Management of environmental degradation of Jeddah coastal zone, Saudi Arabia, using remote sensing and geographic information systems

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Abstract: This study is focused on the environmental degradation of Jeddah Governorate coast. The importance of study area is related to the effect of human factors and their roles in destruction and production of environmental problems in the coastal zone. The study is focused on the problem of land use planning and sustainable touristic development to maintain the marine ecosystem and its natural resources. Also this work is concerned with developing and suggesting strategy to protect the natural resources of the marine environment in relation to the future expansion of population and developmental projects. The study is elaborated using the recent techniques in remote sensing and geographic information system (GIS). TM and ETM landsat images acquired in 1986 and 2003 of the study area were used. Manuscripts and topographic maps of scale of 1: 4000,000 for Jeddah governorate, in addition to data and information obtain from different institutions were also employed. ERDAS Imagine 8.5 software was used for image processing (i.e. Export function, layers tacking, geometric correction.etc.). Results showed that the negative changes in the coast exhibit 84 km as it record a length of 111 km compared to195 km in 2003. This change leads to the depletion of natural environmental marine resources and erosion of the recreational areas at the coast line. Absence of a proper sustainable planning strategy and management for coastal natural resources, cause improper human pressures and disorders in the natural balance of the marine environment. The study has suggested a strategy for sustainable touristic development, represented in building systems and developing laws with continuous work to revise procedures and update the standard limits.
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Keywords: Management; environmental degradation; Jeddah coastal zone; Saudi Arabia

1. Introduction:

Jeddah governorate is considered one of the strategic vital cites in Saudi Arabia because it is located near to the holly Mecca, in addition to its geographic location along the red sea coast and being one of the most important commercial cities in Saudi Arabia (Abu Ouf and EI-Shater, 1991). Jeddah governorate activities and its urban growth are related to their potentials and their growth properties, resulted from its economic and geographic relation with the sea. Jeddah governorate plays an important role in the process of national development as its marine port received about 80 % of the imported resources during the seventies (Al-Sharideh, 199). It also plays a vital role in the transportation of pilgrims and Umrah performers and visitors to and from the holly cities of Mecca and Medina (Al-Ghamdi et. al, 2003). The urban growth is affected by the extension of the sea; hence, its direction is parallel to the coast, usually from south to north. The direction of arrival of the sea breeze shares mainly in directing the land use and interfaces of drawings and buildings (Aleem, A.A. 1989).

Variety of recreational activities along the coast of the Jeddah governorate is one of the important factors for touristic attraction, which qualify it towards the comprehensive concept of touristic sustainable development (Ady et. al., 1995). However, investment projects and misuse of the land lead to the decrease of the recreational areas along the coast line and depletion of marine natural resources (Timothy, D., 1998). Thus, there is an urgent need to conduct research activities to highlight the environmental problems of Jeddah governorate to share in solving the problem on environmental degradation and conserving the marine environment of the governorate (Ahmed and Sultan, 1993).

Study problem & Questions:

The problem of the study is defined by the attempts to answer the following main question;

What are the reality and the possibilities of sustainable tourism development on the sea coast of Jeddah?

This main question will be answered through the following sub questions:

1. What are the negative effects of the indiscriminate tourism development in Jeddah coastal zone?
2. What is the current situation of the coastal environment of Jeddah?

3. What is the change occurred in Jeddah coastal region during the period 1986 – 2003?
4. What are the possibilities of tourism development on the coastal area of Jeddah?

Importance of the study:

The importance and rational of the study can be highlighted through the following axes:

1. Recognizing the current situation of Jeddah governorate coast through modern applications of remote, sensing, geographic information systems and field surveys technologies.
2. Increase of world and Arab interest in touristic sustainable development and planning.
3. Survey and identify the most important problems, which the coastal environment of Jeddah is suffering form.
4. The importance of following a development strategy for sustainable tourism development, preserving the natural resources of the marine environment.

Objectives of the study: the objectives of this study are as follow:

1. Identify the impact of human factors and their role in the destruction and creation of environmental problems of Jeddah marine coast.
2. Suggestions that help to accelerate development and sustainable tourism development to reduce the depletion of natural resources of the marine environment of the study area.
3. Provide as much data as possible for the study area, which may contribute to the sustainable tourism development of strategic plans.
4. Highlight the role of modern technology application areas in sustainable development studies.

2. Methodology:

Digital data driven from landsat satellite images of study area were used, in addition to topographic maps; field surveys and ancillary information were collected (Moore and AI-Rehaili 1989). ERDAS Imagine 8.5 and Arc GIS 9.2 software were used for digital data processing and producing the final layouts.

The study plan:

The study is based on four main axes, namely:

Ø The first axis: general theoretical Axis and deals with the concept of sustainable tourism development and its importance and elements.

Ø The second axis: technical Axis which deals with processing and analyzing satellite images to study and monitor the change in the coastal line during the period 1986 to 2003.

Ø The third axis: deals with defining the human pressures and investment projects and their impact on the marine environment.

Ø The fourth axis: aiming to provide solutions and suggestions which may help in the formulation of a strategy capable of maintaining the balance between sustainable tourism development and marine environment of Jeddah.

Borders of the study area:

Ø **Spatial borders**: The study was done for the northern coast of Jeddah governorate at the areas of (Sharm Abhor, city of lakes, Salman Bay and Dorat Al Arous) (fig.1).

Ø **Temporal borders**: It includes the period between (1986 – 2003), they are the newest and the oldest available LANDSAT satellite imaging dates. Also 2005 which refer to the available IKONOS imaging date.

Data processing:

The digital satellite images have been elaborated using ERDAS Imagine V. 8.5 software, while Arc GIS V.9.2 was utilized for developing digital database of study area (Burrough, 1986 and Tomlin, 1990).

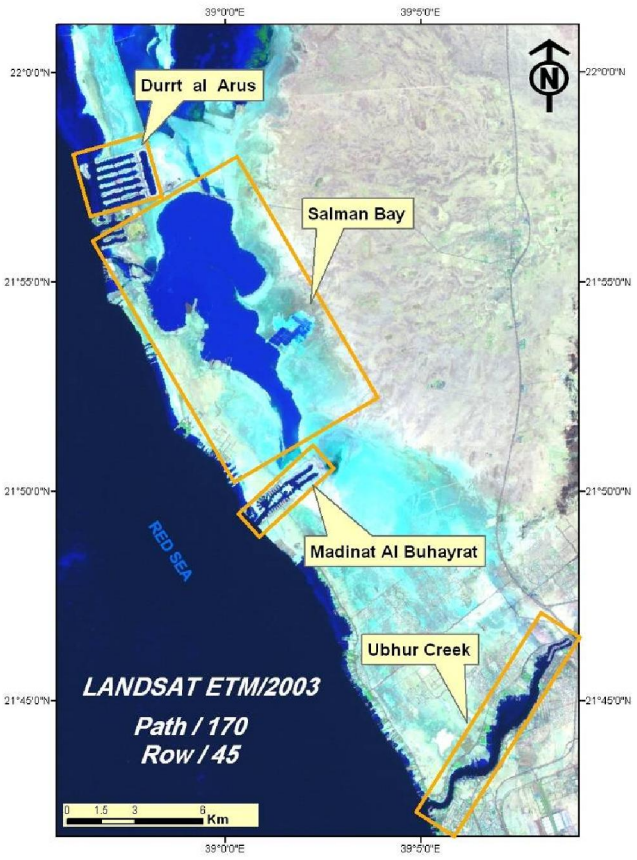


Fig.1. Boundaries of Study area, displayed on Satellite image.

The following steps were taken by the author on the current study;

1. Raw LANDSAT TM and ETM satellite images (Row 45/Path 170) were collected from king Abdul Aziz city for science and Technology (Riyadh city) covering the study area in the period (1986 and 2003) by the American satellite (LANDSAT TM,ETM).
2. The raw satellite data were processed using ERDAS Imagine V.8.5 software via Import / Export function and LAYERSTACK Conditional model (Hussein, I., 1994).
3. Geometric Correction has been elaborated by choosing the projection Type UTM WGS 84 for the zone 38 in order to obtain high accuracy in matching adjacent scenes. More than 30 Ground Control Points were monitored by using GPS in different location within the study on the coast region, as geographical reference for geometric correction (fig.2).
4. The study area was identified on the satellite image using the tool (Area Of Interest-AOI) to subset the study area (Gad, A at.al., 2011).
5. Detecting the changes and defining the areas susceptible to deterioration, on the coastal line during the period 1987 to 2002, was monitored.

Upon finalizing the processing and data analyses, the results were converted (Raster to Vector) for the purpose of are computations and maps reproduction (Nguyen Quec Dinh, 2001 and Pavasovic, 1993).

3. Results of theoretical and practical studies

Study area (Geographical location)

Jeddah city is located in west of Saudi Arabia on the eastern cost of the Red sea (Fig. 5) between latitudes 20º 50´ 57´´ and 22 º 18´ 35´´ (E) and longitudes 38 55´ 42´´ and 39 º 25´ 12´´ (N). It belongs administratively to holly Mecca region.

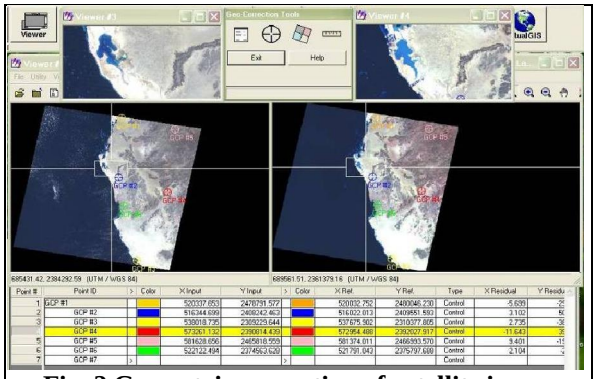


Fig. 2 Geometric correction of satellite image

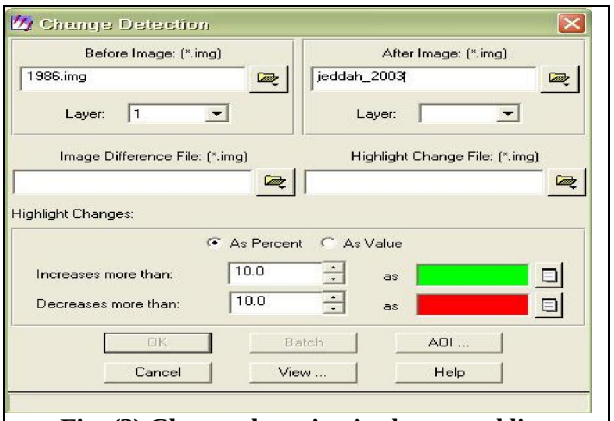


Fig. (3) Change detection in the coastal line

Fig. (4) Converting results to digital data (Raster to Vector)

The geographic location of Jeddah has its impact on the climate; relative humidity is high along the year, especially in summer seasons, where monsoon depressions take place. The temperature is high (+/- 50 º in the middle of year, where the sun is perpendicular on the land surface at the western region (Behairy et. al. 1985).

Negative impacts of random tourism development

In spite of the economic return, the random unplanned investment and tourism projects caused negative impacts. Such impact may disturb the diversity of the marine ecology, constituting marine herbs, algae, fish eggs, robins and small fish shelters. The main base of actual development resides in the mixture of polices, authorities and techniques that keep the balance of environmental elements. Figure (6) shows the change detection, derived from satellite images, occurred on the coastal zone as a result of marine degradation and filling, especially in the areas of Doret El-Arous and Al-Bohyrat city.

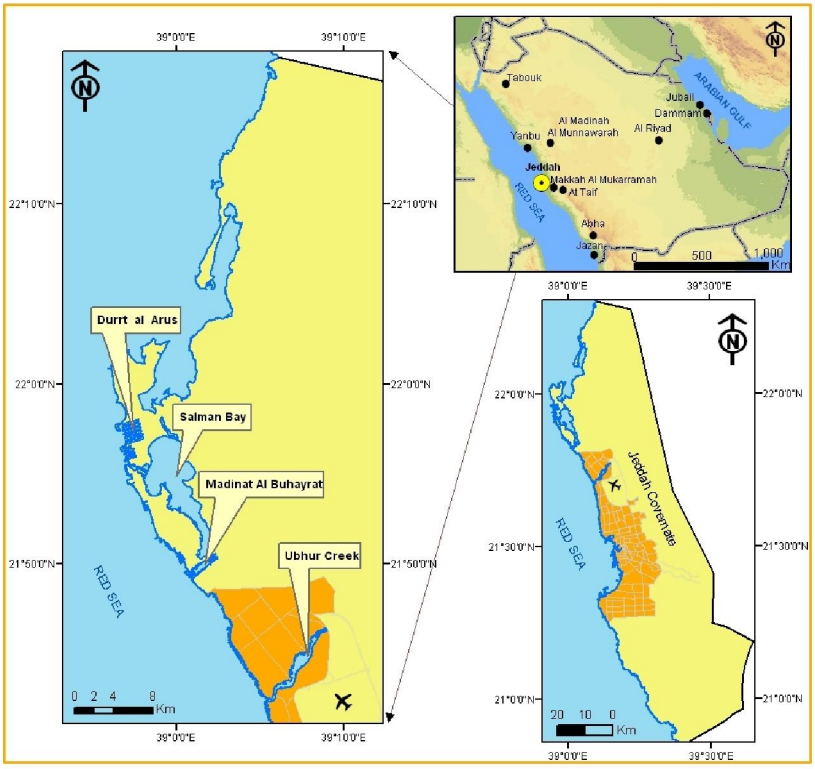


Fig. (5) Geographic location of study area.

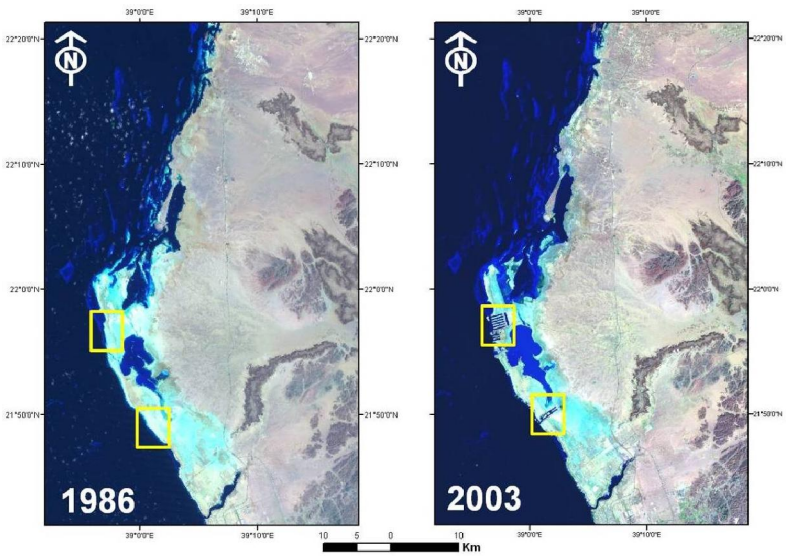


Fig. (6) LANDSAT images of Jeddah coastal zone, 1986 and 2003.

Critical situation of coastal environment

The study has revealed the changes occurred on the coast during the period 1986 to 2003 regarding the coastal length and areas of erosion and filling. Also, areas of coral reefs and native plants eliminated, as a result of haphazard tourism projects, were detected.

Coast of Dorat El-Arous and Soliman bay:

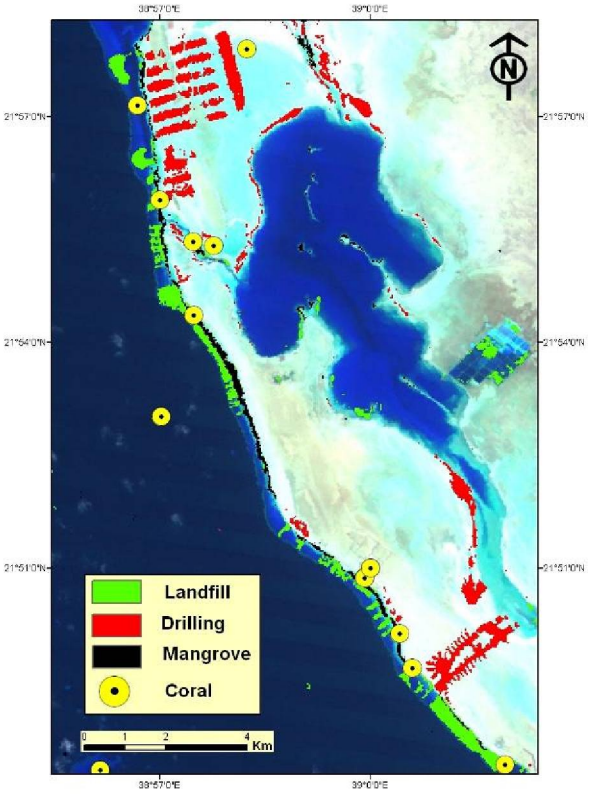
Figure (7) shows that the area was characterized in 1986 by the extension of coral reefs,

diverse marine ecology, and shora trees. Different activities are detected as marine filling (green), erosion processes (Red) and tourism sustainable projects (i.e. hotels, places, homes and resort areas). The area was exposed to extensive ecological deterioration resulted in destruction of coral reefs (Yellow) and elimination of Shora plants (Black) along the coast.

Fig. (7): Erosion and filling processes in Dorat El-Arous and Salman Bay

2- Al-Bohyrat City coast: (fig.8)

Figure (8) shows the exposure of the coast to extensive erosion which leads to destruction and sweeping of some coastal features (i.e. sapkhas). Moreover, direct and indirect effects on coral reef areas were induced by dust storm and degradation of natural vegetation, thus disturbance of marine environment bio-diversity.



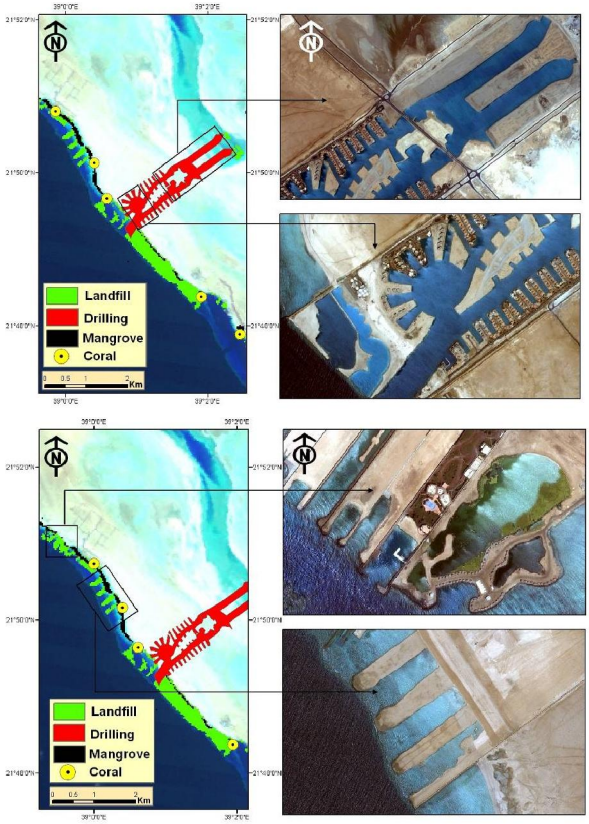


Fig. (8): Erosion and filling processes on Al-Bohyrat coa

3 – Sharm Abhar coast:

The erosion and filling processes have lead to severe environmental degradation of the marine environment of sharm abhar region. Deterioration and destruction of the coral reefs resulted in disturbing the environmental bio-diversity of plants and animals. (Figs.,9 and 10).

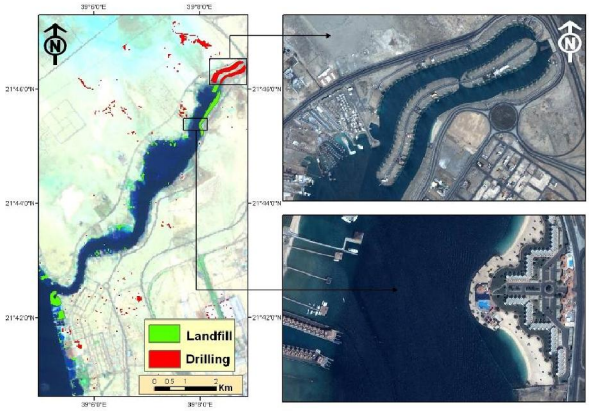


Fig. (9) Erosion and filling processes on Sharm Abhour coast

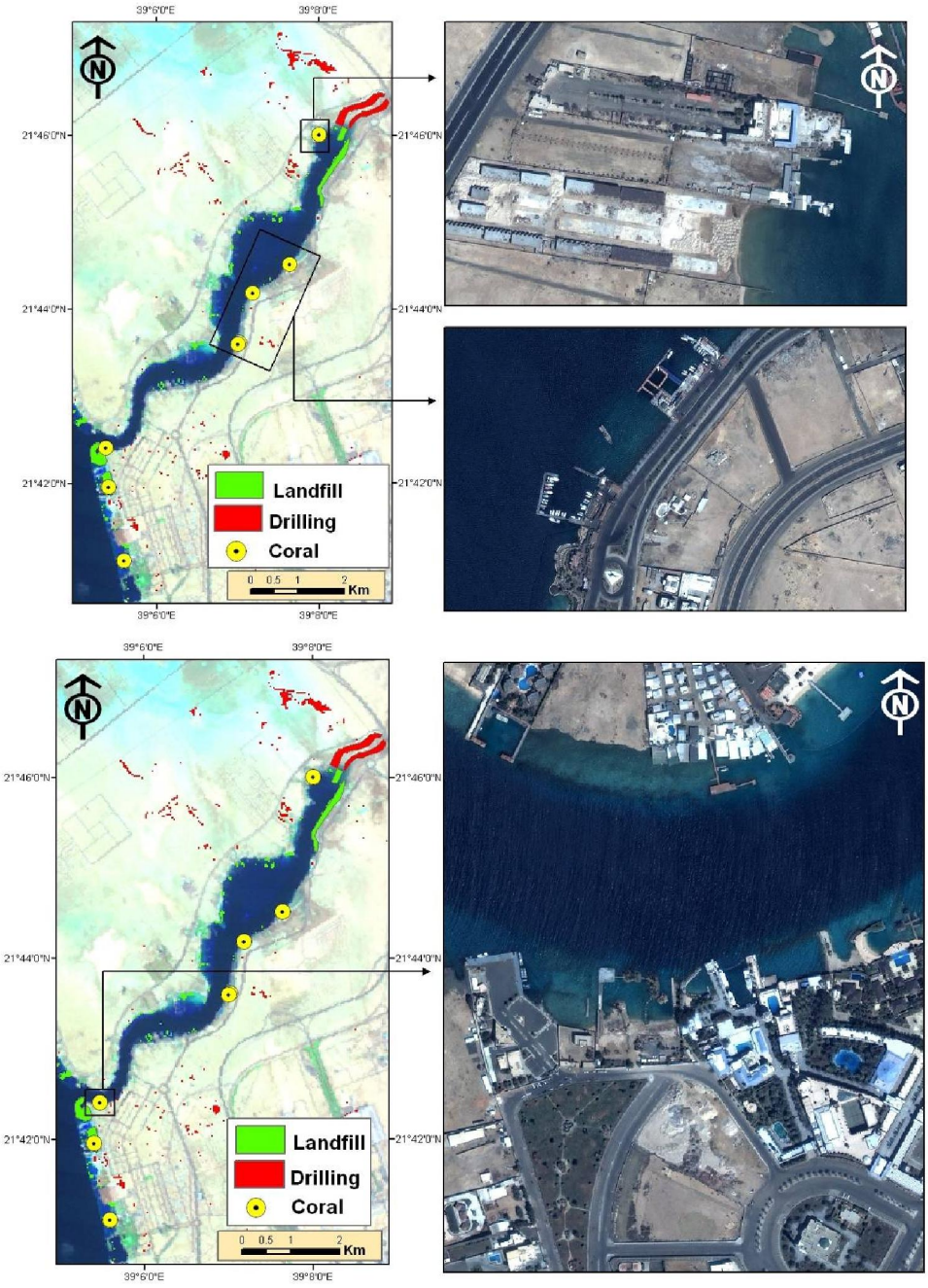


Fig. (10) Erosion and filling processes on Sharm Abhor coast

It is worthwhile to refer to some examples of most important resorts and tourism services, held in the coastal area of sharm abhar and northern cornice. These following project examples had a direct impact on the marine environment of Jeddah as a result of dredging operation and marine debris;
Marina resorts, Ard Al-Saada, Al-Nakhil village, Kristal resort, Laftonein resort

Monitoring the change in the coastal zone 1986-2003:

All satellite images analysis results were converted into digital data to facilitate its usage in change detection and calculating areas of erosion and dredging. Fig.11 shows the change in the coastal line shape, especially in El-Bohyirat City and Dort El-Arous. The blue colour represents the coastal line in 1986, while orange color represents coastal line in 2003.

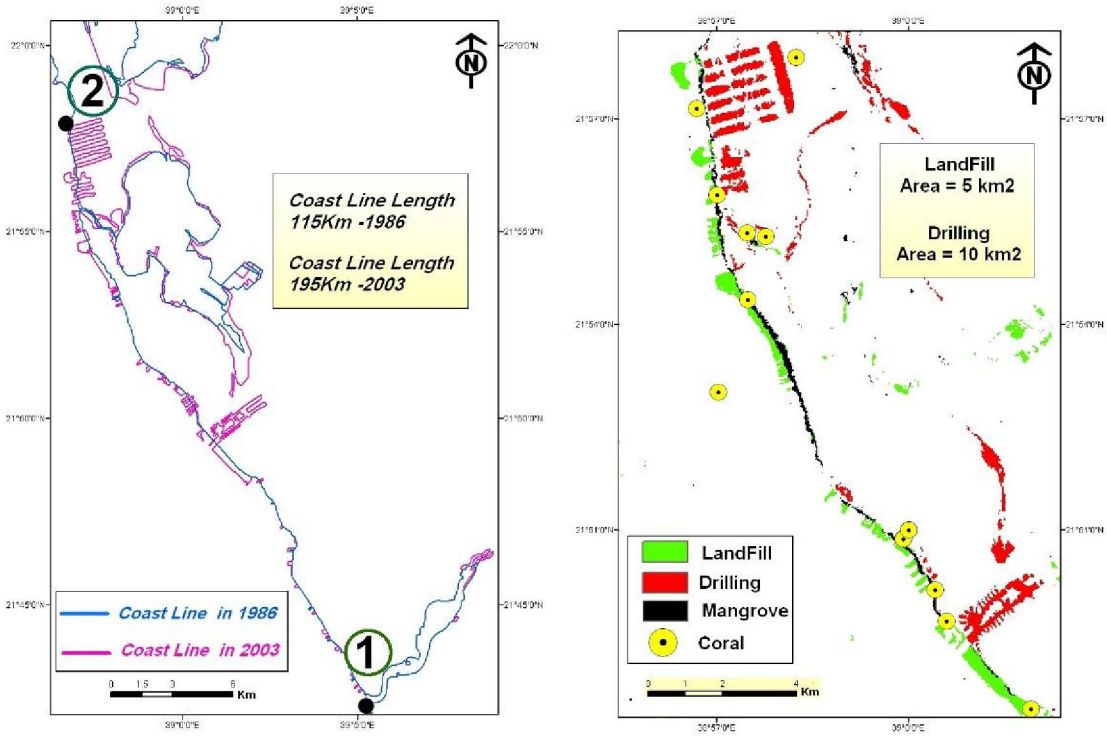


Fig. (11) Computation of changes in the coastal area of Jeddah

It was found that coastal line length in 2003 was 195 km, compared by 111 km in 1986. The change detection revealed that 84 km coastal line length has changed as a result of random projects establishments. Such projects were erected in the absence of required environmental studies. The total dredged area on Jeddah beach amounted 15km^2, out of which 5km^2 represent filling and 10 km^2 represents erosion (table 1).

Table (1) area of dredging and filling and coastal line length (1986-2003)

Length of coastal line 1986	Length of coastal line 2003	Dredging area 1986-2003	Area of landfill 1986-2003	Total area of dredging and landfill 1986-2003
15 km^2	5 km^2	10 km^2	195 km	111 km

In general, the work of dredging and filling of marine coastal line in northern Jeddah city and their harmful impacts due to suspended dust (Fig. 12) cased the deterioration of shoreline plants and coral reefs. Also, pollutants seepage and drainage works have hurt the conditions suitable for marine life

growth. The integration of these negative impacts hit, in its turn, the economic value of the area. The environmental tourism will be seriously affected by these changes of Jeddah coastal zone.

Fig. (12): Dredging and filling in marine coastal line of northern Jeddah city and suspended dust.

Mechanisms and policies for implementing a strategic bases

The most important mechanisms to implement the strategic principles mentioned above can be summarized as follows:

Developing and activating protective mechanisms:

1- Legalizing the system and developing environmental laws, with a continues reviewing and updating the procedures, standards and guide environmental development and protection.
2- Environmental awareness among individuals and authorities.
3- Considering the environmental issues in planning, designing, constructing and operating sustainable developments projects in all sectors, with continuous assessment and evaluation of the environmental impacts.
4- The abundance of information and data on the current status of environments and its expected progress, with continuing the development of monitoring mechanisms, collection, compilation, and representation of information.
5- Environmental management and supporting the central responsible authorities.

Developing a treatment plan

1- Supporting the preventive mechanisms, at the national level, to meet any contingencies as a result of natural disasters and environmental accidents.
2- Application of a sustainable tourism concept, through the creation of lean and friendly environmental tourism with a large financial return.
3- Encouraging tourism enterprises to apply the concept of sustainable tourism through an annual celebration, announcing the names of authorities that succeeded in applying the sustainable environmental concept. Also, placing an adhesive banners on all institution that have applied the concept.

4. Conclusions:

The results and field visits to the study area made to draw the following conclusions:

1- Exposure of the coastal of Jeddah to a severe environmental degradation that has led to destruction of the marine environment of the north.
2- Unsustainable use of marine coastal region interfaces takes place, where environmental measures were not taken into account, disregarding right of future generations in inheriting the marine natural.
3- The study showed a change in the coastal region from 1986 to 2003, as a result of developing unplanned investment and tourism projects.
4- Erosion of most of waterfront areas of the coast as a result of dredging and marine filling.
5- The study showed that the length of the sea coast of the study are of northern corniche in 2003 reached 195 km, while in 1986 was 111 km, recording a difference of 84 km..
6- The study confirmed the absence of regulations, environmental laws and legalizations at the local level and the absence of mechanisms to implement existing regulations.
7- The study showed the importance of applying modern technologies, as effective tools in the studies of sustainable tourism development.

Recommendations:

After shedding the light on the current status of tourism development and its negative effects on the marine environment of the northern coast of cornice of Jeddah, the following recommendations can be pointed out;

1- The responsible authorities should develop and activate policies and strategies to reduce environmental degradation in coastal areas and protect them from erosion and disappearance as a result of random tourism development projects.
2- The official bodies should find mechanisms to implement and enforce regulations and environmental laws to protect what remained of the marine environment and to maintain biological diversity and sustainable use.
3- Studies and researches of the environmental impact assessment should be done by specialists and engineers when planning to set up tourism development projects in the coastal zone.
4- The necessity of activating the coordination between ministries, institutions and land uses relevant departments in order to develop an effective role in protecting the coastal territory and identify suitable areas for each use.
5- The necessity to expand the national system of marine protectorate to maintain the overall biodiversity of different ecosystems.
6- The necessity to support scientific researches and the to establish documentation centers to provide accurate comprehensive environmental information, about current biodiversity situation of coastal areas, for decision makers.
7- Developing the concept of cultural sustainable tourism and holding awareness campaigns to show the importance of this development in the conservation of biodiversity of coastal areas.
8- The need to activate and assesses the environmental control, and inspection of environment when planning tourism development projects in order to maintain the biodiversity of coastal areas.
9- The need to focus on developing scientific progress and modern techniques. It is also

necessary to hold conferences, courses, workshops and to provide accessibility to databases and satellite images for tourism studies and researches.

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