A combined Use of Remote Sensing and GIS to Detect Environmental Degradation in the Jeddah coastal zone, Saudi Arabia

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Abstract: The main objectives of the work are to Identify the environmental degradation factors and their role in the destruction and creation of environmental problems of Jeddah marine coast. In order to develop a sustainable tourism strategic plan to reduce the depletion of natural resources of the marine environment of the study area. 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 to 195 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 of 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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1. Introduction

The major threats to the marine environment of the Red Sea are related to land-based activities. An assessment of land-based sources and activities affecting the marine environment in the region showed that the main impacts arose from urban and coastal development (e.g. dredge and fill operations), industries (including power and desalination plants and refineries), recreation and tourism, waste water treatment facilities, power plants, coastal mining and quarrying activities, oil bunkering and habitat modification (such as the filling and conversion of wetlands). These impacts can be considered under two main groupings, namely coastal developments (alternations) and wastewater discharges (pollution).

The physical alteration and destruction of habitats by coastal development arise from both large scale coastal construction projects including recreational facilities, hotels and restaurants, as well as the smaller scale but the greater number of developments on privately owned riparian land. In some parts of the Saudi Arabian Red Sea, coastal areas are under environmental stress especially where they are close to densely populated and industrialized sites (such as Jeddah,Yanbu and Jizan). The identified threats are expected to increase in future due to the proximity of coral reefs to development sites (Sheppard et. al., 1992). The major threat is a localized one and arises from the expansion of cities by extensive filling of coastal habitats, discharges from desalination plants, raw sewage discharges, dredging, uncontrolled coastal development adjacent to fringing reefs, tourism developments and shipping (PERSGA, 1998).

The practice of extending coastal land by reclamation is exemplified by the type of coastal development that can be seen in Jeddah, which is one of the largest cities in the kingdom Saudi Arabia with a population of about 2.7 million. The situation in Jeddah is completely different from smaller Red Sea urban centers. Jeddah is the principal seaport of KSA, and has witnessed great change after the discovery of oil. It is an entry point for Muslim pilgrims on their annual pilgrimage (Hajj) to Makkah (Abu Ouf and EI-Shater, 1991 and Al-Ghamdi et. al, 2003).

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, 1999). It has become a busy commercial seaport, a leading air terminal, and a major business and industrial center. Under these circumstances, development is inevitable. Development along the Jeddah coastline has in the main taken place without adequate evaluation of the potential environmental impacts.

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 tourist

attraction, which qualify it towards the comprehensive concept of tourist sustainable development (Ady et. al., 1995). However, investment projects and misuse of the land lead to the decrease of the recreational areas along the coastline and depletion of marine natural resources (Timothy, 1998). The construction of large projects has required significant dredge and fill operations which have adversely impacted the coastal environment. In addition to the direct destruction of marine life and key habitats by reclamation, the suspended fine materials resulting from these activities create additional widespread damage to marine life smothering benthic communities and affecting surrounding ecosystems (mangroves, sea grass beds and coral reefs).

Thus, there is an urgent need to conduct research activities to highlight the environmental problems of the Jeddah governorate to share in solving the problem of environmental degradation and conserving the marine environment of the governorate (Ahmed and Sultan, 1993). To fully understand the changes that have already occurred in coastal area, land cover data are needed to generate scenarios of future modification of the environmental system. Land use and land cover data can be obtained using in situ field measurements or remote sensing technology. To extract useful thematic information such as land cover maps from the raw imagery decision-makers must rely on intermediate steps involving scientific expertise, use of calibration data, and image-processing resources. GIS as conceptualized in the literature are used for mapping and analyzing geographic data (Danka and Klein, 2002). They are versatile tools for studying many types of information and for managing different kinds of resources with the potentials of contributing to regional sustainability in KSA.

This paper uses GIS and remote sensing in detecting the extent of environmental degradation caused by human activities in the coastal area of Jeddah, KSA. The emphasis is on the issues and the environmental impacts of sustainable tourism development to reduce the depletion of natural resources of the marine environment. In terms of methodology the paper draws from a mix scale approach based upon the existing literature, access to census databases of Jeddah coastal area and spatial information systems. This information is analyzed using GIS and remote sensing techniques. The main objectives of the work are to Identify the impact of human factors and their role in the destruction and creation of environmental problems of Jeddah marine coast.

Environmental setting of the study area

Jeddah city is located in west of Saudi Arabia on the eastern coast of the Red sea (Fig. 1) 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. The geographic location of Jeddah has its impact on the climate; the 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 to the land surface in the western region (Behairy et al. 1985). The study was done for the northern coast of the Jeddah governorate at the areas of (Sharm Abhor, city of lakes, Salman Bay and Dorat Al Arous) (Fig., 2).

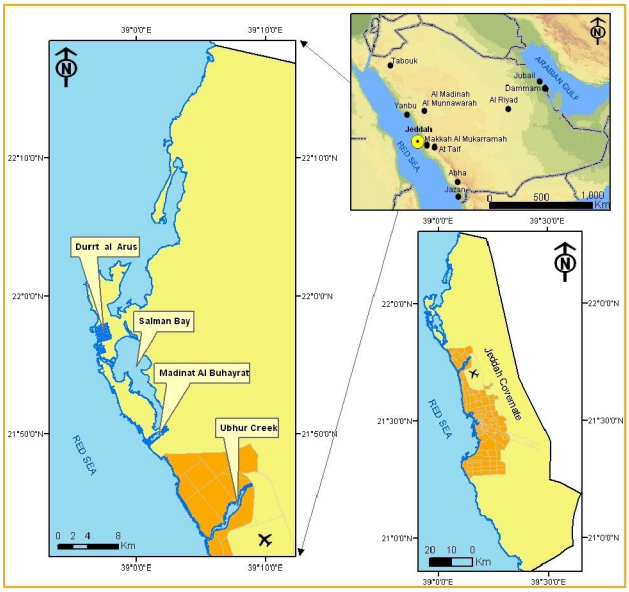

Fig. (1) Geographic location of study area.

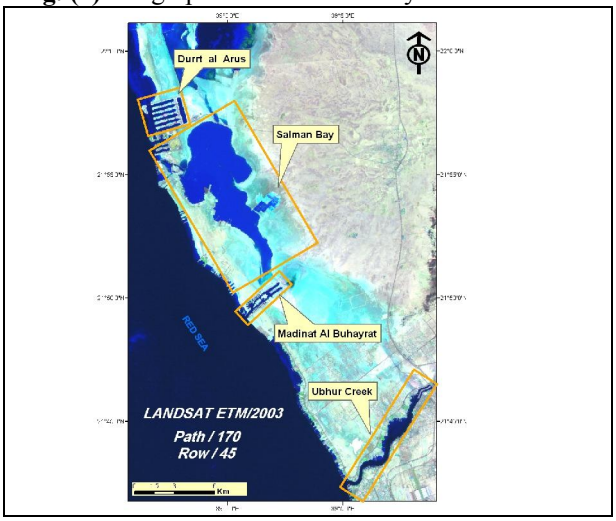

Fig.2. Boundaries of Study area, displayed on Satellite image.

2. Materials and methods:

Digital data driven from Landsat satellite images of the study area were used, It includes the period between (1986 – 2003), they are the newest and the oldest available LANDSAT satellite imaging dates. Also, 2005 which refers to the available IKONOS imaging date. 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 Landsat TM and ETM+ satellite data (Row 45/Path 170) were collected from the king Abdulaziz city for science and Technology (Riyadh city) covering the study area in the period (1986 and 2003) were processed using ERDAS IMAGINE 8.7 image processing software. The images were imported into ERDAS using ERDAS native file format GEOTIFF. Since the images were in single bands, they were stacked together using ERDAS layer stack module to form a floating scene and to group the bands together (Fig. 3). The 1986 image was co-registered with the 2003 image and later geo-linked to allow for the subset of the both images to the study area. Both images were projected to the Universal Traverse Mercator (UTM) coordinates zone 38.

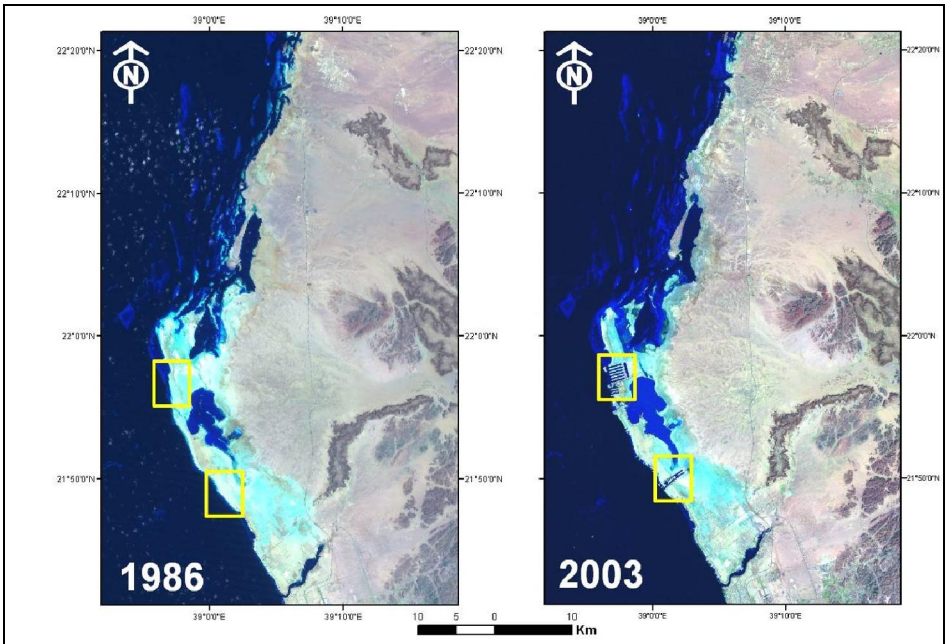

Fig. (3) LANDSAT images of Jeddah coastal zone, 1986 and 2003.

The spheroid and datum were also references to WSG 84. More than 30 Ground Control Points were monitored by using GPS in different locations within the study of the coast region, as a geographical reference for geometric correction (Fig. 4).

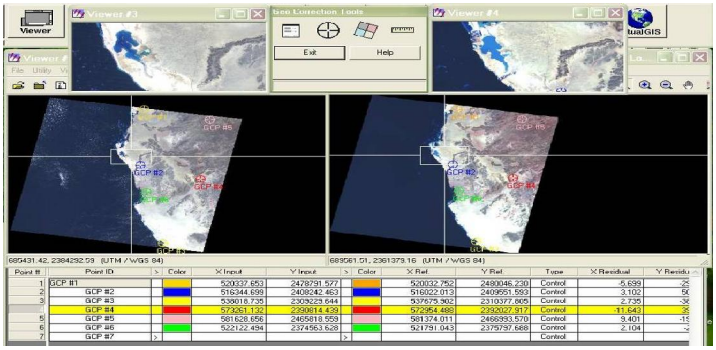

Fig. 4 Geometric correction of satellite images

Enhancement of the images using histogram equalization techniques was later performed on all the images. The images were later displayed as false-color composites with the band combination of red as band 7, green as band 4, and blue as band 2. All the images were later categorized using unsupervised classification technique to identify land cover features within the study area. 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 being computations and maps reproduction (Nguyen Quec Dinh, 2001 and Pavasovic, 1993). This process helped to show the extent of temporal-spatial evolution of ecological change induced by human activities in the selected areas.

3. Results and Discussion

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

3.1- Coast of Dorat El-Arous and Soliman bay:

Figure (5) 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.

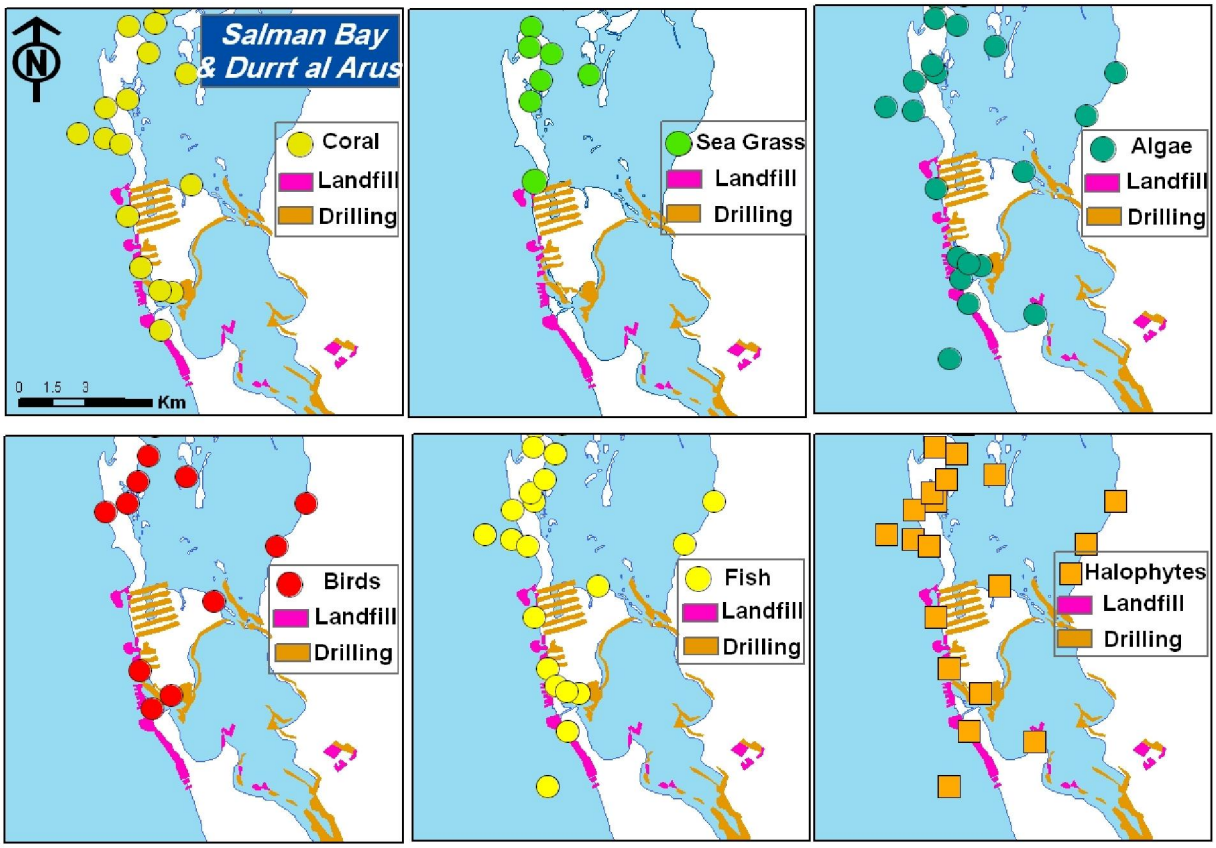

Fig. (5) Erosion and filling processes in Dorat El-Arous and Salman Bay

3.2- Al-Bohyrat City coast:

Figure (6) 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 storms and degradation of natural vegetation, thus disturbance of marine environment bio-diversity.

3.3- Sharm Abhar coast :

The erosion and filling processes have lead to severe environmental degradation of the marine environment of Shame Abhor region. Deterioration and destruction of the coral reefs resulted in disturbing the environmental bio-diversity of plants and animals. (Fig.7).

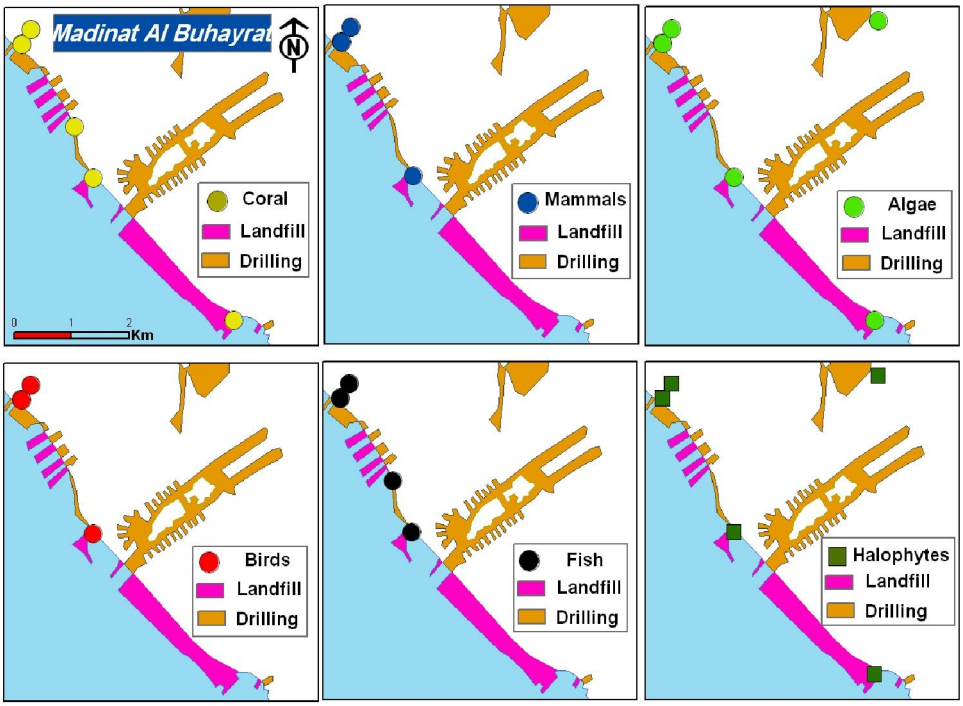

Fig. (6) Erosion and filling processes on Al-Bohyrat coast

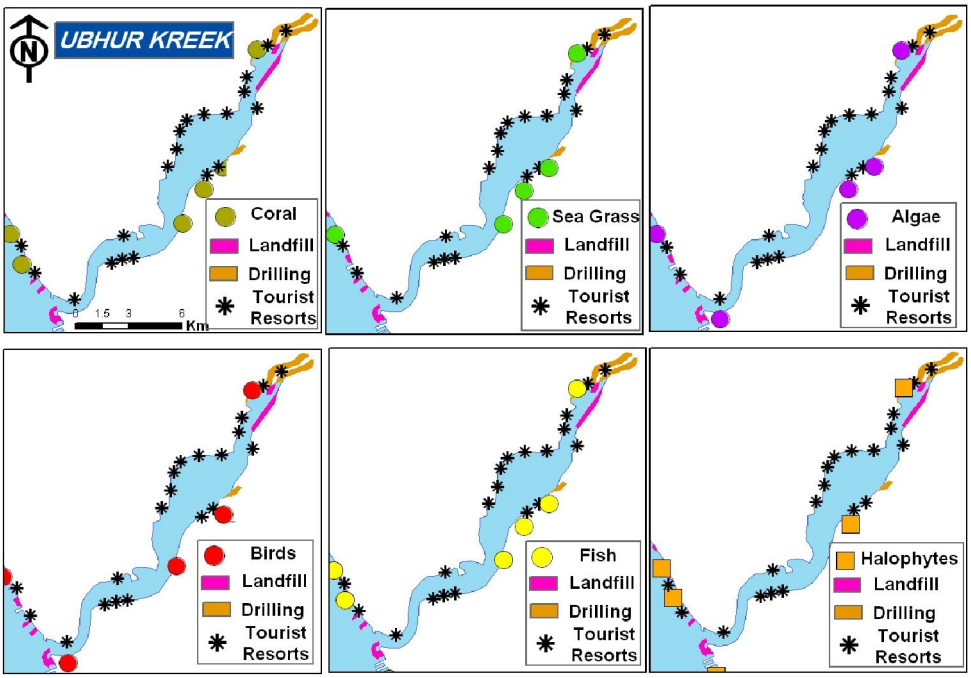

Fig. (7) Erosion and filling processes on Sharm Abhor coast

3.4- Change detection in the coastal zone 1986-2003:

Change detection technique was applied to point out the changes occurred in the coastal area resources elements. The recent satellite images (ETM 2003) were beneficial for updating the coastal map and distribution of erosion and dredging.

Fig.8 shows the change in the coastal line shape, especially in El-Bohyirat City and Dort El-Arous. The blue color represents the coastal line in 1986, while orange color represents a coastal line in 2003.

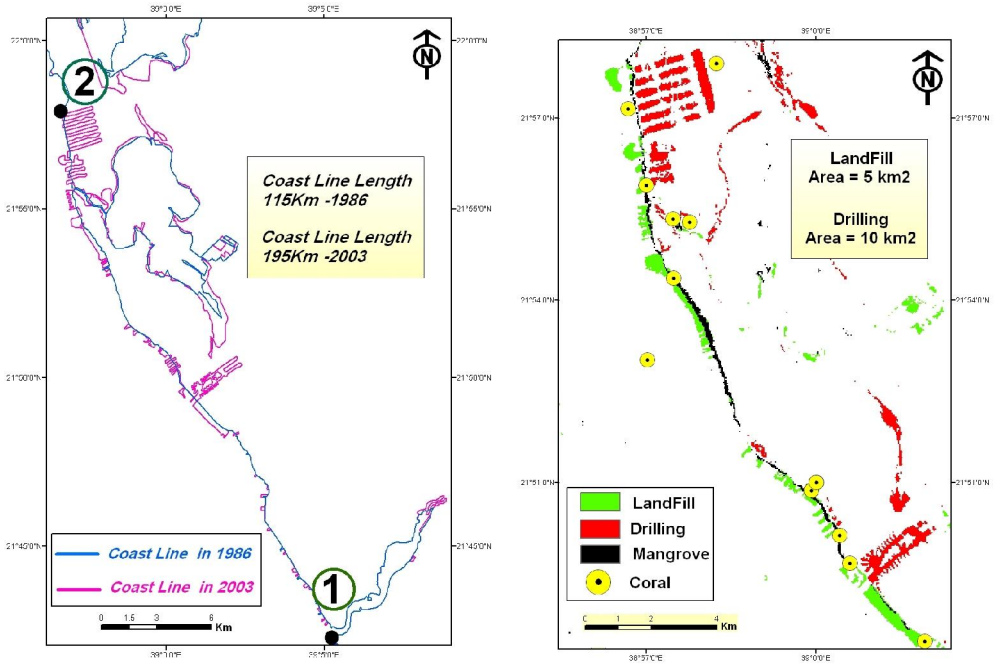

Fig. (8) Computation of changes in the coastal area of Jeddah

It was found that coastal line length in 2003 was 195 km, compared with 111 km in 1986. The change detection revealed that 84 km coastal line length has changed which represent 75.7% from the total length of the coast, 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 15 km^2, out of which 5 km^2 represent filling and 10 km^2 represents an 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

Regading the areas under investigation, it was found that the Dorat El-Arous and Soliman bay shore line was in 1986 (66 km), while increased to 115 by the erosion in 2003. However, Madinat Al-Bohyrat coast, increased from 7 to 31 km in 1986 and 2003. respectively. Nevertheless, Sharm Abhar coast changed from 22 to 30 during the studied period. From the above mentioned discussion the author illustrated that the most eroded area was Madinat Al-Bohyrat coast where the erosion area increase by 442.9% refrenced to 1986, while the less erosion area was in Sharm Abhar coast since increased by 136%.

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

Conclusions:

The results and field visits to the study area made to draw that the exposure of the coastal of Jeddah to a severe environmental degradation that has led to the destruction of the marine environment of the north, as a result of dredging and marine filling. The unsustainable use of marine coastal region interfaces takes place, where environmental measures were not taken into account, disregarding the right of future generations in inheriting the marine natural, due to the absence of regulations, environmental laws and legalizations at the local level and the absence of mechanisms to implement existing regulations.

Recommendations:

From the current status the following recommendations can be pointed out;

1- The need to develop and activate policies and strategies to reduce environmental degradation in coastal areas. As well as, to expand the national system of marine protectorate to maintain the overall biodiversity of different ecosystems. In addition to 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.

2- Applying the environmental impact assessment when planning to set up tourism development projects in the coastal zone.

3- The necessity to establish documentation centers to provide accurate comprehensive environmental information, about the current biodiversity situation of coastal areas, for decision makers.

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