role is greater than other factors in modifying the landform, these human interventions have a significant impact on mangrove communities around the world. The current study aims at reveal the effects of Anthropogenic Induced geomorphological changes on the mangrove forests in Tarut Bay. The problem of the study was crystallized in the light of field observations of the deterioration of mangrove forests in the study area, as well as in the widespread human activity in the coastal region, which is represented in the extensive filling of shallow waters with the aim of urban development to keep pace with the increasing demand for housing, commercial investment and tourism. The study was conducted by remote sensing techniques and making comparisons between satellite images in different years to determine the magnitude of changes, whether in Tarut Bay or Tarut Island, and the impact of these conditions on mangrove communities during the period from 1986-2021. The study came to a number of results, the most important of which are, The area was subjected to major geomorphological changes that greatly affected the mangrove sites, which resulted during 35 years in a decrease in the mangrove area from 13.11 km^2 to 4.5 km^2, where some sites were completely degraded as a result of the continuous cutting of mangrove trees, as is the case in the southern coast of Tarut Island and the southwest coast of Bay of Tarut

Keywords:

Anthropogenic, geomorphological changes, mangrove, Tarut Bay.

ملخص :

يعد الإنسان عاملاً جيومورفولوجيًا نشطًا، ويوصف دوره على أنه أكبر من العوامل الطبيعية في تعديل شكل الأرض فى بعض المناطق، لذا فإن التغيرات الجيومورفولوجية الناجمة بفعل الإنسان تعد أحد أهم التدخلات في البيئة الطبيعية والتى ينجم عنها تأثير كبير على عديد من النظم البيئية في جميع أنحاء العالم ومنها مجتمعات المانجروف. تهدف الدراسة الحالية إلى الكشف عن آثار التغيرات الجيومورفولوجية التي يسببها الإنسان على غابات المانجروف في خليج تاروت. تبلورت مشكلة الدراسة في ضوء الملاحظات الميدانية لتدهور غابات المانجروف في منطقة الدراسة ، وكذلك في النشاط البشري الواسع النطاق في المنطقة الساحلية والمتمثل في الردم بالمياه الضحلة بهدف التنمية العمرانية لمواكبة الطلب المتزايد على الإسكان والاستثمار التجاري والسياحة. أجريت الدراسة بتقنيات الاستشعار عن بعد وعمل مقارنات بين صور الأقمار الصناعية في سنوات مختلفة لتحديد حجم التغيرات سواء في خليج أو جزيرة تاروت ، وتأثير هذه الظروف على مجتمعات المانجروف خلال الفترة ١٩٨٦-٢٠٢١. توصلت الدراسة إلى عدد من النتائج أهمها تعرض المنطقة لتغيرات جيومورفولوجية كبيرة أثرت بشكل كبير على مواقع المانجروف ، والتي نتج عنها خلال ٣٥ سنة انخفاض في مساحة المنغروف من ١٣.١١ كيلومتر مربع إلى ٤.٥ كيلومتر مربع ، حيث تدهورت بعض المواقع تمامًا نتيجة القطع المستمر لأشجار المانجروف كما هو الحال في الساحل الجنوبي لجزيرة تاروت والساحل الجنوبي الغربي لخليج تاروت.

الكلمات المفتاحية: التغيرات الجيومورفولوجية البشرية، المانجروف، خليج تاروت

Introduction and Problem Posted :

Mangrove forests grow on tropical and subtropical coasts (Nguyen, L. & Luong, V. 2019, Kumar, et al, 2010) as these environments provide the ingredients for mangrove growth. In terms of climatic controls for its growth, as it needs an appropriate temperature, there is a direct relationship between temperature and abundance of mangrove forests, where the biomass decreases on the surface of the ground, with increasing latitudes, while the biomass of forests increases in the lower latitudes. The study of (Alongi, 2002) also confirms that mangrove biomass rivals that of tropical forests in low latitudes, where 30 species can be found in the tropics, while reducing to one in the milder latitudes in the north and south.

Mangrove communities are of great importance in the positions they occupy, as they are environmentally important, as they contribute to biodiversity by being a safe environment for a large number of living organisms that complement marine food chains (Kholeif,2007), and provide the marine food web with a number of elements necessary to enrich it. (Biswas et al. 2009) In addition to being considered an important habitats for nesting migratory birds, or considered important stations in the path of movement and migration of birds, (Khalil, 2004) it also has a geomorphological importance for beaches, and represent walls against waves and sea currents in periods of severe storms, thus protect them from exposure to marine erosion. (Cao, H. Chen, et al., 2016; Khalil, 2004, Horstman et al., 2014; Massel et al.,

1999; Parvathy and Bhaskaran, 2017; Vo-Luong and Massel, 2006) Also, mangrove forests have economic importance for the quality of wood and its use in the manufacture of home furniture, (Kumar, A. et al., 2010) .

Tarut Bay is considered one of the ideal locations for the growth of mangrove forests because of the ingredients that support its growth. Mangrove forests are subject to a number of natural factors in order to grow ideally, some of these are climatic factors, such as the availability of appropriate temperature and humidity, Others are marine factors, such as the availability of sufficient salinity and dissolved oxygen, (Prity L. Biswas and Shekhar R. Biswas, 2019). Finally, geomorphological factors, represented in protected sites by virtue of their morphology, such as bays, tidal channels and estuaries, where these sites provide protection for seedlings from destruction as a result of the erosion due to sea currents (McKee KL 1996).

Recently, human have become one of the geomorphological factors affecting the formation of the earth's landforms, and despite its impact is not comparable to tectonic factors or external factors, it is not possible to deny its role in the formation of the terrain, and his influence in shaping the earth's landforms is increasing in front of the increasing demand to take advantage of the potential of geographical locations to meet his needs. (J.Szabó,2010)

Many studies have dealt with the study of the plant communities of mangroves in terms of their growth conditions, their importance and the threats they are exposed to in their places of stability. Among these studies is (Prity L. Biswas and Shekhar R. Biswas's study 2019) focused on studying the importance of mangroves at the ecological and geomorphological levels. (Almahasheer's study,2013) also focused on the deterioration of the mangrove forests in Tarut Bay, and indicated that the state of the forests fluctuated according to the different periods of threats they faced.

The study of Abhijit Mitra (2002) presented the forms of threats facing the mangrove forests in the Indian Ocean, where most of the threats were related to the nature of human activity such as over fishing and the associated shrimp farms as well as the activity of the timber industry. Many studies presented the forms of threats to mangroves around the world, and the deterioration of forests was linked to human activity, as stated in the study of Mahmoud Sarhan and Radi Tawfiq in 2018, as well as a study by Adel Mutamad in 2020, which confirmed the decline of mangrove forests in the southwestern coast of the Kingdom of Saudi Arabia during the period from 1990 -2019: From 40 square kilometers to 19 square kilometres.

Since the eastern region of Kingdom of Saudi Arabia, especially the cities of Dammam, Khobar and Qatif, witnessed in the past three decades a boom urban development level, in order to meet the increasing demand for housing and investment in the

coastal area. A number of companies and people have searched for new land to meet their needs. King Abdulaziz Port has been draining large areas in order to expand and lengthen the port berths and access to the deep water to facilitate the entry and anchorage of ships to the port. These Anthropogenic Induced geomorphological changes may negatively affect mangrove communities. In condition of this, the problem of the study can be formulated in a main question that is, what is The effects of Anthropogenic Induced geomorphological changes on mangrove forests in Tarut Bay?

Materials And Methods

The study materials and methods include: description of the study area, data collection and methods used in this study that are discussed in detail as follows:

1. Description of the study area

1.1. Location:

The study area is located On the eastern side of Saudi Arabia . Its lies between longitude 49^{o} 59' 16"and 50^{o} 13' 12" E and latitude 26^{o} 25' 15" and 26^{o} 45' N, Tarut Bay is located between Ras Tanura in the north and the pier of King Abdulaziz Port. (Fig.1).

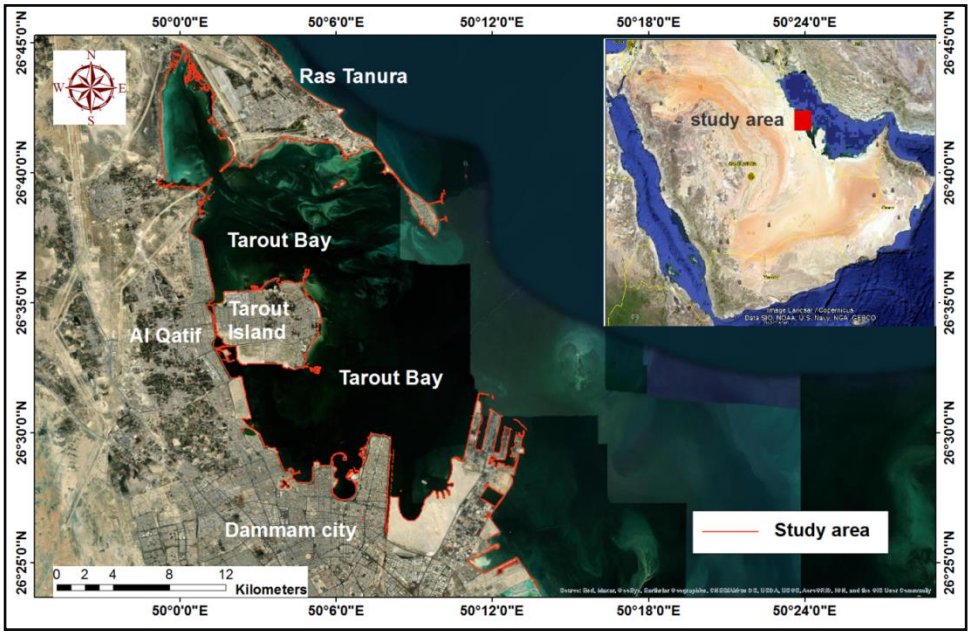

Figure 1. Location of the study area.

1.2. Morphology

The bay of Tarut takes a shape closer to a rectangle, and is connected to it from the northwest by a water extension that takes the shape of a triangle. It has an area of 375.43 km², and Tarut Island occupies an area of 32.35 km^2, As the largest Saudi island on the eastern coast, it was separated from the western coast of the bay by a narrow channel, and is spatially connected to the mainland by two bridges, one at the southwest end and the other in the northwest of the island, It has a coastline of 31.8 km, which is straightened by human interventions. The maximum length of the bay is 40 km, while the maximum width is 15.7 km, and the length of its coast is 173.6 km, which is characterized by straightness in many places. Thus, Tarut Bay is one of the protected bays according to its morphology, where Ras Tanura

extends towards the southeast, while the pier of King Abdulaziz Port extends towards the northeast to create a water surface protected from sea currents and strong waves, even in times of severe storms.

1.3. Marine Characteristics

The characteristics of the marine waters of Tarut bay are an integral part of the characteristics of Arabian Bay, waters as its waters are characterized by salinity, reaching an average of 50 g / liter, and the percentage of dissolved oxygen ranges between 4.8-6.5 mg / liter. The water depth does not exceed 13 meters, the average depth is 3 meters. Shallow areas of less than 2 meters occupy vast areas that are concentrated near From his coasts and the coasts of his island. In Tarut bay, the water moves by the sea currents that move anti-clockwise, (Kampf and Sadrinasab, 2005, Brown, 1986) and the tide in it reaches two meters thanks to its narrowness, tidal speed less than 0.3 m/s; and maximum range in tidal water level is from 0.5 – 2.5 meters (Rakha et al., 2007).the maximum significant wave height is less than 1.5 meters; maximum mean wave period of 3-5 seconds;(Ronald A. Loughland et al.,2012)

1.4. Climate:

The annual average temperature ranged from 26.6-28 °C during monitoring period at King Fahd Station, while Dhahran recorded 25.8-28 °C, while the maximum temperature was recorded between 33.4-35.6 °C in King Fahd Station and 31.6-

33.5 °C in Dhahran. As for the minimum temperatures, they ranged between 20.1-21.1 °C in King Fahd Station and 20.5-22.8 °C in Dhahran Station. The number of rainy days ranged between 18-34 days in King Fahd Station and 18-57 days in Dhahran Station.

The characteristics of the study area indicate that it is a suitable environment for mangrove growth in terms of the morphology of the Gulf, which creates a protected environment for the growth of mangrove seedlings and protects them from removal by sea currents or waves. Besides the astronomical location and the associated climatic characteristics are somewhat favorable to mangrove growth. The Gulf also has marine characteristics that are similarly favorable for mangrove growth. Thus, It can be said that Tarut Bay from a morphological and marine point of view, is characterized by the availability of suitable conditions for mangrove growth.

2. Data Collection:

2.1. Remote sensing data:

Landsat 8 image (Path 164. Row 042) and Landsat 5 image (Path 164. Row 042) a Level 1 Terrain Correction processing (geometric and terrain correction) available in **(http://earthexplorer.usgs.gov/)** as shown in Table 1.

Table1. Attributes of Landsat data of the study area

Satellite	Sensor	Identifier
Landsat-8	Operational Land Imager / OLI/TIRS C2L1 Thermal Infrared Sensor	LC08_L2SP_164041_20210125_20210305_02_T1
Landsat-5	Operational Land Imager / TM/C2L1	LT05_L2SP_164042_19860821_20200917_02_T1

2.2. Topographical maps:

The topographical map was based on a scale of 1: 1000000, plate number 6, and plate number NG39-NW l scale 1: 500000, produced by the Ministry of Petroleum and Mineral Resources - Air Survey Administration to determine the study area and to identify human settlements scattered around the study area. Available at http://www.athagafy.com/maps/Fig-06.jpg.

2.3. Climatic data

The climatic data available on the link http://www.tutiempo.net/en/Climate/ was relied on for the two

stations of King Fahd in Dammam and Dhahran station. Note that the data available for King Fahd station are related to the period from 2006 to 2020, while the data available for the Dhahran station are related to the period from 1947 to 2020.

3. Methods

3.1. Digital images pre-processing Image preprocessing

According to fig.2, which includes images calibration to reflectance and atmospheric correction. Digital image post - processing was applied to extract the statistical features characteristics and information. The post - processing procedures involved data sub-setting, image enhancement of (Red. green and blue) (RGB) composite and false colour display,and image classification using Vis and change detection technique. All the aforementioned techniques were done for the Landsat images to characterize the study area, using specific model in ENVI version 5.2 and Arc G1S version 10.5 software.

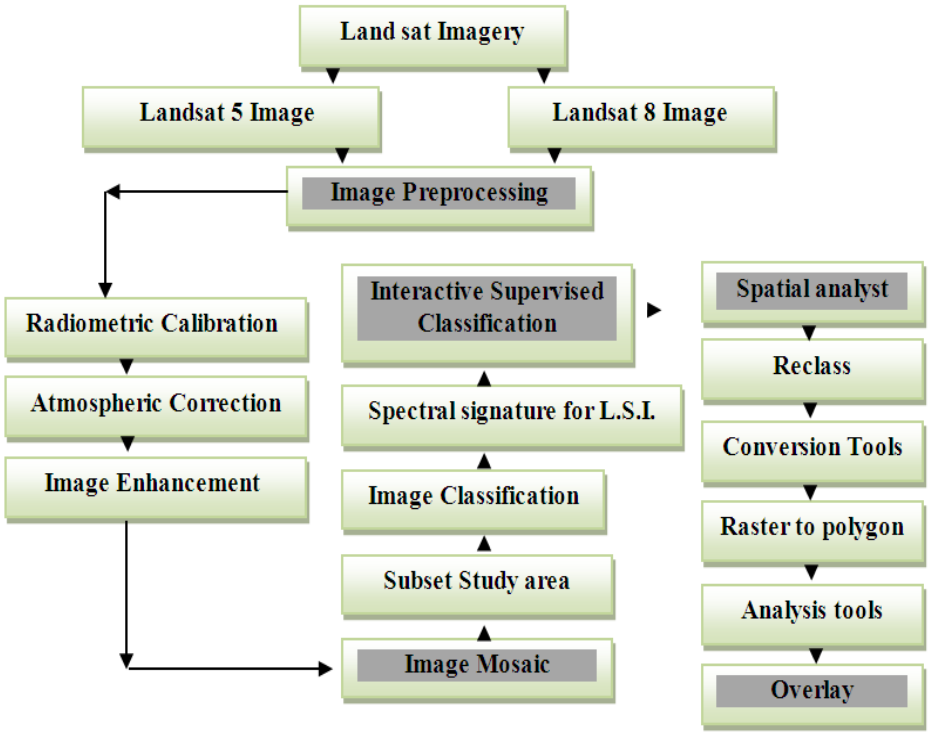

Figure 2. Flow chart of methods used in the study area.

3.2. Satellite Imagery Analytics

The supervised image classification relied on using GIS to extract the geomorphological changes along the coasts of Tarut Bay and Tarut Island during the period between 1986-2021, as well as the changes in the mangrove forests during the same period.

3.3. Geodatabase Analytics

After conducting the analysis on the satellite image and extracting the feature class, a number of tools were used, such as Data Management Tools to perform conversions of file types from areal format to linear format, as well as using a list of analysis tools/overlay/Erase and Identity to demarcate the areas of change in the land and mangrove forests during the monitoring period.

Results And Discussion

- **Anthropogenic Geomorphological changes in both the Bay and Tarut Island**

Table (2),fig3-4 and 6 indicates a decrease in the length of the coasts of both the Bay and Tarut Island during the period from 1986-2021, where the length of the Bay was recorded at 189.6 km in 1986 and decreased by 9 km to reach 180.6 km in 2021, due to the drying processes of the shallow arms that overlap with the land. It is also repeated for the coast of Tarut Island, where it witnessed a decrease in the length of its coasts from 73.9 km in 1986 to 42.7 km in 2021, this decrease is significant due to the changes that occurred along the coast of Tarut Bay, which displaced vast areas of shallow water that overlapped with the land of the island, especially the northern parts, which formed a network of tidal channels as a geomorphological form protected from sea currents and waves,

on whose sides were mangroves.

Table 2.Some morphometric changes in the Bay and Tarut Island

coast length/ Km				area/ Km^2			
Tarut bay	Tarut Island	Tarut bay	Tarut Island	Tarut bay	Tarut Island	Tarut bay	Tarut Island
1986		2021		1986		2021	
189.6	73.9	180.6	42.7	392.6	21.4	345.8	32.5

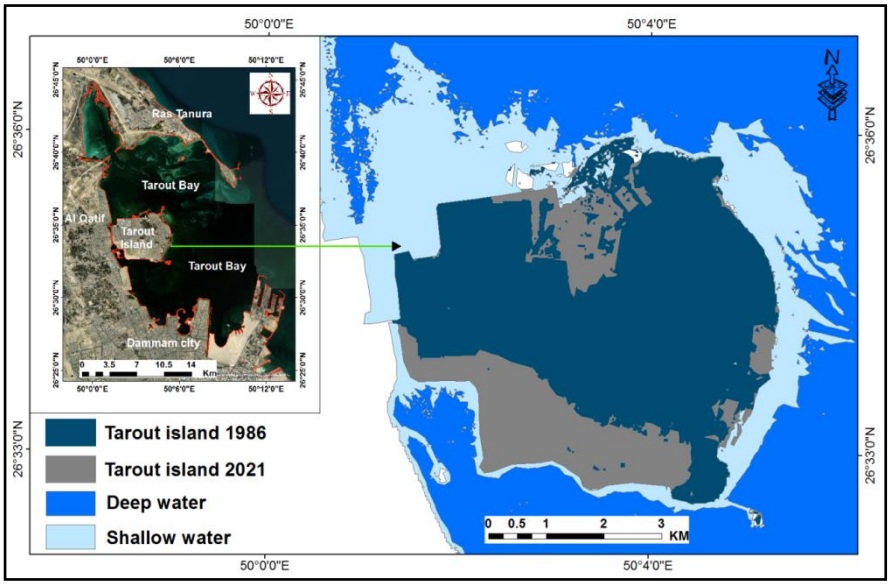

Figure 3 Change detection in Tarut Island during 1986-2021

The areas of Tarut Bay and Tarut Island witnessed huge changes as a result of the drying processes of the shallow areas close to the shore line, resulting in a clear decrease in the bay area from 392.6 km 2 in 1986 to 345.8 km 2 in 2021. In contrast, the area of Tarut Island increased from 21.4 km 2 to 32.5 km2

during the same period. This comparison indicates significant changes in the study area, which may affect its plant life, especially the mangrove forests. Figures (3,4,5) indicate that there are areas of shallow water adjacent to the land with an area of 61 km^2, which are areas that stimulate investment, as they have the same characteristics as the areas that has been dried.

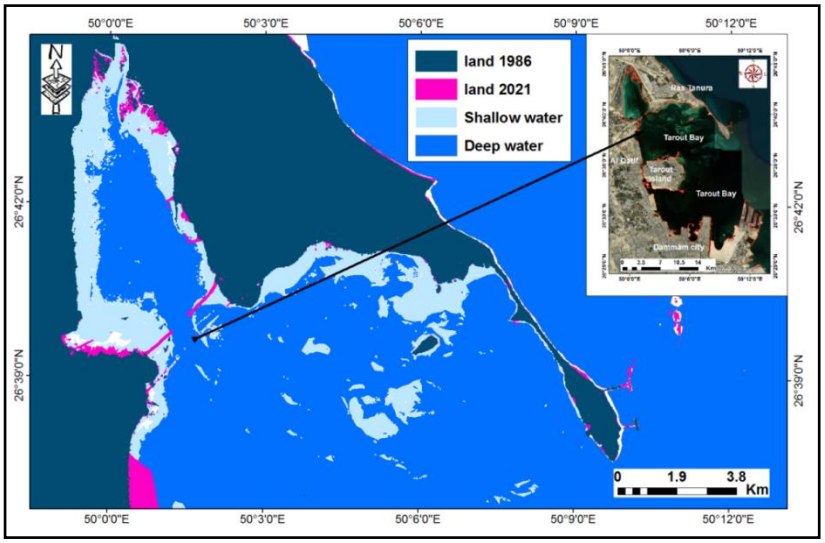

Figure 4 change detection in northern Tarut bay during 1986-2021

Figure 5 Mangrove swamps drained north of Tarut Island

Also, Tarut Island witnessed a transformation of its shape,

as the geomorphological changes led to the transformation of the island from an irregular shape in 1986 to a circular island in 2021, where the ratio of its average length to an average width was approximately 1:1. These changes also shifted some of its coasts from an arc or irregular shape to coasts close to straight. Fig.3

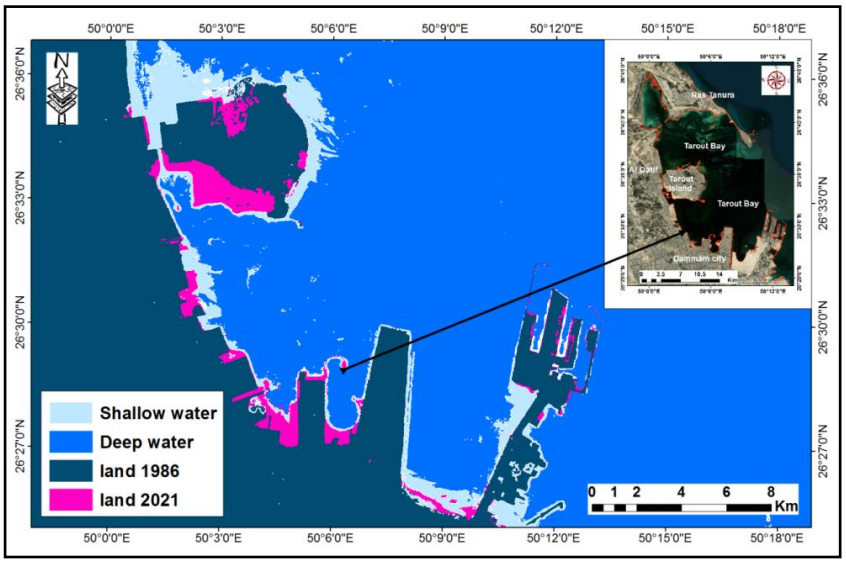

Figure 6 Change detection in Southwest Tarut Bay during 1986-2021

From the above, it is clear that there are spatial differences in the size of the changes caused by human as a geomorphological factor, because these changes increased in the southern and southwestern coasts of the Bay, as well as in the northern and southern coasts of Tarut Island (table 3). The northern parts of the Bay are characterized by low urban density, and construction is limited to Aramco, which takes Ras Tanura as its location, as well as the city of Safavi on the northwestern coast of the Bay, while on the western and southwestern coasts of

the Bay we find large urban complexes, which are from north to south: Qatif and its extension in Tarut Island, Saihat city, Dammam city and parts of the city of Al-Khobar. This approach reflects the existence of a direct relationship between the density of urban settlements and the changes that occurred on the coasts of both the Bay and Tarut Island.

- **Changes in the mangrove forests**

The year 1990 is considered the year of the setback for marine ecosystems in the Arabian Gulf (Hanan A. et al 2013), where ecological diversity witnessed its lowest levels after the Kuwait war, due to the large volume of pollutants in the waters of the Gulf, as the mangrove in Tarut bay decreased by half, and the Gulf Cooperation Council countries made a great effort to revive ecological diversity again. These efforts resulted in an abundance of mangrove forests, whose areas had doubled in Tarut Bay, but the forests faced by urban utilization hazards of the coastal areas, and their deterioration occurred again.

Table 3. Changes in the mangrove forests on the coasts of Tarut Island and Bay

Area	sites	Site Description	Mangrove area/km^2		Degradation rate %	Total area of change/km^2
			1986	2021		
Tarut Island	1	The northern coast of Tarut Island	2.27	0.63	-72.2	2.43
	2	East coast of Tarut Island	0.61	0.24	-60.7	1.12
	3	The southern coast of Tarut Island	2.23	0	-100	7.01
Tarut bay	4	The northeastern coast of Tarut Bay	1.75	1.79	+2.3	10.5
	5	The west coast of Tarut Bay	4.55	1.84	-59.6	12.07
	6	The southwest coast of Tarut Bay	1.7	0	-100	23.63

According to table 3, the mangrove forests were subjected to a noticeable deterioration in the study area, estimated at 65.8% on average. The area of the mangrove forests in 1986 was about 13.11 km^2 which decreased to 4.5 km^2 in 2021. The degradation reached 77.6% on Tarut Island, while the rate of mangrove forest degradation on the coasts of Tarut Bay was 53.9%.

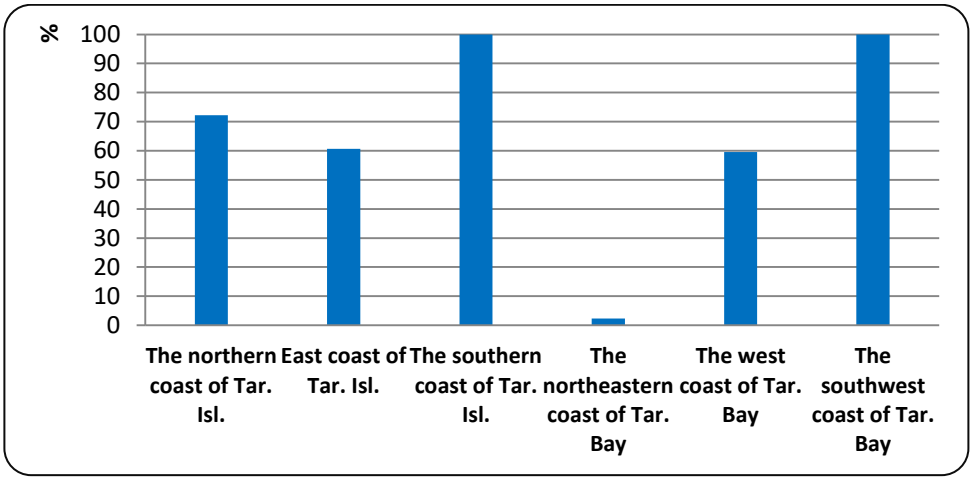

Figure 7 The rate of mangrove deterioration in different locations in the study area

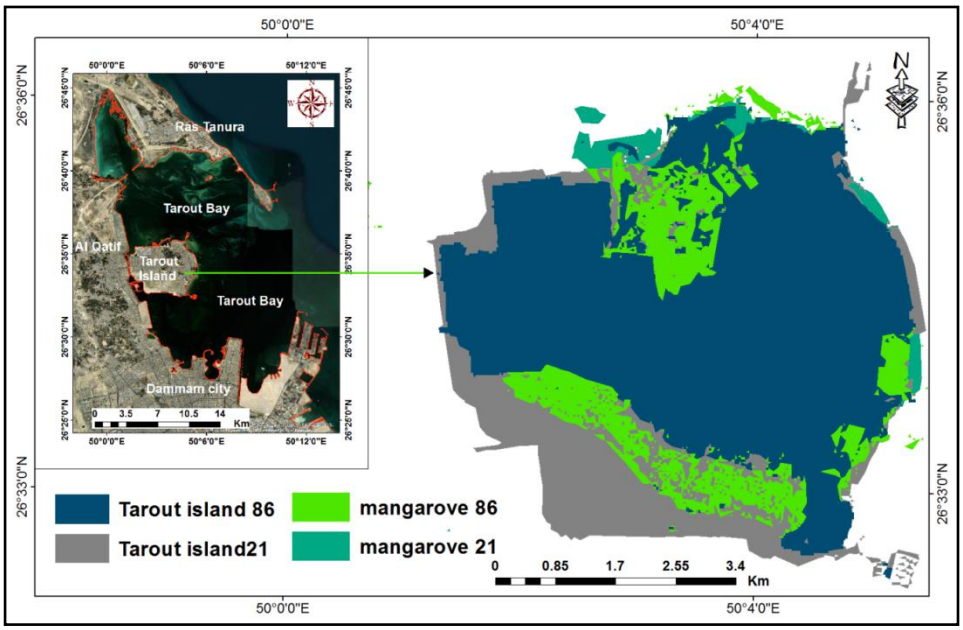

Figure 8 The effect of geomorphological changes on the mangrove forests of Tarut Island

As for the mangrove sites, there are places that have undergone complete deterioration, as is the case in the southern coast of Tarut Island and the southwestern coast of Tarut Bay, Fig9-10. These areas were carved out as a result of draining swamps in order to search for new lands for King Abdulaziz Port on the one hand, and real estate investments on the other.

The north and northeastern coast of Tarut Bay experienced mangrove forest improvement, with the rate of improvement estimated at 2.3%. This may be due to the small areas exposed to drying and backfilling on the one hand, and on the other hand, the active cultivation operations adopted by Aramco in the northern and northeastern part of Tarut Bay, where Ras Tanura meets the rest of the Kingdom of Saudi Arabia.

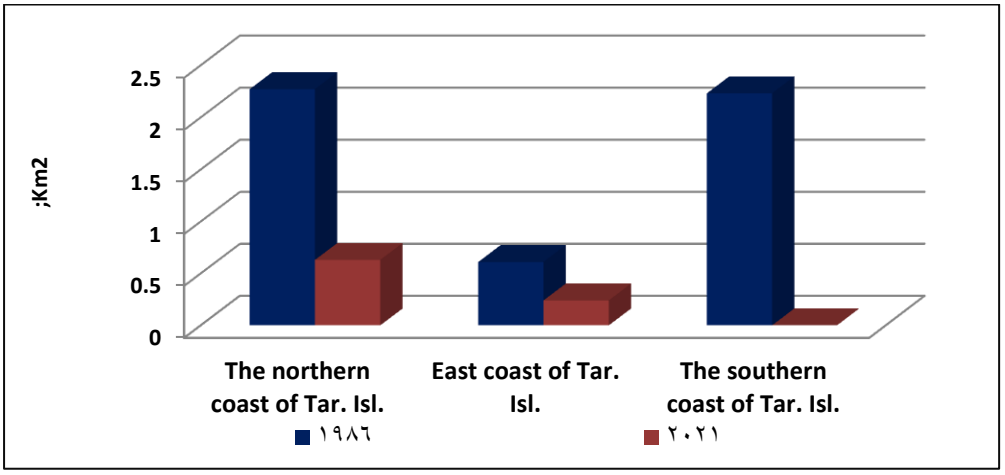

Figure 9 The evolution of the mangrove area on the coasts of Tarut Island during the study period.

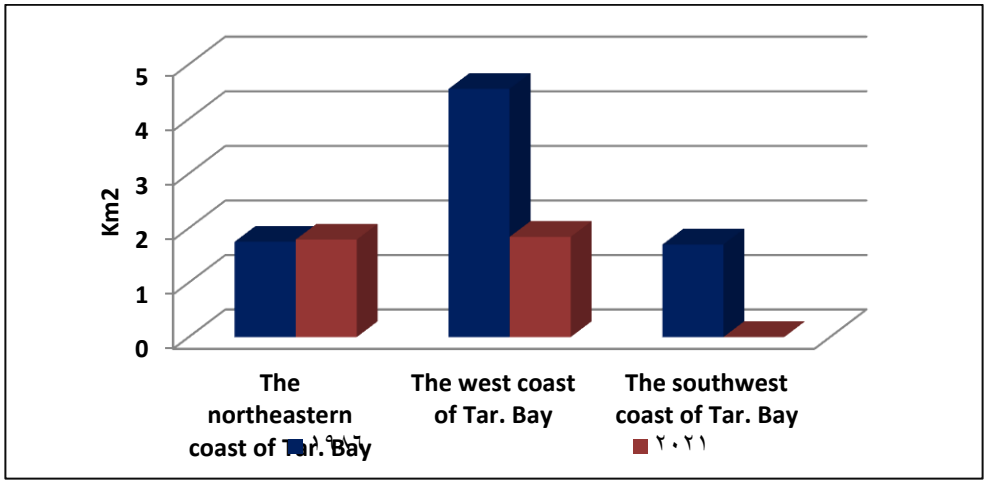

Figure 10 The evolution of the mangrove area on the coasts of Tarut Bay during the study period.

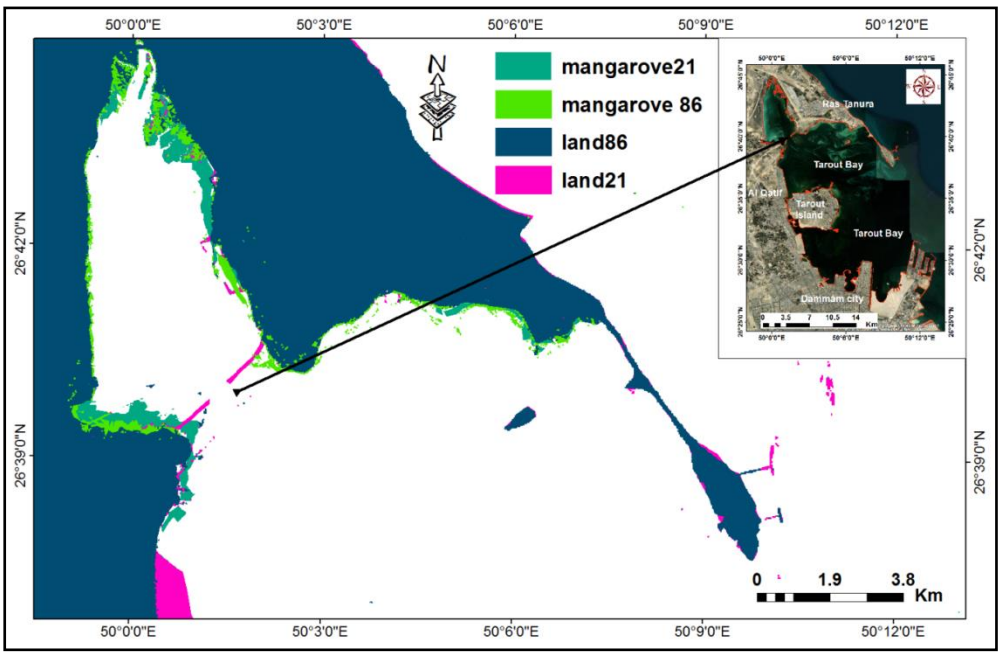

Figure 11 The effect of anthropogenic geomorphological changes on the mangrove forests of northern Tarut bay.

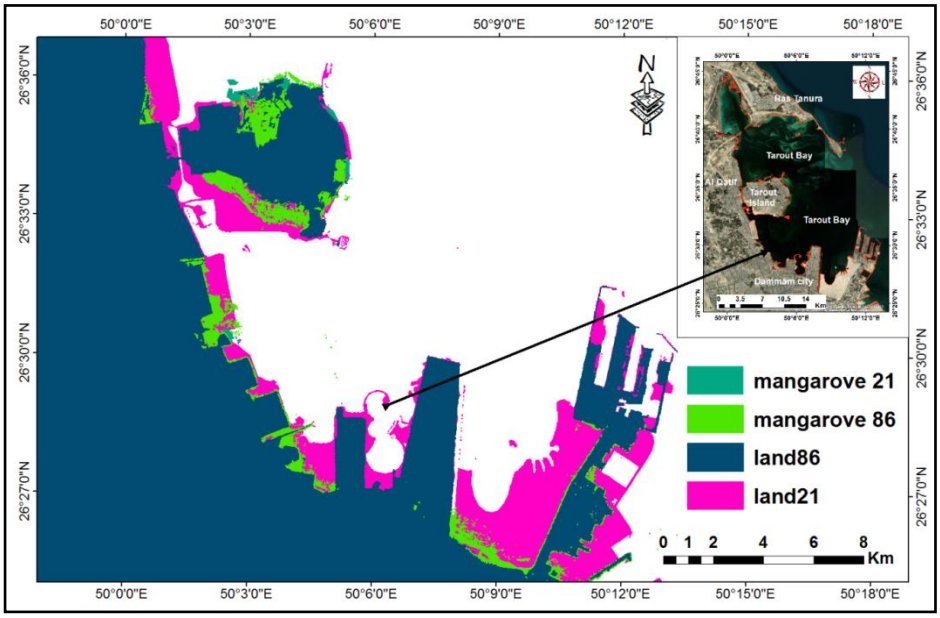

Figure 12 The effect of anthropogenic geomorphological changes on the mangrove forests of Southwest Tarut bay.

Figure 13 Construction of road networks over mangrove swamps after draining them north of Tarut Island

Figure 14 Construction of road networks over mangrove swamps after draining them east of Tarut Island

Conclusions And Recommendations

The exploitation of the coastal area for the purpose of development does not conflict with the preservation of mangrove forests, but the development of coastal areas needs to understand their nature as an ecosystem with inputs and outputs and contains highly complex food chains. An ingredient for development that adds value to the region, also if the purpose of human activities is to develop the regions, this does not mean that development in a particular sector is done without considering the losses incurred by the neighboring environments, so the development process must be comprehensive, linked to the nature of the local environment, sustainable in nature for this, For its role first: in the ecological economy, where the mangrove forests contribute to the enrichment of marine life whose impact is reflected in the region's richness in Fisheries. Second: Being part of the marine ecosystem, any deterioration that affects it will have an impact on the larger ecosystem.

According to the current study, which reveals the impact of Anthropogenic geomorphological changes in Tarut Bay on mangrove communities, the study concluded that mangroves are subject to deterioration, as their area decreased from 13.11 km2 to 4.5 km2 as a result of over-cutting and draining its swamps in order to search for new lands, fig.8,11-14 that can be used in urban and economic development. Although the study was limited to revealing the causes of mangrove deterioration related to geomorphological changes, field observations revealed other

reasons for mangrove deterioration, such as the pollution of the coastal environment with solid waste and the spread of green algae and other reasons that need further study. Therefore, the study proposes a number of recommendations in the light of its discussions and results

- Tarut Bay is unique in that it is of great environmental value, as the United Nations Environment Program classifies it in category V and VI, and there are many geomorphological sites suitable for mangrove propagation, which are shown in Figure (3,4,5), where the shallow lands adjacent to the coasts of the island and the bay can be used to establish large-scale mangrove farms These farms simulate the ecological mangrove park, which is located on the northwestern and northeastern coast of Tarut Bay, which was designed by Aramco, as a kind of social responsibility towards the local community in which it operates. This experience can be generalized with companies operating in the region to add new areas of mangroves to enrich life environment in the region. Figure (15A) indicates one of the sites with shallow waters, which shows traces of tidal channels dug by tidal currents, which are unexploited areas for environmental development. On the other hand, on the northeastern coast of the Bay (Figure15 B), this geomorphological feature was exploited to establish the largest mangrove park in Tarut Bay.

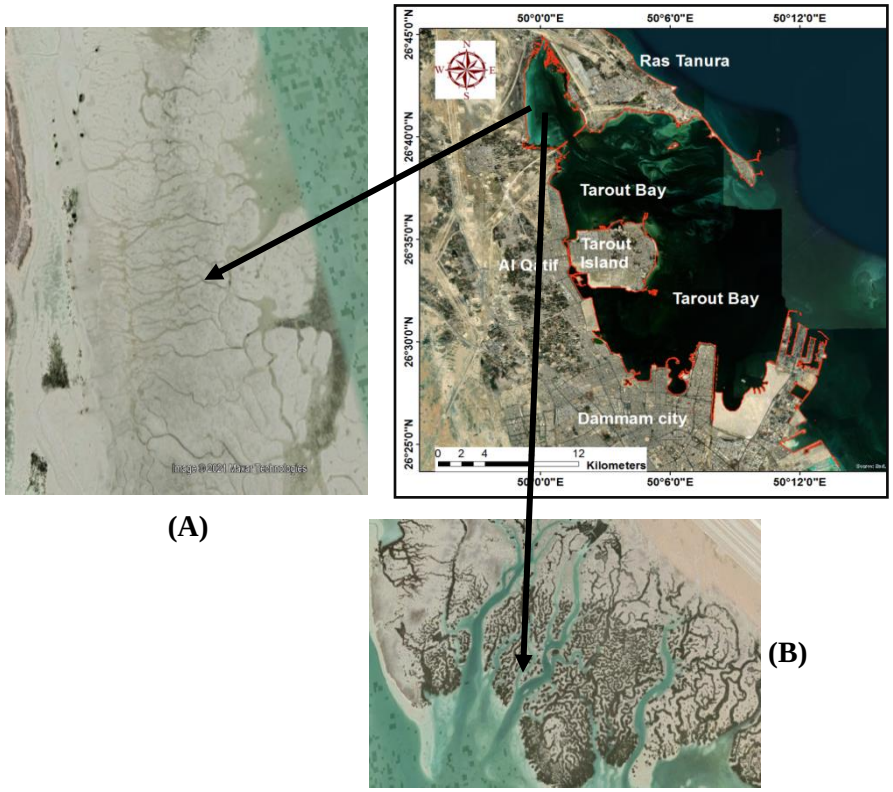

Fig.(15) A model for two sites, the first being exploited for mangrove cultivation, and the other unexploited

- Expansion of the cultivation of mangroves in the northern part of Tarut Bay, as it is less exposed to human pressure in the demand for housing, as well as the availability of a large network of tidal currents that can be exploited in the cultivation of mangroves on its sides. This is to simulate the farming project in the northeastern part of the Bay.

- Work to purify the tidal canal north of Tarut Island to allow water to reach its lower extremities in order to preserve what remains of the mangroves.

- Work to establish an environmental monitoring network aimed at monitoring the public health of the mangrove environment and the changes that occur to it, as well as monitoring any encroachments on the coastal environment and conducting periodic water quality procedures to know the hydrographic characteristics of the Gulf waters and stopping any sources that change their characteristics, which is reflected positively on the biological diversity of mangrove forests

- Satellite images reveal that the mangrove forests in the study area are subject to fluctuations in their area that correspond to the size of the threats or the protection of the marine environment, which reflects the ability of the mangrove forests to restore the ecological balance within their ecosystem provided the threats stop. This must be emphasized to stop any existing threats to give the mangrove forests the opportunity to rehabilitate themselves, especially as they colonize geomorphological sites that support their growth, as well as their colonization of an environment suitable for their growth.

- Since mangrove forests fall within many scientific disciplines such as plant sciences, soils, geomorphology and climate, scientific networking and bridging links between specialized research centers must be conducted to search for new areas in which mangroves can be cultivated, in addition to spreading and increasing environmental awareness of the local population about the economic importance of mangrove forests. Methods of conservation and detection of the environmental cost caused by the degradation of mangrove forests. As well as monitoring climate changes and their repercussions on mangrove forests

- Stopping the urban sprawl according to the laws of protecting the coastal environment and plant communities because of their great value in the environmental diversity in the region.

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