ASSESSING THE IMPACT OF CLIMATE CHANGE AND SEA LEVEL RISE ON THE SHORELINE OF ALEXANDRIA CITY – RECREATION AREA

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Abstract

Coastal areas, the most attractive for a tourists, are becoming increasingly threatened by climate change and sea level rise (SLR) which led to increase the coastal erosion. Shoreline change is used in the detection of coastal erosion in coastal areas. The Digital Shoreline Analysis System (DSAS) with ArcGIS can be used in monitoring the shoreline change using a number of statistical measures including; Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR). This study aims to assess the impact of SLR due to climate change on Alexandria coasts. GIS and RS with DSAS were used in monitoring changes in the shoreline of Alexandria. The satellite images of 30 m resolution were used for the period (1985-2021) and geomatically corrected using Supervised Classification to determine the land uses and land cover changes. GIS was used for change detection, monitor changes in the land use and shoreline and predict the future changes in the shoreline for 10 and 20 years. The results showed that Alexandria shoreline has moved inland with different values along the coasts in the period (1985-2021) and the predictions showed more increase in 2031 and 2041. Results of this study could help policymakers to plan adaptation strategies to mitigate these impacts.

Key words: Climate change, sea level rise, shoreline change, RS, GIS, DSAS.

Introduction

Climate change and sea level rise presenting a number of challenges in coastal areas. Climate change is increasing as a result of human activities and natural processes and If it continues, it could have a variety of undesirable impacts including; flooding, drought, erosion and wetlands loss. In the 20^{th} century, the global mean sea level rise has been increased to be (10-20 cm) (IPCC, 1996). By 2100, SLR is expected to be between 20 and 88 cm (IPCC, 2001). SLR could have long-term effects on coastal areas including; coastal erosion, submergence, saltwater intrusion into coastal aquifers, loss of agricultural land, and rise in the coastal water table (Abd-Elhamid 2010).

The Mediterranean basin is one of the most vulnerable regions to climate change. The southern parts of the Mediterranean basin is more threatened than the northern parts (Nicholls and Hoozemans, 1996). Egypt’s North coasts are subject to highly risk due to its relatively low elevation (El Raey et al., 2005). Alexandria is the most important Egyptian cities on the Mediterranean that has big investments in different sectors such as tourism, industry and agricultural. Egypt Second National Communication Report, 2010 has expected sea inundation will lead to emigration of 6.5 million people from Alexandria in 2100 working in the tourism field.

A number of studies assessed the impacts of sea level rise on Egypts northern coasts including Alexandria (e.g. El-Raey et al., 1995-2005-2010; Frihy, 2009, Abou-Mahmoud, 2021). These studies showed that Egypt will face the following consequences: inundation and loss of beaches, loss of tourism, loss of agricultural and fishing land. Also, contamination of fresh water aquifer, soil salinity, water logging, agricultural losses and loss of land productivity due to saltwater intrusion. Egypt is among the top countries in the world expected to be most affected by sea level rise (Dasgupta et al., 2007). Some studies have been conducted to assess the potential impact of SLR on Egyptian coasts and reported areas of high-risk in the Nile delta, Alexandria, Beheira, Port Said and Damietta.

RS and GIS could help in risk monitoring and management. Satellite data is helpful to give overview of large and regional scales. Satellite data have been used in monitoring the effect of climate change on Nile Delta (Abdel Hamid et al., 1992). Shoreline geometry is an important parameters in the detection of coastal erosion and deposition and the study of coastal morphodynamics. Digital Shoreline Analysis System (DSAS) with ArcGIS can be used in measuring, quantifying, calculating and monitoring shoreline change. A number of statistical change measures within DSAS including; Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR) (Temitope, 2004). This study aims to assess the impact of climate change and sea level rise on the shoreline and innundiation of Alexandria city. GIS with DSAS were used in this study for shoreline change detection after collecting the required data from satalite images for the period (1985-2021).

Material and methods

Case study

Alexandrial is located on the northern coasts of Egypt (30°50\ to 31°40\ N, 29°40\ to 32°35\ E) and extent for 60 km length along the Medereranian Sea (see Figyre 1). It is the third-largest city in Egypt after Cairo and Giza, the total area is 2679 km^2 and population about 5.2 million (2022). The climate is influenced by the Mediterranean Sea, moderating its temperatures, causing variable rainy winters and moderately hot summers, with daily maximum temperatures (12 to 18°C) and minimum temperatures 5°C. The land use of the city is varied between agriculture areas, urban areas, water areas and desert as shown in Figure 1.

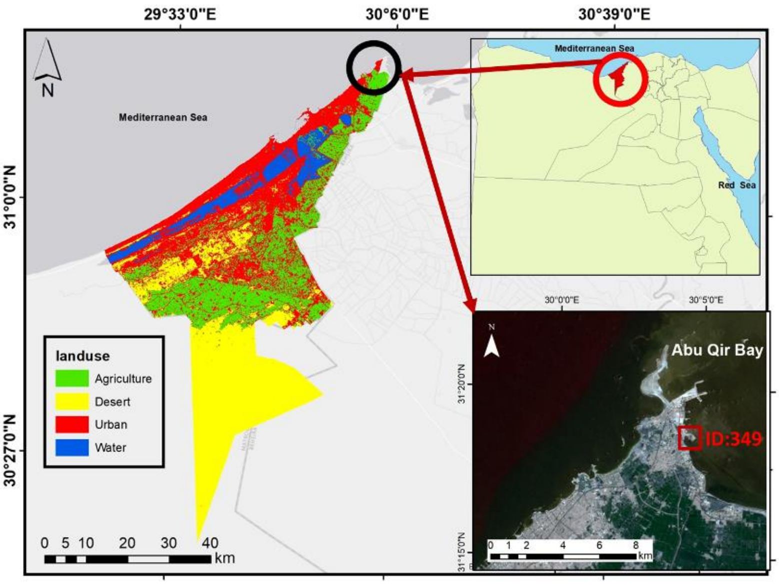


Fig. 1: Location map of the study area

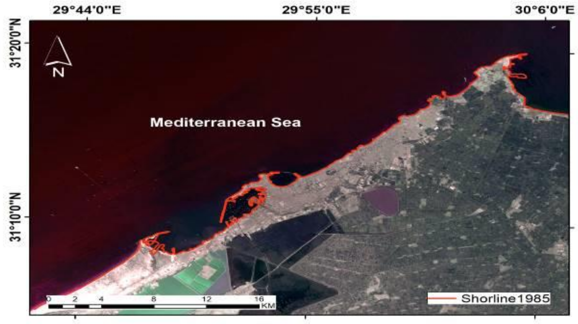
Methodology

The Digital Shoreline Analysis System (DSAS) is an important GIS tool that can be used in a number of studies including; monitor past and present shoreline positions and geometry, evaluating coastal behaviour, shoreline dynamics, historical trend analysis, coastal system dynamics, shoreline changes, cliff geometry modelling and estimations, mapping of historic configurations of shoreline position over the period covered by available spatial data, evaluation of historic changes and trends, evaluate the time-series of change at specific locations of shoreline and predict patterns of shoreline behaviour (Temitope, 2004). DSAS provides a number of statistical measures, including the Shoreline Change Envelope (SCE); is a measure of the total change in coastline movement taking into account all known shoreline positions. Net Shoreline Movement (NSM); is the distance between the oldest and youngest shorelines is known as. End Point Rate (EPR); is calculated by dividing the distance between the oldest and youngest coastline points by the time elapsed between them (Thieler et al., 2009). GIS and RS are one of the modern techniques that links climate data with its spatio-temporal framework to show the changes that may occur due to climate change. GIS and RS with DSAS are used to assess and model climate changes and sea level rise impacts on the shoreline of Alexandria city during the period (1985-2021) and its future projections.

The work has been done on four steps as following. (I) Data collection, which represents the collection of topographic maps of Alexandria and LANDSAT satellite images with a resolution of 30 meters from1985 to 2021 for five periods (1985-1995-2005-2015-2021) from USGS. Then Geometric Correction and Atmospheric Correction have been done for the collected data to be used in creating database of shoreline using ArcMap. (II) Data storage and retrieval; this step includes the process of digitizing the data and storing with linking to each other to facilitate recall, using GIS and RS. (III) Data processing and analysis; this step represents changing the pattern and level of the data and removing input errors through the process of creating and updating the data. This step includes digital processing of satellite images, including the Supervised Classification process to determine the land uses and shoreline, and then a change detection process for the images. ENVI.5 program is used to detect changes in the land use and shoreline for the collected satalite images for the period (1985-2021). ArcGIS 10.8 is used to create geodata base for the shoreline and base line of the study area. DSAS tool was connected to ArcGIS and used to detect the changes in the shoreline and forecast the future movement of the shoreline for 10 and 20 years. (IV) Data presentation; in this step database is represented and displayed in forms of maps, tables, graphs, images and reports and presenting them to decision makers.

Results and discussion

GIS with DSAS have been used to detect shoreline change in Alexandria city due to climate change and sea level rise for the period (1985-2021). DSAS was used to digitize shoreline changes from maps, and NSM and EPR were calculated. The distance between the oldest (1985) and youngest (2021) shorelines is calculated by NSM, and it shows the total change in shoreline position over a 36 year. By dividing the distance of shoreline movement from the earliest to most recent shorelines by the time period, EPR is the net shoreline movement into an annual rate of shoreline change. Figures 2a-e show the shoreline of Alexandria for the selected five periods (1985-1995-2005-2015-2021). The maximum Net Shoreline Movement (NSM) is 213.7 m and the maximum errosion rate (End Point Rate, EPR) is 5.94 m/year.



(a) 1985

(b) 1995

(c) 2005

(d) 2015

(e) 2021

Fig. 2: The shoreline of Alexandria city (1985-2021)

It has been observed that eastern parts of Alexandria are highly affected by coastal errosion and the shoreline has moved more inland but the west and middle parts have less effects due to the excistance of some defence structures that constructed in the last decade. A pilot area (Abio Qir Bay) has been selected in the eastern part of Alexandria as it is highly affected by the coastal errosion. Figures 3a-e show the shoreline at Abio Qir Bay for the five periods from 1985 to 2021. The maximum Net Shoreline Movement (NSM) is 129.24 m and the maximum errosion rate (End Point Rate, EPR) is 3.59 m/year. Then DSAS and GIS were used to forcast the shoreline after 10 and 20 yeras as shown in Figures 4a and b. The results reveal that the eastern part of Alexandria has exposed to high errosion in the study period.

(a) 1985

(b) 1995

(c) 2005

(d) 2015

(e) 2021

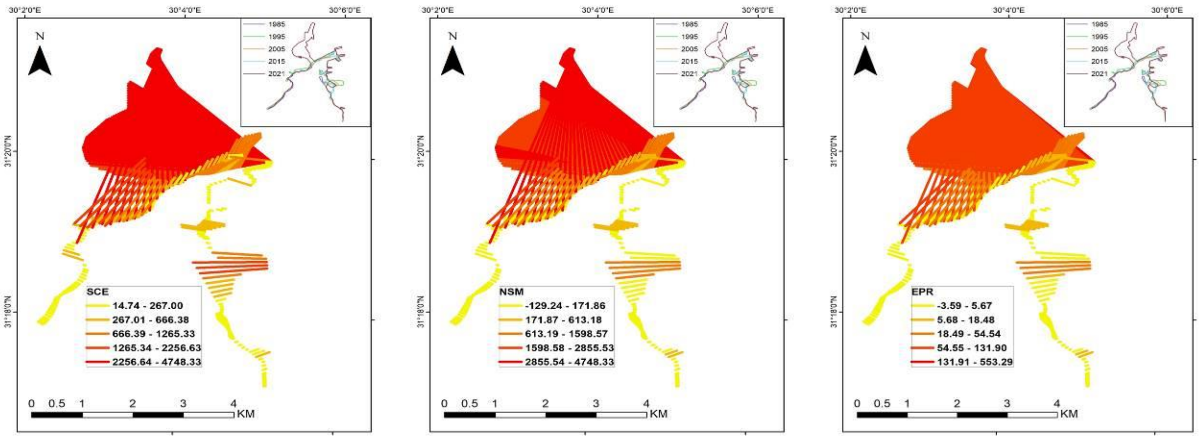
Fig. 3: The shoreline at Abio Qir Bay (1985-2021)

(a) 2031

(b) 2041

Fig. 4: The forcasted shoreline at Abo Qir Bay (2031 and 2041)

To highlight the rate of change in the shoreline, one profile (ID:349) has been selected in Abu Qir Bay as shown in Figure 1. The results of SCE, EPR and NSM are shown in Figures 5a, b and c. The red colours show the movement of shoreline to the sea due to construction of defence structures and yelow colour show the movement of shoreline to the land which increased the errosion at this peofile.



(a) SCE (b) NSM (c) EPR

Fig. 5: Results of shoreline cgange at Abu Qir Bay, Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM) and End Point Rate (EPR)

To summarize the effect of sea level rise on Alexandria shoreline, a relation between the shoreline change measured from the base line is ploted with time as shown in Figure 6 for five periods from 1985 to 2021 and the predicted shoreline after 10 and 20 years (2031 and 2041). The results revealed that the shoreline is changed inland and more errosion has occured in this area which needs urgent protction measures to stop the shoreline errosion and protect these areas.

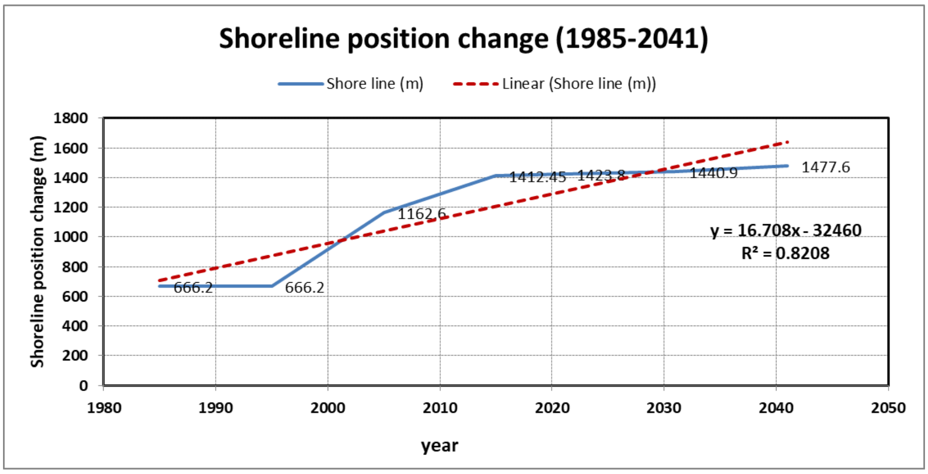


Fig. 6: The shoreline change with time at profile A (1985-2041)

Conclusion

Coastal regions are among the most affected regions by climate change and sea level rise. Egypt's Mediterranean coastline will be mostly affected by sea level rise, as a large portion of it including the Nile Delta is below mean sea level. This study examined the effects of climate change and sea level rise on the shoreline of Alexandria city for the period (1985-2021). ArcGIS and RS with Digital Shoreline Analysis System (DSAS) were used in monitoring the shoreline change. A number of statistical measures have been discussed including; Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR). GIS was used for change detection of the shoreline and predict the future changes in the shoreline for 10 and 20 years. The results of this study revealed that the shoreline of Alexandria has extreamly affected by sea level rise especialy in the Estern part and the predictions showed more increase in 2031 and 2041. Results of this study could help in protcting the affected area by applying appropriate measures to stop the coastal errosion.

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Souhrn
Pobřežní oblasti, které jsou pro turisty nejatraktivnější, jsou stále více ohrožovány změnou klimatu a zvyšováním hladiny moří (SLR), což vede k nárůstu pobřežní eroze. Změny břehové čáry se používají ke zjištění pobřežní eroze v pobřežních oblastech. Systém digitální analýzy břehových linií (DSAS) s ArcGIS lze použít ke sledování změn břehových linií pomocí řady statistických měření, mezi něž patří: obálka změny břehové linie (SCE), čistý pohyb břehové linie (NSM), rychlost koncového bodu (EPR). Cílem této studie je posoudit dopad SLR v důsledku změny klimatu na alexandrijské pobřeží. Při sledování změn na alexandrijském pobřeží byly použity GIS a RS s DSAS. Byly použity satelitní snímky s rozlišením 30 m pro období (1985-2021) a geomaticky korigované pomocí Supervised Classification pro určení změn využití půdy a půdního pokryvu. GIS byl použit ke zjištění změn, sledování využití půdy a změn pobřeží a k předpovědi budoucích změn pobřeží na 10 a 20 let. Výsledky ukázaly, že pobřeží Alexandrie se v průběhu období (1985-2021) posunulo do vnitrozemí s různými hodnotami podél pobřeží a předpovědi ukázaly větší nárůst v letech 2031 a 2041. Výsledky této studie by mohly pomoci tvůrcům politik při plánování adaptačních strategií ke zmírnění těchto dopadů.

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