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Monitoring and Assessing the Coastal Ecosystem at Hurghada, Red Sea Coast, Egypt

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Abstract:

In the framework of the investment plan, the government of Egypt introduced an accelerated development of Hurghada in collaboration with the private sector, as early as 1980's. The government intended to construct tourist resort communities, which required establishment of infrastructures. The demand of such facilities, in absence of enforced environmental roles led owners to implement processes of landfilling and dredging for the purpose of smoothing, paving and widening the beach in order to construct swimming pools, marinas and other recreational facilities. Such activities came on the expense of the marine ecosystem and especially assault on the coral reef communities.

For monitoring and assessing such oppressive activities; MSS, TM, ETM+, and SPOT XS 4 satellite images acquired during 1972, 1984, 1992, 2004 and 2011. Shoreline change detection from 1972 to 2011 reveals landfilling of some 7.56Km^2 and dredging of 2.67km^2, with loss of 5.34km^2 of the reef tracts. At the same period, the region has witnessed expansions in urban and road network by 16.47km^2 and 8.738km^2 respectively.

The Egyptian government issued the essential laws for regulating and saving the coastal ecosystem, yet mostly violated. Activation of such laws, applying judicial officers, toughening penalties and establishment of coastal building front line (CBFL), and a reef protection line (RPL) are important tasks especially south of Hurghada to the Egyptian-Sudanese borders to preserve the remnants of such unique coastal ecosystem.

Keywords: Satellite images, Hurghada, Red Sea, coastal ecosystem, shoreline changes, urban, road network, environment laws

1. Introduction

The Red Sea is the world's northernmost tropical seas (Lieske & Myers 2004). Since the 19th Century, the Red Sea coastal plain of Egypt has been of a great interest for several researchers. The pioneer geologic works include that of Ehrenberg (1834), and Walther (1888) who studied the fringing and older coral reefs of Red sea and Sinai. The Red Sea and Gulf of Aqaba areas of Egypt estimated to comprise about 1500 km of coral reef including the coastal and island margins, of which 800 km of the fringing reef extends only at the coast from Hurghada to Egyptian –Sudanese borders. The drowned reefs recorded at depths of 10m and more below the sea level (Abdel-Fattah 1998, Borhan *et al.* 2003). The Red Sea coastal plain is covered mainly with Miocene and later deposits. Pre Miocene rocks are of very limited distribution. The strata have a regional eastward dipping to the sea with several NW-SE trending faults. The coast is dissected by several extensive wonderful wadis running from the high hills and debouching into the Red Sea eastward with the characteristic silisclastic beach (Said 1990). Emergent coral reef terraces exposed at elevations between 35m and 1m above the present sea level (Abdel-Fattah 1998).

Due to its unique marine ecosystem with the characteristic marine habitats, the Red Sea is one of the most important repositories of marine biodiversity all over the world. It has an extraordinary range of biological diversity and endemism. The Red Sea is the habitat of over 1,000 invertebrate species, more than 1200 species of fishes, and coral reefs, mangroves and sea grasses represent resources for tourism attraction frequented of different temperaments and hobbies. (Shaalan 2005, Barrania 2010).

The Northern Red Sea Islands area (Figure 1) announced as a protectorate by the resolution of the Prime Minister of Egypt no. 1618 for the year 2006. The decision included 21 islands located in shallow water not more than 100m depth and covers an area of about 1992 km^2. The protectorate comprise sensitive coastal ecosystems such as scattered clusters of sea grass, mangroves, and more than a thousand species of living corals, echinoderms, molluscs, crustaceans, fish, reptiles, birds and mammals objects. Northern Red Sea Islands are very important strategic areas because of outstanding geographical location, which oversees the Strait Gopal, a southern entrance to the Gulf and the Suez Canal (EEAA 2008).

Such resources encouraged the government of Egypt to support the investment in the coastal plain of the Red sea especially for touristic activities. One of the target point for such investment activities was Hurghada region. Hurghada was originally a small fishing village located at (33° 41′ 3″ to 34° 04′ 03″ E and 27° 00′ 14″ to 27° 25′ 30″ N, Figure 1). The coastal plain of Hurghada extends for about 62 km length from El Gouna to Sahel Hasheesh and for about 35 km, wide with a total area of about 1625 km^2, of which are 791 km^2 inland and 834 km^2 sea water. Later in the 1980s, it became the most famous tourist resort target on the Egyptian Red Sea. The growth of the coastal urban areas at Hurghada generates a range of threats to the nearby shoreline habitats. The construction of such tourism resorts essentially required infrastructure works on harbors, airports and mining the reef areas for construction materials (Bryant et al. 1998). Such constructions essentially required a plan of laws and roles controlling and regulating such activities. Intensive investigation is required for the expected hazards that may face such numbers of tourists arrived from different countries. One of such hazards off course was the human impacts itself either from the investors or from tourist on the natural resources of this virgin region.

Remote sensing has been used in combination with geographical information systems (GIS) and global positioning systems (GPS) to assess land cover change more effectively than individual remote-sensing data (Müller & Zeller 2002). These have been widely used in several parts of the world's coast in monitoring temporal changes and assessing the hazards. Among studies monitoring coral reef damage, sites of mangrove, sea grasses and coastal dynamics in Egypt are: El-Gamily *et al.* (2001), Moufadallah (2005), Vanderstraete *et al.* (2005, 2006), Arnous & Green (2011), Dewidar (2011), Mowad (2013), Taha *et al.* (2013), El-Asmar *et al.* (2013; 2014), and El-Damaty & Elkhrachy (2014). A worldwide, such as in Abu Dahbi (Yagoub & Kolan 2006), in Bandar Abbas, Iran (Tamassoki *et al.* 2014), in Yemen (Sagheer *et al.* 2011), in Saudi Arabia (Kumar *et al.* 2010, Al-Olayan 2014), in Turky (Sesli & Aydinoglu, 2003) in China (Yuxuan *et al.* 2011), and in Canada (Vaz & Bowman 2013). Change detection algorithm is essential in detecting and identifying the nature of the changes, their areal extension and the spatial patterns (Macleod & Congalton 1998). There are two methods for change detection have been widely used; these are image differencing and post-classification comparison (Singh 1989).

The present study is an attempt aims to monitoring the anthropogenic changes resulted with resorts construction. The latter means the need for wide and extended beaches able to accommodate tourist's activities, and will definitely lead to processes of dredging and landfills mostly come on the expense of marine life. This study also examines the effectiveness of environmental laws in protecting the coastal ecosystem and ways to enforce the environmental laws on both investors and tourists.

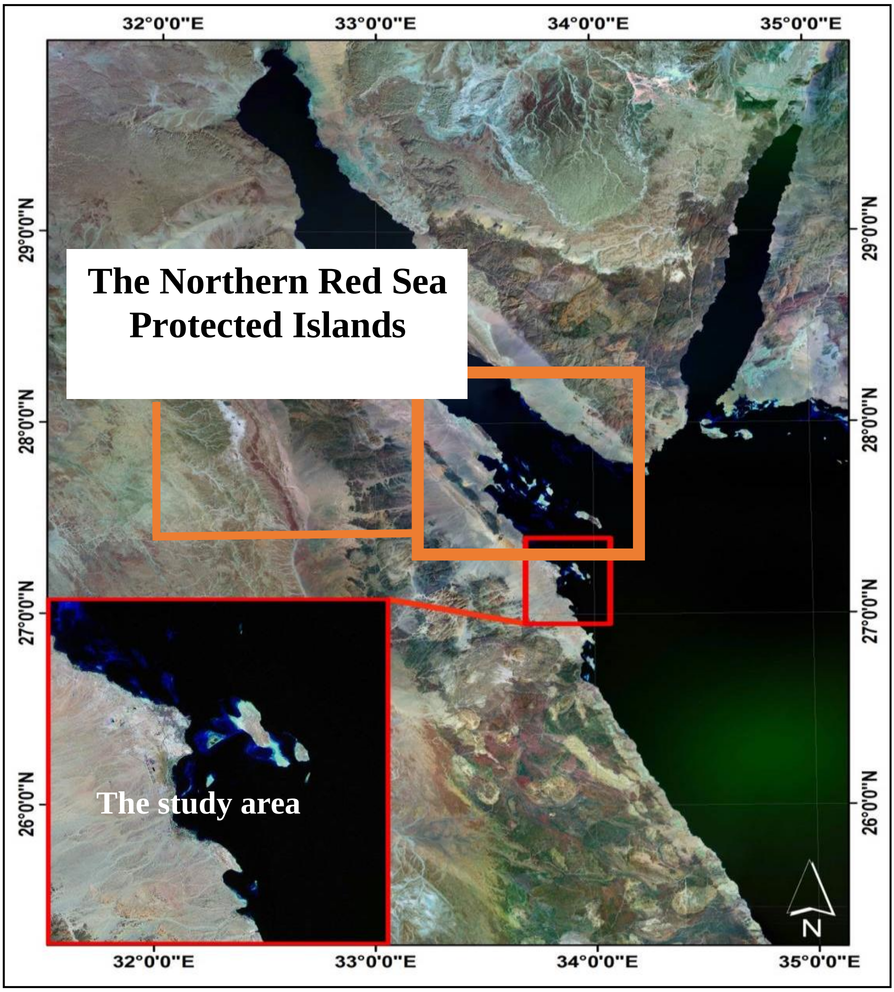

Figure 1. Location of the study area, Hurghada (Red) and the Northern Red Sea Protected Island (Orange), Red Sea, Egypt.

2. Materials and Methods

Remote sensing techniques consider the best solution for detecting the regional changes and exploring the new phenomena over the earth surface and even for the other planets surfaces. Satellite remote sensing has the potential to provide accurate and timely geospatial information describing changes in LU/LC (Foody 2003, Herold *et al.* 2002, 2003, and Yuan *et al.* 2005). Generally, change detection involves the application of multi-temporal data sets to quantitative analysis of the temporal change of the phenomenon (Lu *et al.* 2004, Srivastava *et al.* 2012).

The basic principle behind using digital data is that any subtle change in LU/LC results in a change in the radiance of that object detected by satellite sensors at a range of spatial, spectral and radiometric resolutions (Wilson *et al.* 2003, Mundia & Aniya 2005, Xiao *et al.* 2006). For example, the conversion of land use from rural to urban land causes change in the visible portion of the spectrum (brightness) the changes from vegetation to non-vegetation land use cause difference in the near-infrared (NIR) radiation (greenness) and the change in the shortwave-infrared (SWIR) reflects change in moisture content (wetness) (Lunetta & Elvidge 1998). A number of techniques on LU/LC changes have been reviewed (Lu *et al.* 2004). LU/LC change detection generally employs one of two basic methods: pixel-to-pixel comparison and post-classification comparison (Dennis & Colfer 2006, Dewidar 2004, and Mukherjee *et al.* 2009), which compares two or more separately classified images of different dates (Serra *et al.* 2003, Shalaby & Tateishi, 2007). Post classification comparison is considered the more appropriate and commonly used method for change detection (Lillesand *et al.* 2004).

Landsat (MSS, TM, and ETM+) and SPOT+4 satellite remotely sensed data utilized to achieve the objectives of the present study. The acquired images for years 1972, 1984, 1992, 2004 and 2011 respectively. In addition to a group of seven topographic maps used with 1:25.000 scale. Atmospheric correction applied to the Landsat and SPOT images, using the dark object subtraction method of Chavez (1996). All satellite images has been geo-referenced and geometrically corrected to a WGS 84 datum (world geographic system), UTM (Universe Transverse Mercator), and projection with Zone 36 North using ground control points during the field verification using Guno Trimble GPS. This process completed by using ERDAS IMAGINE 10 software with Root Mean Square Error (RMSE) of geometric corrected images; 0.0141(MSS), 0.0059(TM), 0.0045(ETM) and 0.0012(SPOT) respectively. Finally all images are converted from digital number (DN) values to physical unit (W/m^2 sr µm), using the calibration data given in the header file (metadata) of the images. ENVI 5.0 software used to perform an unsupervised ISODATA classification on both subsets (land and water bodies) for SOPT 4 and Landsat images. The ISODATA classification process yielded 30 classes for land body of Landsat images and 30 classes for land area of SPOT4 image. To minimize the seasonal effects on LU/LC change, all images selected with similar calendar dates. The total four bands (Band 2, 3, 4 and 5) combinations considered into account for the image classification. However, to reduce the computation time a subset of 4005,369 pixels of the area considered in this study. For the selection of the training and validation sets of pixels from the TM imagery, it suggested that a minimum of 10–30 band cases per class used for training (Petropoulos *et al.* 2011).

Landsat images data covering the study area have been digitally processed, analyzed and interpreted to produce a LU/LC map at a scale of 1: 50.000. This based mainly on the multilevel LU/LC classification system for use with remote sensor data adopted by the U.S. Geological survey (Anderson *et al.* 1976). The produced Landsat images classification maps clearly displays the major classes of LU/LC in the study area. The accurate special registration of the two images is essential for all change detection methods. This necessitates the use of geometric rectification algorithms that register the images to each other or to a standard map projection. In addition, most of the methods require a decision as where to place the threshold boundaries in order to separate areas of change from those of non-changes.

The dynamic movement of the coastline along the study area in terms of advancing by accretion or retreating by erosion highlighted and measured using ArcMap software by digitizing the shoreline position in the Landsat and SPOT satellite images. Two thematic maps showing the relative coastline position in each date were prepared to present the regions, which experienced erosion and those exposed to accretion. A geographic information system (GIS) is a system used to describe and characterize the earth and other geographies for the purpose of visualizing and analyzing geographically referenced information. Many have characterized GIS as one of the most powerful of all information technologies because it focuses on integrating knowledge from multiple sources (for example, as layers within a map) and creates a crosscutting environment for collaboration.

Field validation conducted by selecting random points for each habitat class along the entire area of study at Hurghada. About 200 points selected as reference for each class at different locations including all area of this study. GPS points taken for the validation of the image data. About 200 points selected per class chosen collectively in different regions of the study area and were the same for both images, SPOT and Landsat. These points were randomly selected and at the same latitude and longitude in both images. The algorithm then compares the pixel data in the image to the user-defined parameters and produces a classification output. The supervised classification performed by maximum likehood algorithm using ENVI 5.0 software. After a complete supervised classification has performed, the change detection to calculate the area of each class has done. This process completed by converted the supervised classification into vector layers using ENVI 5.0 software and then using ArcGIS 10.1 to perform the contextual editing for each class to complete the calculation of class areas.

3. Results

3.1. Shore line changes

It is quite apparent that the shoreline is stable and no areas of natural erosion/accretions detected along the coast of Hurghada. This in fact attributed to the rocky nature of the coast (Figure 2A,C and D) with abundance of coralline terraces (Figure 2E, F) in addition to absence of true strong waves and drifting currents. However, processes of landfilling and dredging (Figure 2A, B) in order to widen and extend the beaches to accommodate touristic expansion have observed. Such processes infected the natural shoreline and the biodiversity which inhabiting the coastal area and came on the expense of the coral reef communities. The observed dredging of hard rocks and corals related to construction of swimming bays (Figure 2 G, H) which seem have erosion patterns, and landfilling for marinas constructions which appear as accretion patterns (Figure 2I, J). 59 marinas constructed on the beach on the expense of coral reef tracts (Figure 2A) The observed satellite image of 1984 (Figure 2B, C and D) shows the coast of Hurghada, before the development activities with no evidence of anthropogenic interference, while in 2000, 2014 images (Figure 2B) the situation is completely changed, patterns of dredging and landfilling detected at different locations of the coast (Figure 2G-J).

Erosion/accretion pattern on shoreline of Hurghada from years 1972 to 2011 recorded and illustrated (Figure 3). The total area of accretion (landfilling) was calculated as 0.49 km^2 for the period of time 1972-1984, while the total area of erosion (dredging) for the same time period was 0.35 km^2. During the period from 1984-1992 the area of accretion became 2.68 km^2 and from the period 1992-2004 more accretional areas were detected (3.32 km^2), while little increase in the erosional areas being 0.37 km^2 and 0.44 km^2 respectively (Figure 3 in table & graph). The increase in both landfilling and dredging during the period from 1984-2004 appears contemporary to the increase in tourism activities with consequent construction of resort facilities and infra structure. From 2004 to 2011 most constructions have been already fixed their infra structure, in addition to decline in number of tourists because of the political situation However, still areas of erosion detected north of Hurghada related to marine and coastal works in El-Guna resort (Figure 3).

3.2. Urban Changes

Generally, a growth in total urbanization area along Hurghada detected during the study periods from 1972 to 2011 (Figure 4). Urbanization was quite ambitious during the last 39 years. If we take 1972 as the base-line data, it concluded that developed areas have tripled 1992-2011 (Figure 4 in table & graph). The urban area at 1972 was about 2.012 km^2, while it reached to 17.95 km^2, with change rate about (+16.47 km^2) from 1972 to 2011. Most expansion in urban areas was during 1992-2004, parallel in time to touristic facilities and related infrastructures related to tourism activities and facilities (Figure 4 in graph).

In fact, this study records several patterns of human induced hazards to the coastal ecosystem at Hurghada. Such hazards include damage of coral reefs due to constructions of beach facilities and extensions including swimming pools, and marinas with essential boat anchoring in addition to damage associated with diving sports and fishing. Oil spillage, sewage, phosphate pollutions, and littering and trash of water bottles and plastic bags represent different patterns of pollution threatening the coast of Hurghada.

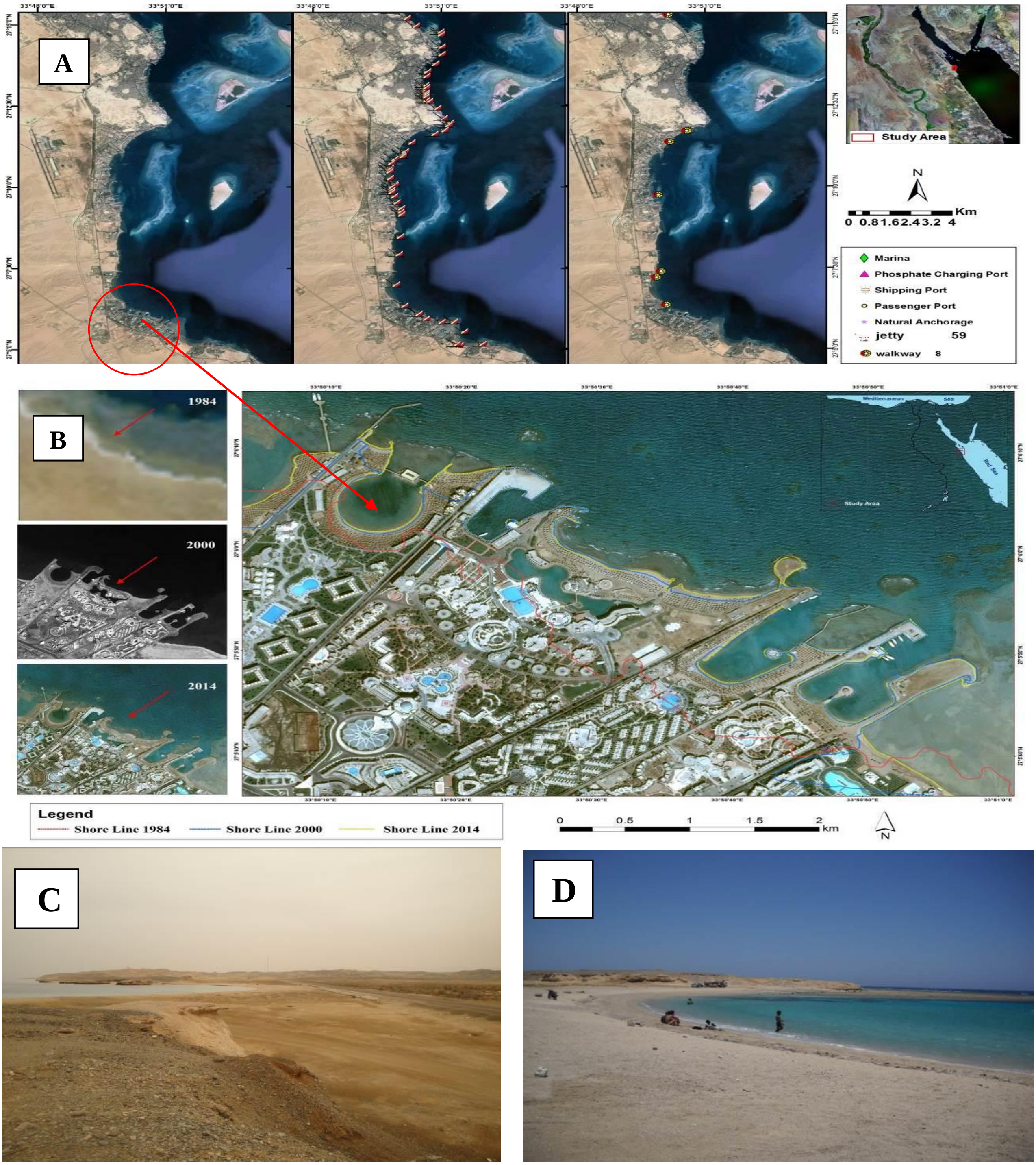
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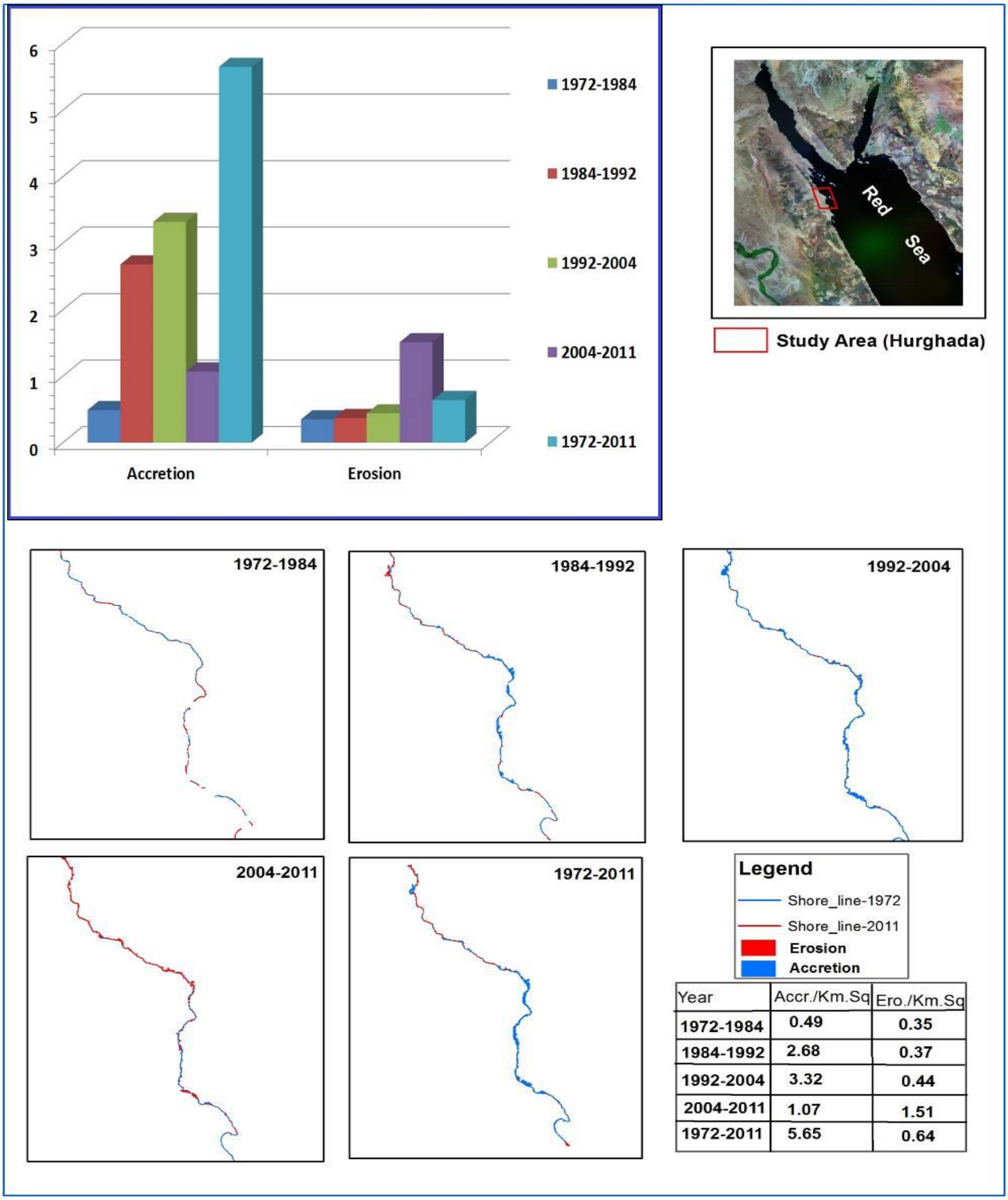
Figure 2. Satellite images of 1984-2014 showing different constructions along the coast of Hurghada including marinas walking areas and swimming pools (A), Close up showing shoreline changes and patterns of landfilling and dredging (B). Field photos of the coastal plain at Hurghada north (C) and south (D) before development activities in 1984, Coral reef tracts at different locations submassive to phaceloid colonies of Galaxea fascicularis (LINNAEUS) (E) and *Goniastrea retiformis* (LAMARCK) (F) dredging and landfilling at El Gouna, (G), dredging and landfilling at Sahl Hasheesh (H), marina at Sahl Hasheesh (I), and landfilling at Magawish (J) (photos G - J from Persga/GEF, (2003



Year	Accr./Km.Sq	Ero./Km.Sq
1972-1984	0.49	0.35
1984-1992	2.68	0.37
1992-2004	3.32	0.44
2004-2011	1.07	1.51
1972-2011	5.65	0.64

Figure 3. The status of erosion (red) /accretion (blue) of the Hurghada shoreline between "1972 – 2011". Rates of erosion and accretion during the studied periods recorded in the attached table and graphically represented (modified after Khaled 2013).

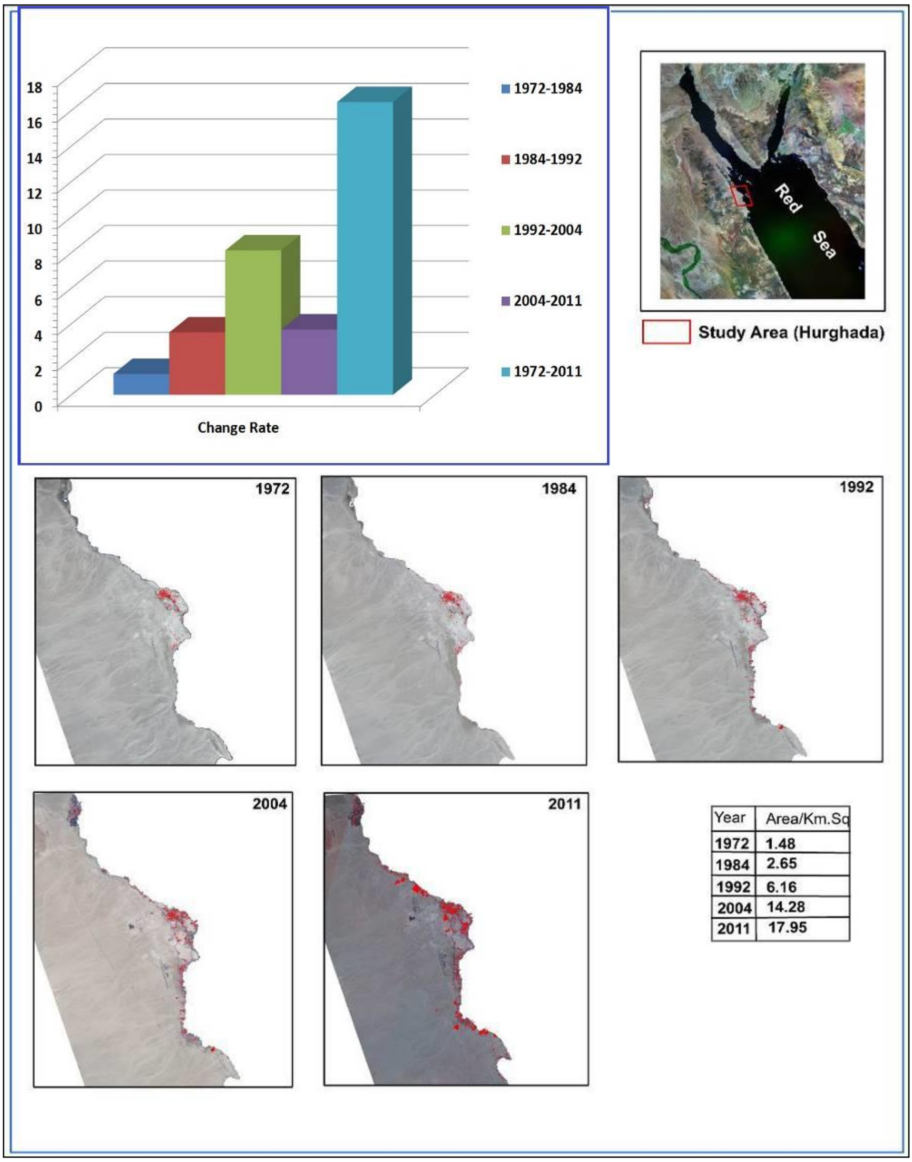


Figure 4. The status of development of urban areas (red) along the Hurghada between (1972-2011). The rates of expansion recorded in the attached table and graphically represented (modified after Khaled 2013).

3. 3. Roads Network Changes

Road development in Hurghada appears contemporary to the urbanization to fulfill the urban and tourism requirements, and reflects how the future development plans are ambitious. Roads area and the change rates at the period of 39 years represented and illustrated (Figure 5 in table & graph). Roads area at 1972 was about 2.012 km^2, while reached to 10.75 km^2 with change rate about (+8.738 km^2) from 1972 to 2011. This explains the beginning of the roads developments at 1984 with change rate about (+1.268 km^2).

4. Strategy and Legislation

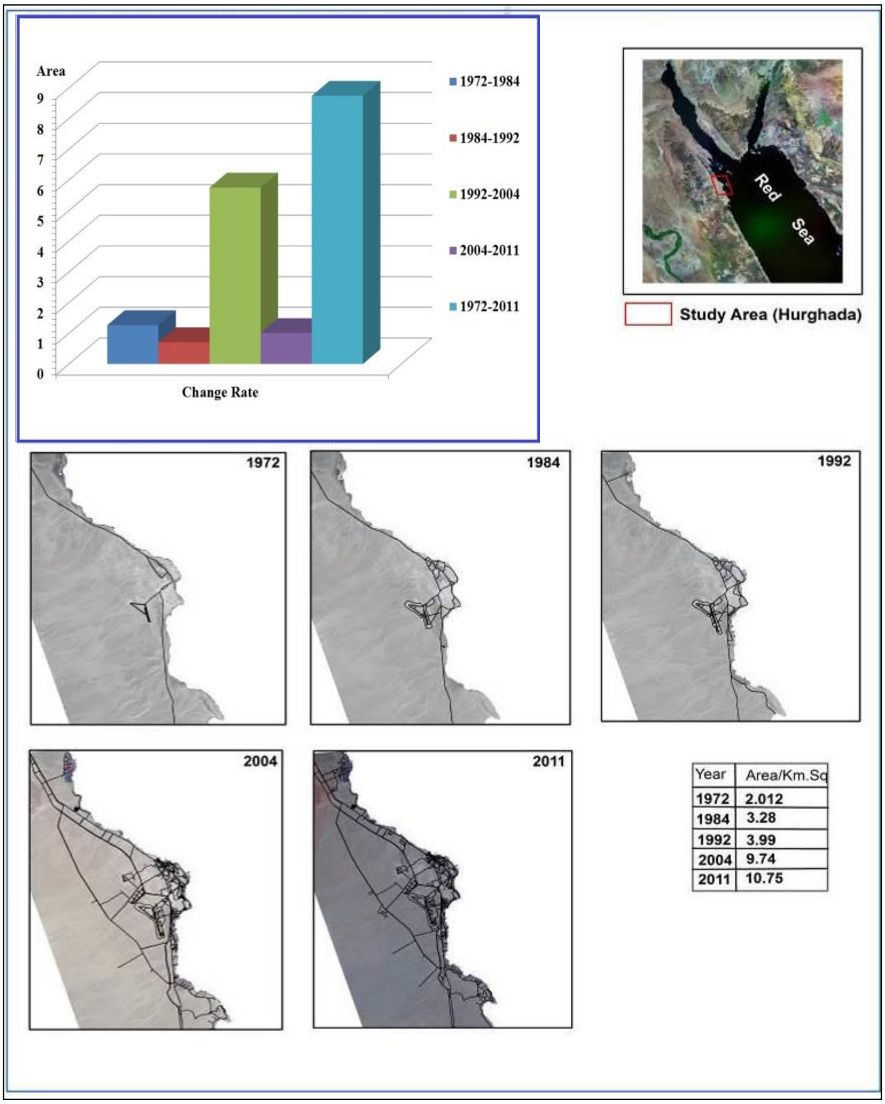
The study area is potential in geologic heritage and biodiversity. The Authority of Environmental Affairs dated back to 1982, which replaced by the Egyptian Environmental Affairs Agency (EEAA), is a fundamental in management and supervision of the natural reserves of specially protected areas in Egypt. In 1995 the (EEAA) was given the authority to participate with the concerned agencies and ministries in the preparation of a National Integrated Coastal Zone Management Plan for the Mediterranean Sea and The Red Sea coasts" according to article 5 of the Environmental Law No 4 of 1994 (Law 4/1994). Through its articles and executive regulations, EEAA plays a critical role in the preparation of the National Committee of the Integrated Coastal Zone Management (ICZM) plan for the Mediterranean Sea and the Red Sea coasts, and has been instrumental in the creation and function of the National Committee for ICZM in 1995 (ICZM 1996 a, b ; EEAA 2008). When comparing to 16 countries along the Mediterranean coastal zones, Egypt is very progressive in its approaches to coastal management. For example, while there is no legal framework under which all applicable laws related to coastal zone are consolidate, the national laws on environment (Law 4/1994) and on protected zones (Law 102/1983) provide the basis for management of the coastal areas. These laws always referred to the consideration of any coastal development project, and used as a basis for monitoring of coastal environment and the environmental impact assessment.

In 1983, the president decree 102/1983 was declared regarding the natural reserves of protected areas indicating in its article II that; prohibited activities or actions that destroy, damage or deteriorate the natural environment, or harm wildlife and marine biodiversity. It is also prohibited , in particular, Hunting, taking or transfer any objects or organic materials such as shells, coral reefs, rocks or soil for any purpose, destruction or transfer of plants located in the protected area and damage or destruction of the geological formations or geographical regions that are home to animal or plant species.

In 1994 president promulgated the environment law4/1994 and amended by law 9/2009. However, construction for tourism facilities with urban expansion and road construction along Hurghada coast did not stop, while accomplished in an accelerated rates from 1992-2004, without any considerations of environmental laws. This is in fact due to the absence of judicial officers and presence of different ways of corruptions. Due to catastrophic events of damage of coastal ecosystem in several islands, removal of mangroves and dredging of coral reefs in order to construct marinas and swimming beaches, the prime minister declared the northern islands of Red Sea (Figure 1) as a natural reserve. However, absence of good governance, and hand trembling in the application of these laws, in addition to, corruption of local councils led to an obvious decrease of the coral reef areas along the coast of Hurghada (Figure 6).

5. Discussion

The present study shows a total area of accretion (landfilling) was 7.5 6km^2 and about 2.67 km^2 erosion (dredging) for the 39 years (1972 to 2011). El-Gamily *et al.* (2001) has made landfill detection for the same area (Hurghada) based on two Landsat TM-images of 1984-1991 respectively for the same study area. He calculated the landfill (accretion) areas to be 3.95 km^2. Dewidar (2002) has made landfill detection for the same area based on two Landsat TM-images of 1984-1997 respectively for the same study area (Hurghada). He calculated the landfill areas (accretion) to be 2.3 km^2. Moufadallah (2005) calculated the total area subjected to landfilling and dredging in the coastal strip from north of Hurghada to south of Safaga between 1984 and 2000 as 6.5 km^2, of which 3.6 km^2 as landfill and 2.9 km^2 as the (eroded) dredging area. Vanderstraete *et al.* (2006) has made change detection map indicating the shoreline changes in the same region (Hurghada) through a 13-year period (1987–2000) using Landsat (TM, ETM+) images. They found the average landfilling area (accretion) during the study period was about 4.0 km^2 and the dredging (erosion) area was about 2.0 km^2. Kamh *et al.* (2012) has made change detection map for the urban expansion and its spatial patterns in the Hurghada area through 18-years period (1987–2005) using Landsat (TM, ETM+) and ASTER images. They estimated landfilling along the coastline from El-Gouna resort at the north of Hurghada to Sahl Hashish area at the south was 4.5 km^2.



Year	Area/Km.Sq
1972	2.012
1984	3.28
1992	3.99
2004	9.74
2011	10.75

Figure 5. The status of development of Road network along the Hurghada between (1972-2011). The rates of expansion recorded in attached table and graphically represented (modified after Khaled 2013).

During 1972, the area of reef tracts was 17.20 km^2 and reached in 2011 to 11.86 km^2 with total loss of reef tracts at Hurghada by about 5.34 km^2 (Figure 6 in table). Such a lack related to the processes of landfilling and dredging along the coast for resort facilities such as swimming pools and marinas construction (Figure 2 G-J). In addition to some damage due to boat anchoring, trampling, boat crashing, and diving sports, which led to breaking of coral reef. Vanderstraete *et al.* (2006) introduced a GIS risk assessment map for the coast of Hurghada, it shows that a relatively broad medium risk zone is stretching out all along the coast north and south of Hurghada. In consequence, 86% of the coral reef systems are under medium to high risk of being damaged by negative consequences of human coastal activities. Jameson *et al.* (1999) introduced a coral damage index (CDI), to screen sites to obtain a perspective on the extent and severity of physical damage to coral. Sites are listed as "hot spots" if the percent of broken coral colonies (BCC) $\geq$ 4% or if the percent cover of coral rubble (CR) is $\geq$ 3%. They applied their index "CDI" on a real-life management situation of Hurghada. The extent of coral damage covered all diving sites. 40% of studied sites were designated as "hot spots" that required management action. 31% of the "hotspot" were identified by both broken coral and rubble criteria, 25% by only broken coral criterion and 44% by only coral rubble criterion of the CDI, suggesting that past breakage was responsible for most of the observed damage. 63% of the "hot spot" were at 4 m depth versus 37% at 8 m depth, suggesting that most of the damage was caused by anchors dragging across the reef in shallow water. The severity of coral damage, reflected by CR, was the greatest at Small Giftun at 4 m depth (333% above the CDI) and El Fanous at 8 m depth (325% above the CDI).

It is interesting that Frihy *et al.* (2004) confirm that coral reefs are important recreational and aesthetic resource for tourists and can provide protection for marinas and beaches, which are often found behind reefs. Moreover, they mentioned that conserving such reefs is a benefit to protect water front facilities. However, they contributed effectively to the deterioration of the marine ecosystem in Hurghada through consultancy works acting on landfilling and dredging of coral reefs in order to construct marinas and other beach facilities for most of resort villages along Hurghada coast. Sensitive coral reef areas should consider the natural protective elements that in turn would minimize dredging to create recreation facilities and thereby not affecting the surrounding environment.

Over the present study period an expansion in urbanization area was detected with a total average increases by 16.47 km^2. El-Gamily *et al.* (2001) calculated the total changes of urban area to be 3.7 km^2. Dewidar (2002) calculated the total changes of urban area to be 11.86 km^2. Vanderstraete *et al.* (2006) found the urban area increased during the period of 1987 to 2000 from 4.9 to 31.1 km^2 respectively. Kamh *et al.* (2012) found the urban area increased during the period of 1987 to 2005 from 8 to 31.67 km^2 respectively. The total area of road network along study area increased by 8.738 km^2 for the period of 39 years from 1972 to 2011. Vanderstraete *et al.* (2006) found the road area increased from 1987 to 2000, the average increase changed from 0.12 to 0.25 km^2 respectively. In Kamh *et al.* (2012), the total road network expansion increased from 1987 to 2005 from 0.12 to 0.26 km^2 respectively.

Indirect impact to these urbanization severally investigated, among was that of Madkour (2013) who studied the impact of human activities on heavy metal contents of many coral reef environments along the Egyptian Red Sea coast. He concluded that the highest values of metal content infected coral reefs at Hurgahda and Safaga associated with urban expansion and harbors construction. Such heavy metals polluted the marine ecosystem and lead to death of living corals and other grasses. Mohamed & Mohamed (2005) on the other hand, investigated the ecological factors threatening the life of coral reef communities at Hrghada. They concluded that 26 reef assemblages affected by high temperature, exposure to solar radiation and sedimentation and turbidity in sea water either as human impact or naturally of terrestrial run off through desert wadis (Fabricius 2005). Fine grained sediments resulting f rom dredging activity badly affect the living corals nearby. Such dredging of coral reef also would have a negative effect on the stability of the beach and cause losses and damage for the recreation facilities.A localized death in the coral communities due to pollutions from sewage discharge and as a result of spillage of phosphate dust during loading of phosphate minerals onto ships are not excluded. Similar conclusion was mentioned in Abu Hilal (1985) at the Gulf of Aqaba. It is interesting to mention that the landfilling (accretion) at Hurghada with a total area of 6.00 km^2 of which 2.68 km^2 during the period from 1984 to 1992 and 3.32 km^2 during the period from 1992-2004. Most of dredging (erosion) came later during 2004 to 2011 with a total dredging area of 1.51km^2 (Figure 3 in table). The latter is accompanied to expansion (8.12 km^2) in urban (Figure 4 in table) and road networks (5.75 km^2) (Figure 5 in table). This explains that most of resort beaches and villages were constructed on landfilling areas on the expense of the submerged beach rock and reef tracts of which 2.35 km^2 were lost during the period from 1984-1992

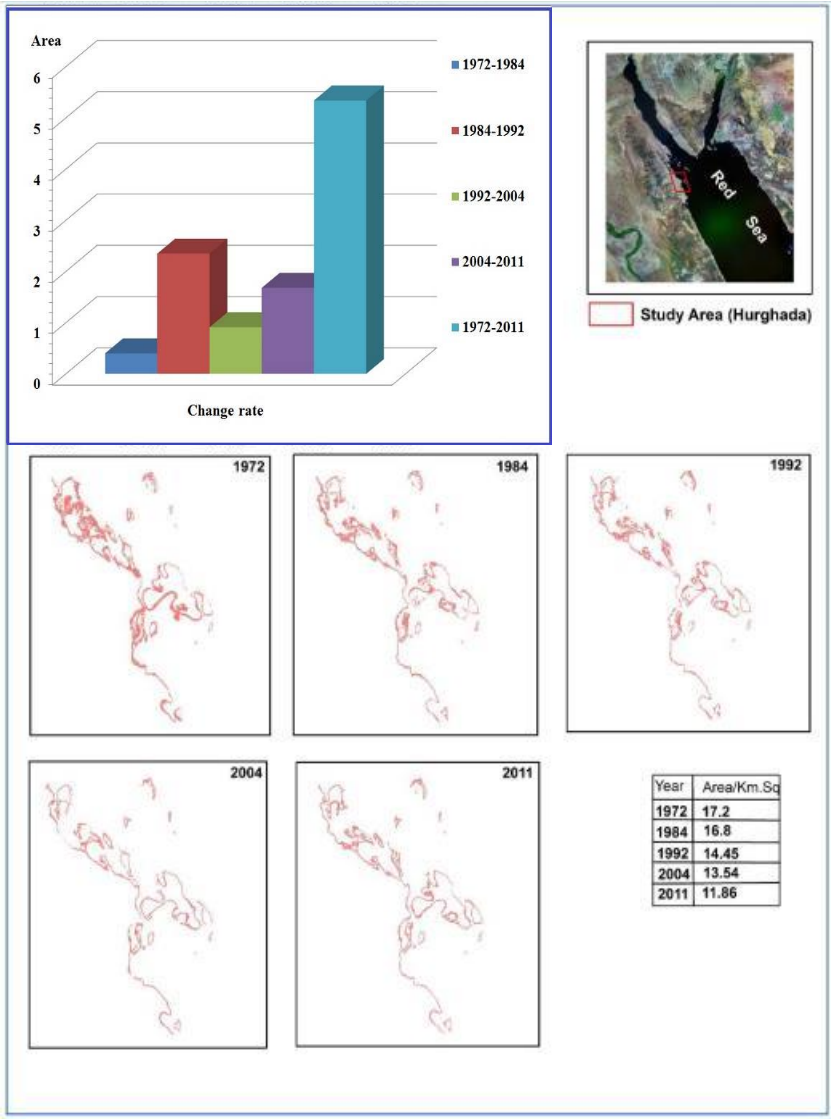


Figure 6. The status of development of coral reefs along the Hurghada between (1972-2011). The rates of changes recorded in attached table and graphically represented (modified after Khaled 2013).

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Finally, Hurghada provides a very clear example of the conflict between rapid and uncontrolled tourism development and the environment in Egypt. In the last ten years, the population of Hurghada has increased more than ten times, the number of Hotels reached 127 hotels and resorts with about 40,000 beds, these expected to be doubled within a few years. Many developments have taken place in the littoral zone and even on parts of the reef flat, which has been land filled or dredged (Figure 2). Land filling sea, dredging beaches and building within the 200 meters set-back zone (Figure 2), is the challenging conditions facing the EEAA in enforcing the environment laws in Hurghada. Recent statistics show that more than 60% of the tourism development projects in Hurghada built on landfilling over a total area of 1.7 million hectares (Borhan *et al.* 2003).

Several steps are required to overcome human incursion on coastal areas. It is interesting to mention that most of these steps previously recommended in Frihy *et al.* (1996) and in Borhan *et al.* (2003), however, the problem still exists. In fact, the situation does not lack for new laws, but the activation of existing laws, toughening the penalties, whether on investors or owners of properties or offender tourists themselves are required. A large number of cases have referred to the State Attorney for the violation of the law number 4/1994 and its executive regulation ER 338/95, either by land filling works or changing the coastline. Continuous awareness of both executive governance and investors several meetings should convene, in order to enforce the law and resolve the problem without compromising its efficient implementation. Guidelines and measures for present or future development activities in the coastal zone have formulated and certain principles/policies have established. Among are; future landfilling or dredging activities will not allowed, shifting of the plans to landward direction to allow for a two hundred meters distance between buildings and the coastline, especially in virgin land zones, and establish pass ways/passages between neighboring sites with a minimum width of 10m for emergency access. An environmental impact assessment (EIA) report should submit with the request/application for all new projects or extensions of existing projects covered by Law number 4/1994 and its executive regulations. Establishment of coastal building front Line (CBFL), a limit of any future construction along the coast and reef protection line (RPL), which is a line not to be exceeded by any future shoreline training operations. Mooring and anchoring of boats and ships along the coastline must be controlled and restricted to certain areas. Prevent private marinas and construction of the integrated marinas is essential to serve existing and foreseen need.

6. Conclusions

The present study introduces the satellite images for environmental impact assessment and change detection of the coastal ecosystem at Hurghada, Red Sea coast, Egypt. To achieve this study, satellite images representing the period of 39 years from 1972 to 2011, in addition to field observations are used. This study demonstrates shoreline changes due to dredging (erosion) of 2.67 km^2 and landfilling (accretion) of 7.56km^2 from the coast for the purposes of resort facilities, with consequent expansion of the urban by 16.47 km^2 and the road networks by 8.738 km^2. Dredging and landfilling for resort constructions come on the expense of reef flat in order to widen the beach and keep 200 meters set-back zone. However, no one of investors committed with the legislation controlled such development. These are the major challenging conditions facing the EEAA to enforce the environmental laws along the Red Sea coast of Egypt.

In absence of active legislations accompanied with severe governmental corruption several serious encroachments on the coastal ecosystem led to loss of reef tracts evaluated at the coast of Hurghada to be equal to 5.34 km^2, with great deterioration in the biodiversity of the coastal ecosystem. Implementation of environment laws, applying judicial officers, toughening severe penalties and establishment of coastal building front line (CBFL), and reef protection line (RPL) are important tasks to keep the intangible virgin areas of the coastal ecosystem.

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