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Remote sensing and GIS for monitoring coastal changes in El-Alamein area, Matrouh, Egypt

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1. Abstract

Coastal areas are very dynamic because they are influenced by different anthropogenic and natural factors. Therefore, it is very important to assess the temporal changes in land use and land cover (LULC), and shoreline. The present study aims to monitor changes in shoreline and LULC in the El-Alamein area, Egypt. Radiometrically corrected multi-temporal Landsat images dated 2000, 2010, and 2020 were processed to produce LULC maps and to delineate shorelines to assess changes using ENVI 5.3 and ArcGIS 10.5. A field trip was conducted to identify the main LULC units and to improve the resultant maps. Results showed that the El-Alamein coastal area was greatly impacted by land reclamation and urban growth in the last two decades, with urban areas increasing from 11.13 km2 in 2000 to 22.67 km2 in 2010 to 55.83 km2 in 2020. Further, the vegetation class increased from 15.63 km2 in 2000 to 52.17 km2 in 2010 to 86.41 km2 in 2020. Shoreline maps show that the total areas of accretion and erosion were 1.3380 and 0.3067 km2 during (2000-2010), as well as 0.3541 and 0.6205 km2 during (2010-2020), respectively. A higher rate of accretion was reported in the first period (2000–2010), while in the second period (2010–2020), erosion was predominant. It can be concluded that the El-Alamein coastal area is considered one of the pioneering regions of development that showed a positive impact on the land resources. It's recommended to regularly assess the changes that might occur to mitigate the potential hazard.

Keywords: Remote sensing, shoreline changes, land use/cover, El-Alamein

2. Introduction

Coastal areas are very important for human beings as they witness cultural and economic exchanges between different nations. Most of the big cities that have famous harbors around the world are situated in coastal areas. One-third of the world's population lives near or on the seashore. Due to abundant natural resources, urbanization and the population have rapidly increased in coastal areas **(El-Zeiny et al., 2016)**. Both anthropogenic (e.g., coastal development) and natural pressures (e.g., coastal erosion and accretion) disturb the delicate nature of coastal zones, particularly shoreline morphodynamics, which influence the socioeconomic environment in that area **(Emam and Soliman, 2020)**. Various developmental projects are distributed in the shoreline areas, placing great pressure on them, leading to diverse coastal hazards like sea erosion, seawater intrusion, coral bleaching, shoreline change, etc.

The total length of the Egyptian Mediterranean coastline is about 995 km, and the western coastline of Egypt, from Alexandria to Sallum on the Egyptian/Libyan border, is about 550 km long. They are considered one of the most intensive sites of tourism development due to their unique aesthetic values and recreational potential **(El-Sharnouby et al., 2015; Frihy and Deabes, 2012)**. The coastline is remarkably characterized by the existence of unconsolidated Pleistocene carbonate ridges, which are the most prominent geomorphologic features in this region **(Butzer, 1960; Fourtau, 1893; Said et al., 1956; Shukri et al., 1956)**. Generally, coastal landforms are highly dynamic **(Kumaravel et al., 2013)**.

In the 1980s, as recreation and tourism have economically become more important at the shoreline, coastal development, in the form of recreation resorts, has increased along the western coast of Egypt. Among these resorts, a large-scale recreation center was developed in 1989 at Historic El Alamein, about 94 km west of Alexandria. El-Alamein region is best known as one of World War II's most active battle sites (**Delft Hydraulics, 2000**). The success of the establishment of New El-Alamein city will motivate building many eco-city projects in Egypt that address broader global issues of climate change and sustainability **(Salama et al., 2020)**. In 1989, a group of natural wetlands backing the coastline of El Alamein was artificially modified into a large recreation lagoon which has been the cornerstone of the El Alamein Marina Resort, these lagoons used to be hypersaline and were formed naturally along this area (**Lindell et al., 1991**).

Remote sensing technology has proven to be of great importance in acquiring data for effective resource management and hence could also be applied to coastal monitoring and management. Further, the application of Geographical Information Systems (GIS) in analyzing the trends and estimating the changes that have occurred in different themes helps in the decision-making process **(Ramachandran, 1993; Ramachandran et al., 1997).**

The availability of repetitive, synoptic, and multi-spectral data from various satellite platforms (e.g., IRS, LANDSAT, SPOT) has helped to generate information on varied aspects of the coastal and marine environment **(Nayak, 2002).** Remote sensing has also been widely used in environmental change detection studies. The integration of different modern scientific tools (i.e., remote sensing, GIS, and GPS) is extremely valuable in the development and analysis of databases. Such integration is also valuable for the development and elaboration of management action plans **(Mass, 1999; El-Zeiny et al. 2016).**

Human interventions along the northwestern Egyptian Mediterranean coast recently interrupted the stability of the Marina El-Alamein shoreline and resulted in spit evolution. Considering Egypt’s vision 2030 for developing the northwestern Egyptian coast, continuous and up-to-date monitoring programs have become essential to ensure sustainability **(Emam and Soliman, 2020)**. Generally, the earth's surface is continuously changing due to natural or human activities; for example, pests, agro-forestry, lightning strikes, wildfires, storms, agricultural expansion, economic, technological, social, and historical factors, and urban expansion **(Borak et al., 2000)**.

Usually, the changes on the earth’s surface are categorized into land use and land cover (LU and LC). To recognize and analyze the environmental impacts of LULC change, up-to-date, precise information on LULC change is required **(Barnsley et al., 2001; Giri et al., 2005)**. Digital change detection is the process of determining and describing land cover changes and land-use characteristics based on co-registered multi-temporal remotely sensed data. Currently, El-Alamein New City witnesses widely spread construction activities, including the establishment of new urban, industrial, and mega projects, which require more knowledge and investigations into different aspects **(Salama et al., 2020)**.

In this study, remote sensing and GIS techniques were utilized to monitor and quantify temporal changes along the shoreline of El-Alamein, Matrouh Governorate, and determine the hazardous effect due to erosion and accretion and its rate. Further, it aims to assess landscape characteristics and changes in the El-Alamein area.

3. Study area

The study area is located on the northwestern coast of the Mediterranean Sea of Egypt in the El Alamein area, between latitudes 30º 42´ 30″ N and 30º 59´0″ N, longitude 28º 45´0″ E and 29º 12´0 ″ E (Figure 1). El-Alamein is in Matrouh Governorate and comprises Sidi Abdel-Rahman and Tal El-Ais villages. Prior to gaining fame as a battleground, El-Alamein was a small village planted with palm and olive trees. Now it represents one of the newly developed coastal areas which has multiple practices including recreational, commercial, industrial, and urban activities. The study area includes the coast of the new El-Alamein city which is under the lights because of the country's developmental efforts there (**State Information Service, 2018**).

The area has a semiarid Mediterranean climate, characterized by a short rainy winter and long warm summer months (May to September) of clear sky, high radiation, and no rain. The prevailing wave directions (WNW, NW, and NNW) create an easterly longshore current (from west to east). On the other hand, waves approaching from the N, NNE, and NE generate westward-flowing longshore currents (**El-Banna and Hereher, 2009**).

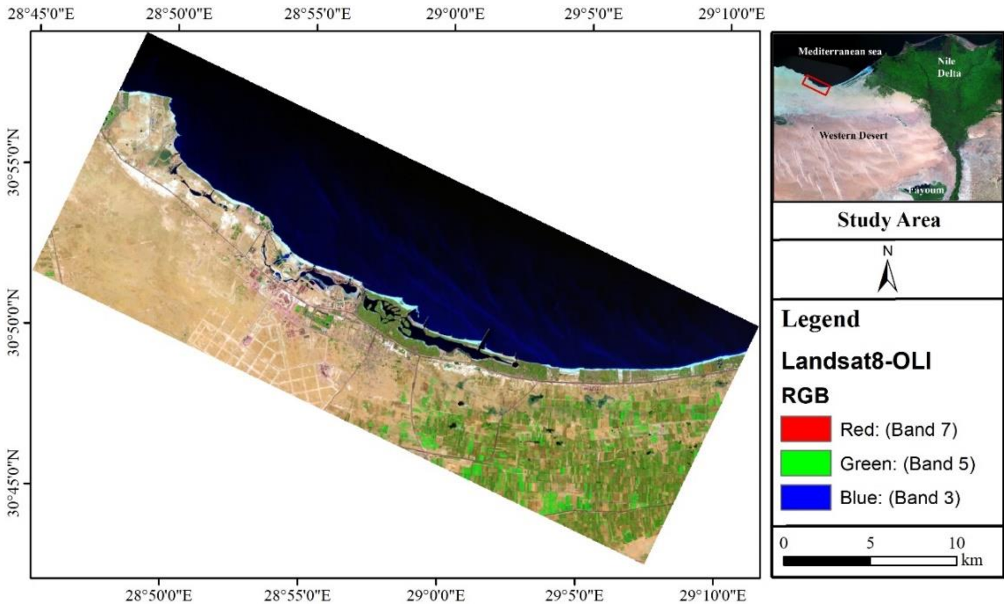

Fig (1). Study area location map

4. Materials and methods

4.1. Satellite data acquisition and pre-processing

Initially, three multispectral Landsat imageries (TM, ETM, and OLI) on July 4, 2000, July 8, 2010, and July 19, 2020 were freely downloaded for the El-Alamein area. The data set was created by the U.S. from the Geological Survey and was obtained in geographic tagged image-file format (Geo TIFF). The data type is level 1, which provides systematic radiometric and geometric accuracy derived from data collected by the sensor and spacecraft. The study area is in one scene: 178–39. Spectral data acquired by satellite sensors is affected by a number of factors, including sensor-target-illumination geometry, atmospheric absorption and scattering, sensor calibration, and satellite data processing procedures, which tend to change with time. To monitor genuine landscape changes as revealed by variations in surface reflectance from multi-temporal satellite imageries, it is necessary to perform the radiometric correction. Radiometric calibration refers to a set of methods applied during image processing that include corrections related to topography and sun angle, the sensitivity of the remote sensor, and atmospheric scattering and absorption **(El-Zeiny and El-Kafrawy, 2017)**. Radiometric calibration and atmospheric correction were the basic preprocessing steps followed by correcting Landsat data, then the scene was spatially cropped to resize the study area.

4.2. Image processing

Image processing is applied to change and alert the original raw data to bring out visual details. To make use of image processing software, the data must be in the form of digital raster data. With these picture elements (pixels), a variety of mathematical operations can be performed **(Abdel-Hamid, 2010)**. They used Landsat data, which is already in digital raster format. Image classification is the procedure of automatically categorizing all pixels of an image into land cover classes **(Lillesand et al., 2003)**. Pixels making up multi-spectral images may be automatically clustered into categories that can be given labels, such as water, vegetation, urban, etc. Therefore, a pixel may be characterized by its spectral signature, which is determined by the relative reflectance of the target area in the different bands **(Sabin, 1997)**. The most common methods of image classification are supervised and non-supervised classification. Supervised classification is a user-controlled technique in which pixels are assigned to classes according to pre-determined training sites obtained previously from ground data, maps, and aerial photographs **(Jensen, 1996).** The primary purpose of image classification is the creation of thematic maps of land cover **(Mesev, 1997)**. Another goal of image classification is to update existing data or to improve the quality of the data. One of the most important types and most accurate classifiers of supervised classification is the Maximum Likelihood Classifier **(Lillesand and Kiefer, 1987)**.

For estimating land use and land cover change using supervised classification of remotely sensed data **(Lillesand and Kiefer, 1994)**. **Chan et al. (2001)** applied this technique as the standard statistical method for classifying remotely sensed data. **Campbell (1996)** showed that the maximum likelihood classifier is considered a powerful classification technique. In this study, it was used to produce a land use and cover map for the study area to define the existing natural resources and the dominant influences on human activities within the El-Alamein area.

4.3. Accuracy assessment

Verification of the identified four classes (urban, vegetation, bare land, and water) was done using ground observation points and Google Earth imagery **(El-Zeiny and Effat 2017)**. A total of 17 ground observation points were used to validate LULC maps in the year 2020 (Fig. 2). To assess the accuracy of the classified images in the years 2000, 2010, and 2020, random samples of verification were identified and used. The land use and cover classes of these samples were checked by visual interpretation using high spatial resolution Google Earth images dated 2000, 2010, and 2020. Accuracy assessment shows the degree to which the derived image classification agrees with reality or confirms the truth **(Campbell 1996)**. Overall accuracy is the most popular measure of accuracy assessment. The locations of these points were converted into ENVI regions of interest (ROI), which were then used to calculate accuracy. On the other hand, Kappa analysis is a discrete multivariable technique used in accuracy assessment that can be used to quantify the level of agreement **(Jensen, 1996)**.

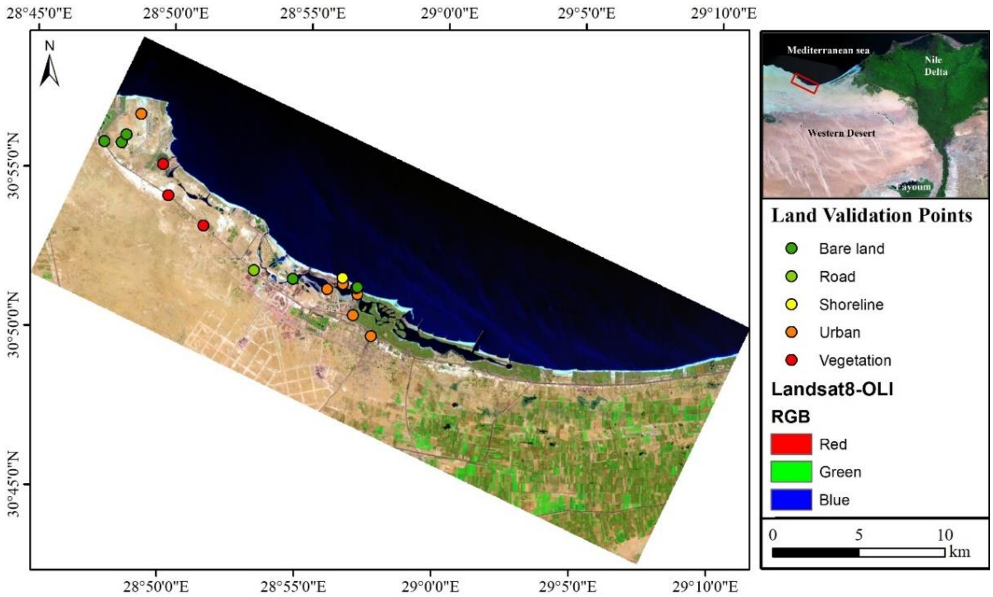

Fig (2): Distribution of LULC field verification points.

4.4. GIS analyses

5.4.1 Shoreline delineation

Combing remote sensing and GIS technologies cannot only supply a platform to support hierarchical integrated analysis on resource and environment but also integrate the obtained information into a comparative theoretical land quality analysis. The most common shoreline detection technique applied to visibly discernible shoreline features is manual visual interpretation, either in the field or from aerial photography, for example, with aerial photography, the image is corrected for distortions and then adjusted to the correct scale before a ‘‘shoreline’’ is either traced directly or scanned into a computer, corrected, adjusted for scale, and digitized, in the field, a GPS is used to digitize the visible shoreline feature in situ, as determined by the operator **(Boak et al., 2005).** The maps in this study were used to extract the shoreline by the on-screen digitizing technique. All data were projected to WGS-84 of the Universal Transverse Mercator System (UTM) of geographic coordinates.

5.4.2 Shoreline change detection

In the current study, quantification of the erosion/accretion rates and areas of eroded and accreted regions was carried out using on-screen digitizing of features that are obvious in the multi-temporal satellite data (i.e., shoreline). A GIS thematic layer was built where areas of erosion and accretion were computed. Simply, a conversion of the GIS polyline into a polygon was carried out to separate areas of erosion and accretion. To facilitate the study of erosion and accretion, the region would be divided into three equal sectors (Sector A, Sector B, and Sector C). Sector A is the western part of the El-Alamein Shoreline. Moving a little eastward, Sector B was located where El-Alamein's new city is found. Sector C represents the eastern part of the El-Alamein Shoreline. Fig (3).

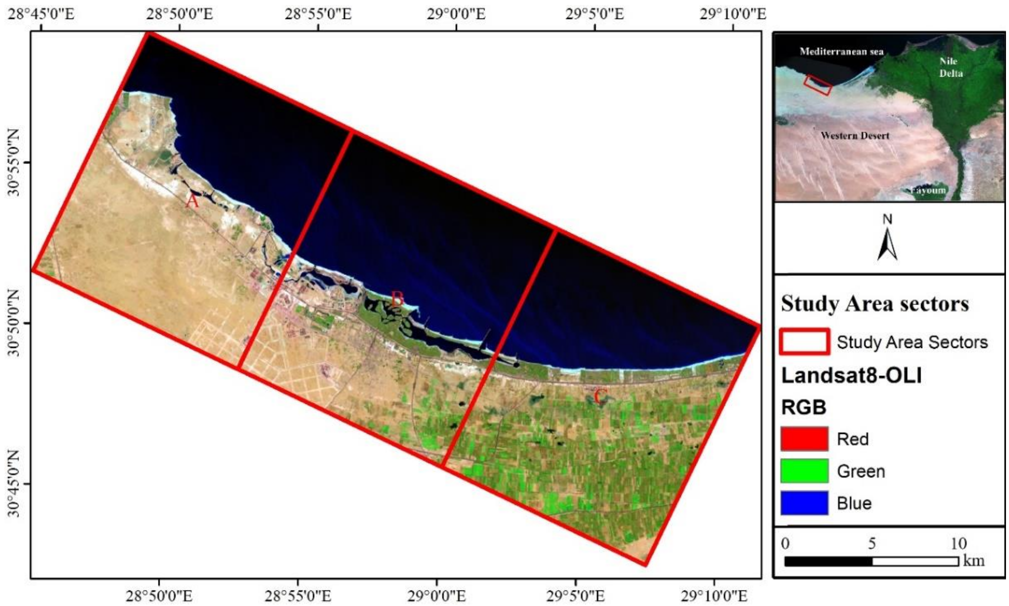

Fig (3) Study area sectors.

5. Results and discussion

5.1. Monitoring the land use and land cover (LULC)

One of the main applications of remotely sensed data is the change detection study to monitor changes in LULC such as modernization, urbanization, and other practices on the environment **(El-Zeiny, and Effat 2017)**. Such changes could explain the impact of human activities on LULC. Three LULC maps were produced in the present study (Fig 4,5,6) to detect the changes. Modernization and urbanization have always been attractive to decision-makers however little attention has been directed to the resultant adverse impacts. In the present study, LULC changes were monitored in the last 20 years (2000-2020) in two different periods: 2000-2010, and 2010-2020.

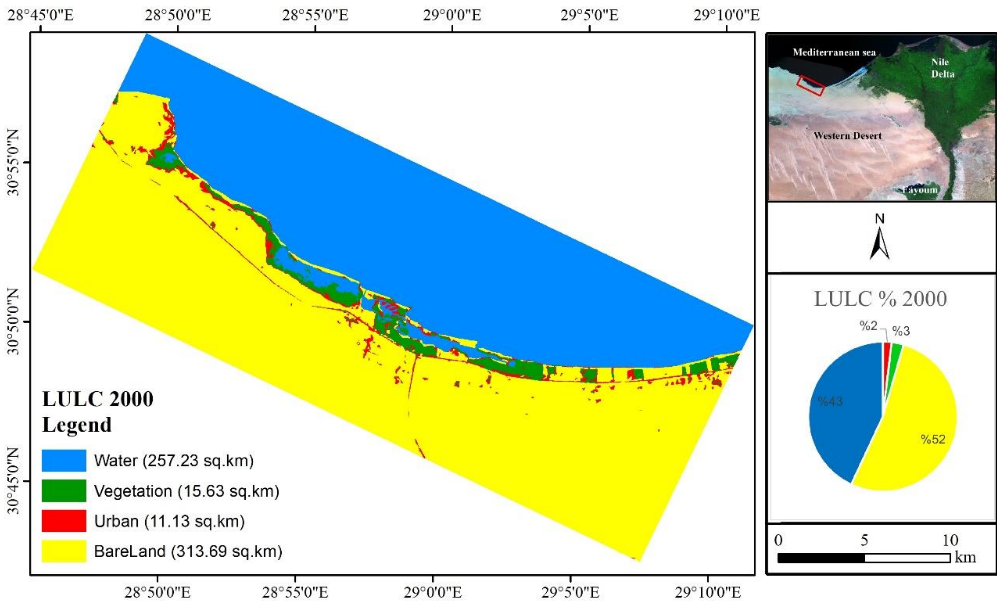

Fig (4): LULC map for Landsat TM image (2000)

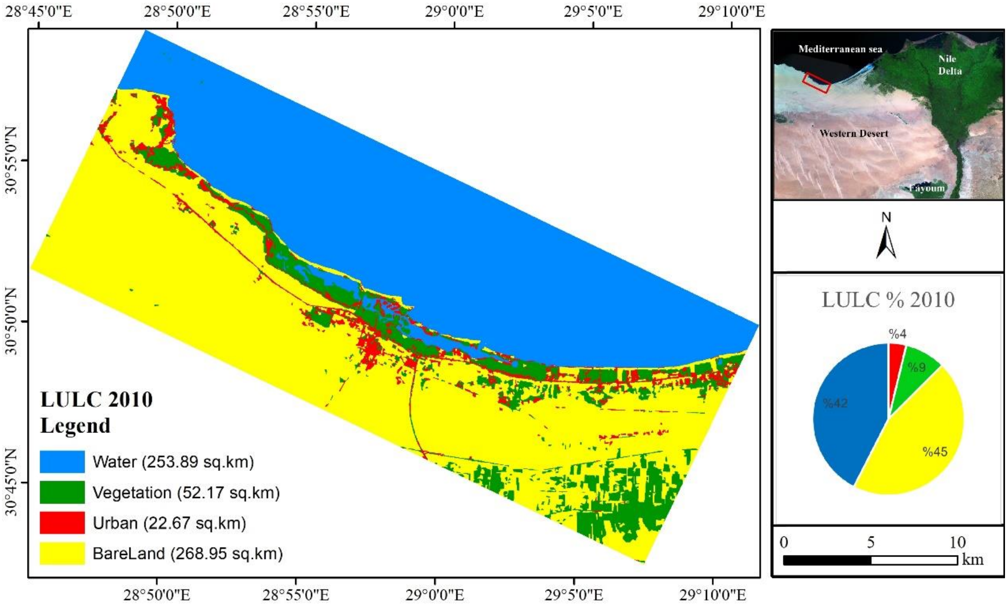

Fig (5): LULC map for Landsat ETM image (2010)

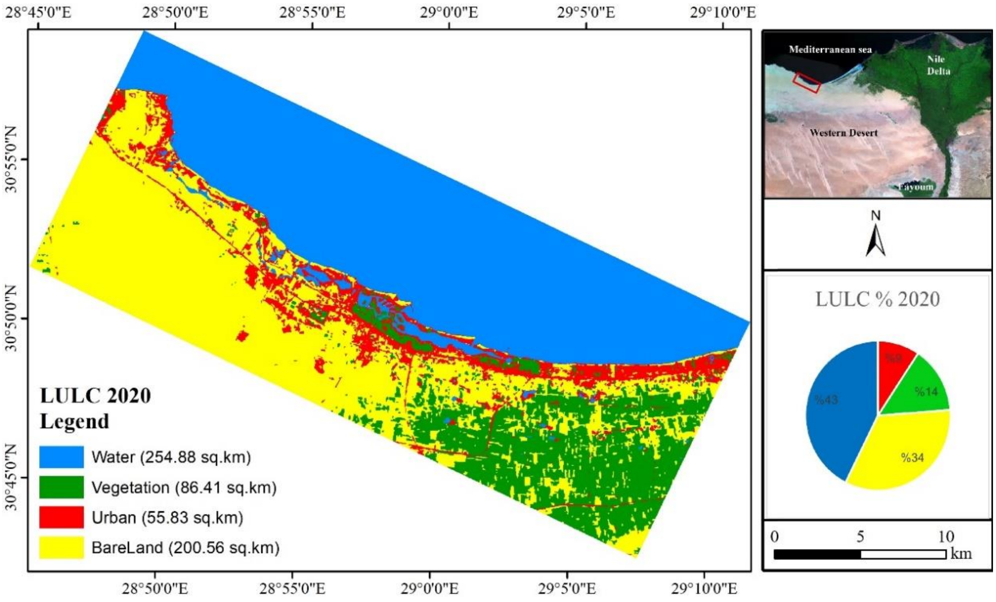

Fig (6): LULC map for Landsat OLI image (2020)

The area of every single LULC class of the three studied years was assessed and calculated on ArcGIS, and it was observed that urban and vegetation areas were increasing with time on account of the bare land areas. The urban class increased from 11.13 km^2 in 2000 to 22.67 km^2 in 2010 to 55.83 km^2 in 2020. Furthermore, the vegetation class increased from 15.63 km2 in 2000 to 52.17 km^2 in 2010 to 86.41 km^2 in 2020.

On the other hand, the bare-land areas decreased with time, from 313.69 km^2 in 2000 to 268.95 km^2 in 2010 to 200.56 km^2 in 2020. However, the class of water areas was subjected to a non-significant change. It was noticed that the periodic increase in urban areas and agricultural lands were synchronized with a decrease in the bare land areas during the whole period of study (Fig 7). This loss indicates the impact of governmental projects on LULC **(El-Zeiny and Effat 2017)**.

The maximum periodic decrease in the bare land areas was recorded in the period 2010–2020 (68.39 km^2), while the minimum decrease was detected during 2000–2010 (44.74 km^2). On the other hand, a remarkable increase in urbanization was observed during 2010–2020, recording 33.16 km^2, and a remarkable increase in vegetation was reported during 2000–2010, recording 36.54 km^2. This can be explained as an impact of the area's developmental projects (i.e., urban development and land reclamation) that remarkably influenced land cover during the whole period of study (2000–2020).

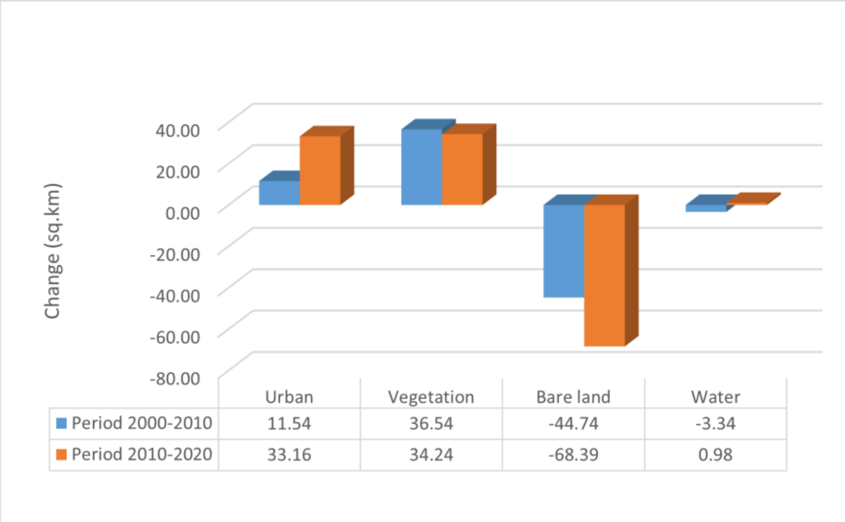

Fig (7): Periodic changes/ in LULC classes

5.2. Overall accuracy

The overall accuracy obtained was 99.54%, 99.16%, and 98.10% for 2000, 2010, and 2020, respectively. The maximum accuracy was obtained for the LULC map in the year 2000 applied on the Landsat TM image while the minimum accuracy was recorded in the year 2020 for the Landsat OLI image. The Kappa coefficient results for the classification maps obtained were 0.99, 0.986, and 0.96 for 2000, 2010, and 2020, respectively (Table 1).

Table 1: Accuracy assessment for LULC maps at different years.

Year	Overall Accuracy %	Kappa Coefficient
2000	99.54	0.99
2010	99.16	0.986
2020	98.10	0.96

5.3. Monitoring shorelines changes

El-Alamein shoreline is one of the most dynamic parts which undergo remarkable changes (i.e., erosion and accretion) during the two studied periods (i.e., 2000-2010, and 2010-2020) (Fig 8, 9). The eroded and accreted areas during the two periods are shown in (Table 2) and (Fig 10). The total areas of accretion and erosion were 1.3380 and 0.3067 km^2, respectively during (2000-2010), as well as 0.3541 and 0.6205 km^2 during (2010-2020). This indicates that the study area was subjected to a higher rate of accretion than erosion in the last two decades.

Compared with **Emam and Soliman, 2020**, their results revealed that during 1987–2017, the Marina El-Alamein shoreline experienced very high accretion along the western side. On the other hand, the eastern side of the resort experienced erosion with a maximum distance of 92.78 m. Regarding changes in the total area, Marina El-Alamein’s coast gained 1.130 km^2 (0.038 km^2/year) of land and lost 0.1115 km^2 (0.004 km^2/year) of its total area throughout the last 3 decades (1987–2017).

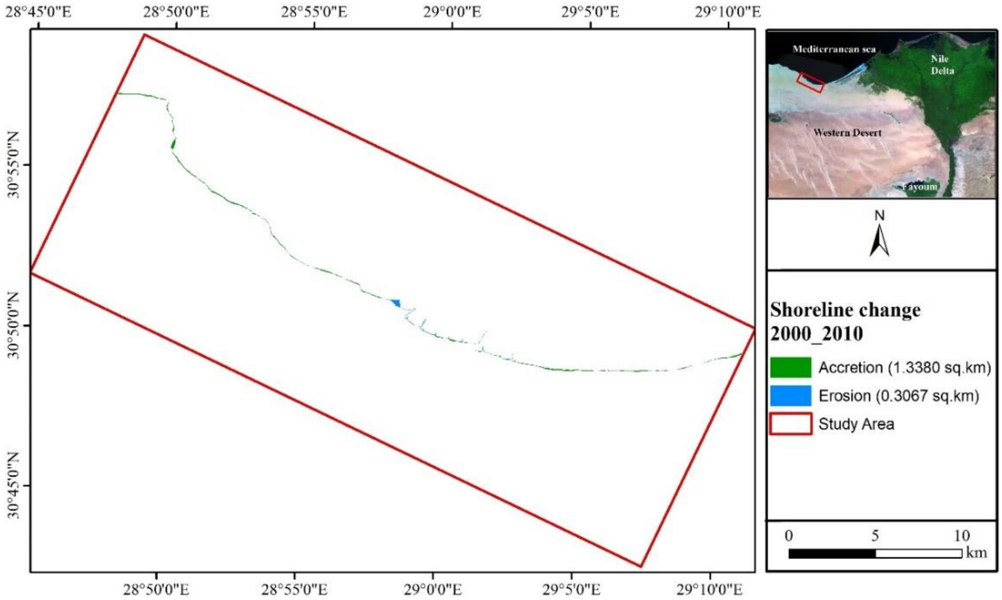

Fig (8): Change in shoreline from 2000 to 2010.

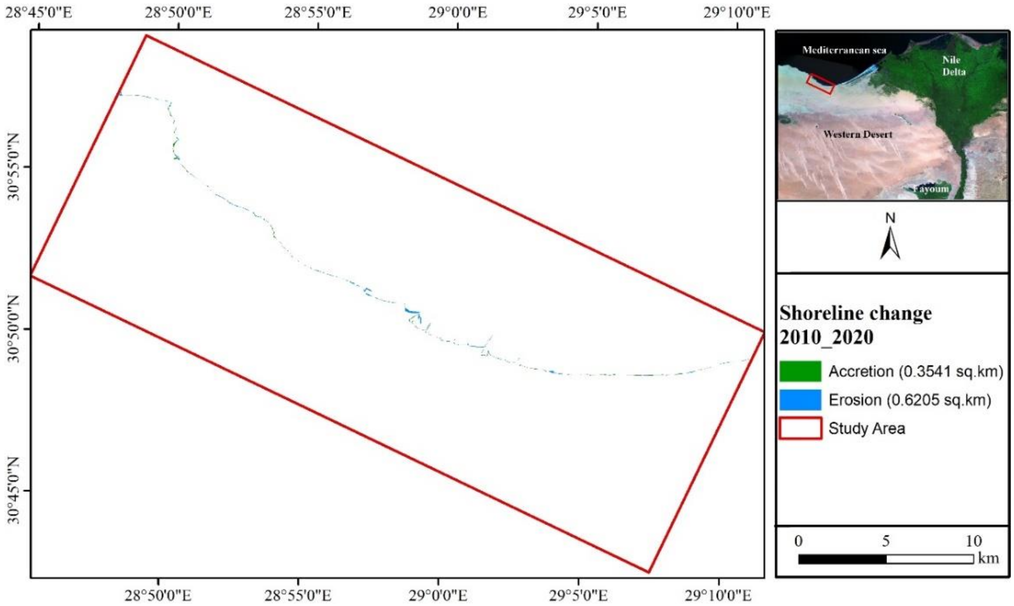

Fig (9) Change in shoreline from 2010 to 2020.

Table (2): The total accreted and eroded areas km^2 in the two periods

Period	Accreted area (km²)	Eroded area (km²)
2000 to 2010	1.3380	0.3067
2010 to 2020	0.3541	0.6205

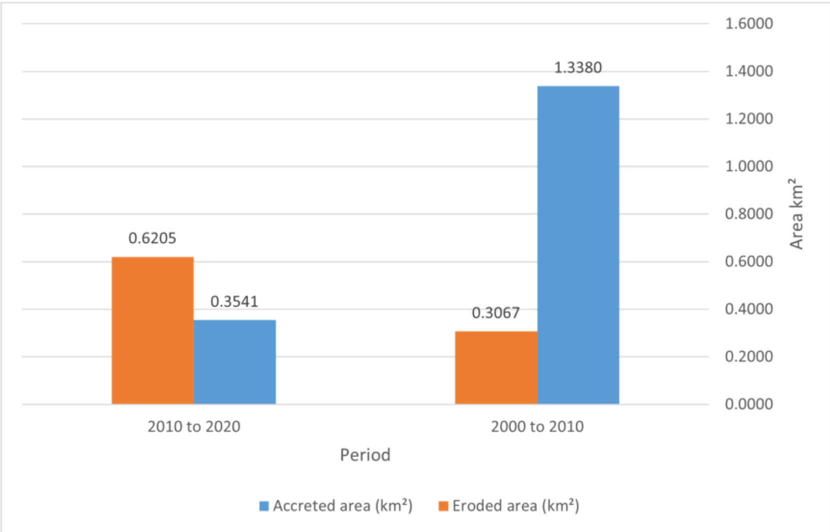

Fig (10) Erosion and accretion in 2000-2010 & 2010-2020 periods

The study area was divided into three equal sectors (A, B, and C) to easily illustrate the differences in erosion and accretion in each period (Fig 11, 12). The most significant accretion in the first period (i.e., 2000-2010) was in sector A (0.6047 km^2) and the most significant erosion was in sector B (0.2679 km^2). However, in the second period (i.e., 2010-2020) the most significant accretion was in sector C (0.1303 km^2) and, the most significant erosion was in sector B (0.3176 km^2). In the first period (i.e., 2000-2010) areas of accretion can be ordered as follows; 0.6047 km^2 (Sector A) >

0.4503 km^2 (Sector C) > 0.2825 km^2 (Sector B). However, the eroded areas ordered as follows; 0.2679 km^2 (Sector B) > 0.0360 km^2 (Sector C) > 0.0027 km^2 (Sector A). In the second period (i.e., 2010-2020), areas of accretion ordered as follows; 0.1303 km^2 (Sector C) > 0.1217 km^2 (Sector A) > 0.1021 km^2 (Sector B). However, the eroded areas ordered as follows; 0.3176 (Sector B) > 0.1933 km^2 (Sector A) > 0.1093 km^2 (Sector C) (Table 3) and (Fig 13). Spatiotemporal shoreline analysis along the Marina El-Alamein coast revealed more accretion than erosion during the studied intervals as also reported in **(Emam and Soliman, 2020)**.

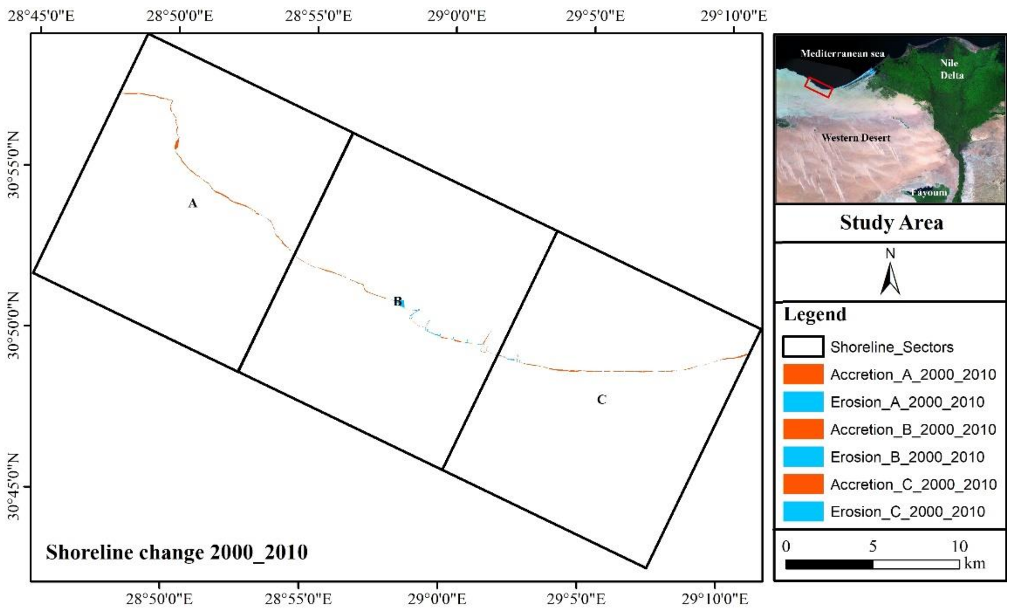

Fig (11) Shoreline change 2000-2010.

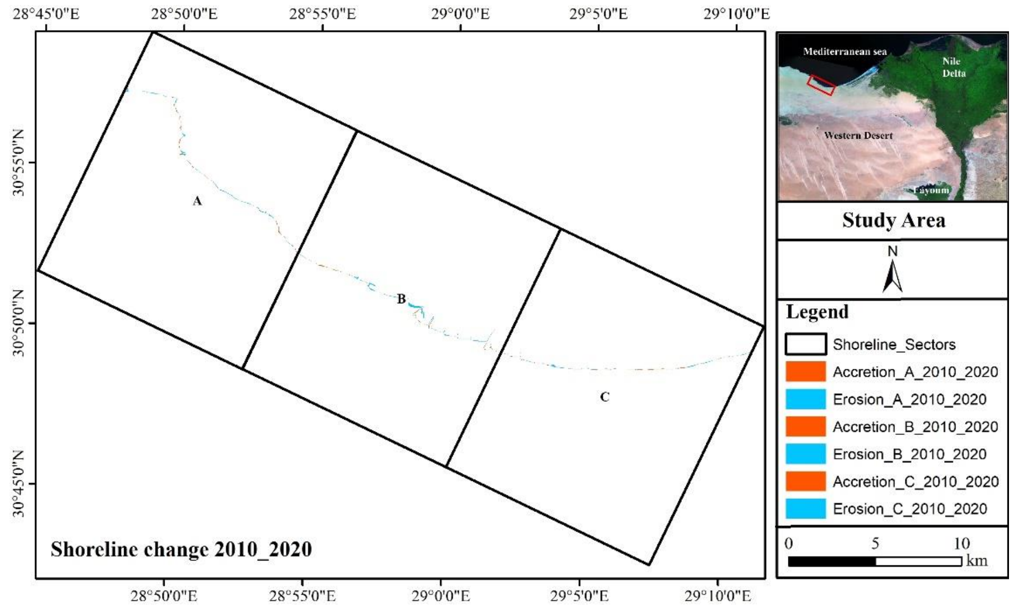

Fig (12): Shoreline change 2010-2020.

Table (3) The eroded and accreted areas km^2 in sectors.

Period	Sectors	Accreted area (km²)	Eroded area (km²)
2000 to 2010	A	0.6047	0.0027
	B	0.2825	0.2679
	C	0.4503	0.0360
2010 to 2020	A	0.1217	0.1933
	B	0.1021	0.3176
	C	0.1303	0.1093

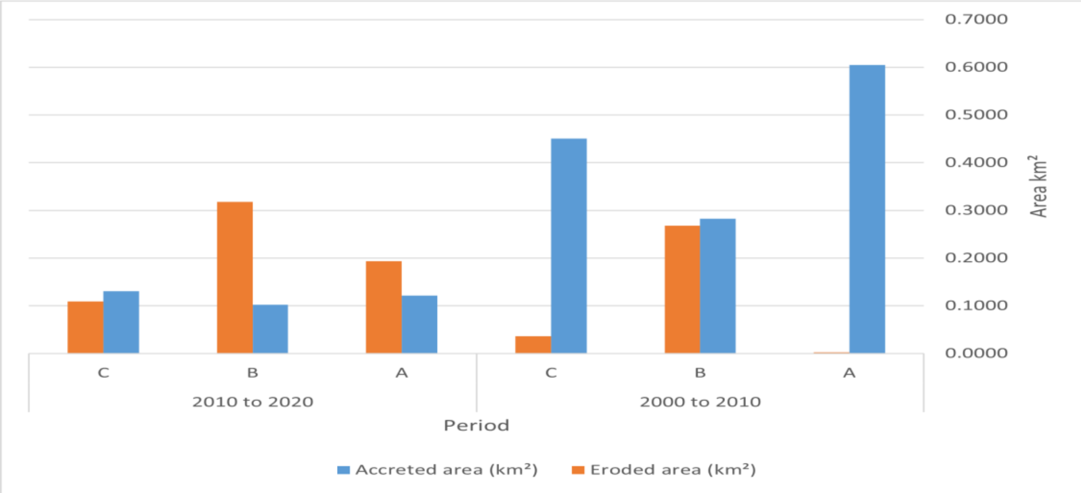

Fig (13) Erosion and accretion in 2000,2010 & 2020 shorelines sectors

6. Conclusion

Remote sensing technology was utilized in the present study to delineate and monitor LULC and LST changes in the El-Alamein area, which proved of great importance in acquiring data for effective resource management and hence could also be applied to coastal monitoring and management. It can be concluded that the study area is very dynamic and subject to a high rate of accretion. The most significant accretion in the first period (i.e., 2000–2010) was in the western sector (0.6047 km2), and the most significant erosion was in the middle sector (0.2679 km2). The LULC assessment maps noted a continuous increase in the total areas of urban and agricultural lands as a result of land reclamation and urbanization projects in the El-Alamein region. Strategic environmental monitoring programs, coupled with long-term considerations, are required when developing coastal engineering structures to ensure the sustainability of available natural resources with the aid of space-borne technology.

7. Acknowledgment

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