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FULL LENGTH ARTICLE

Impact of human interventions and coastal processes along the Nile Delta coast, Egypt during the past twenty-five years

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Abstract The coastal zone of the Nile Delta lodges highly populated cities (e.g. Alexandria, Port Said) together with small towns and villages. It represents the major industrial, agricultural, and economic resource of the country. The area has been subjected to extensive and excessive unplanned developmental projects to foster the economic status of the local communities that, however, negatively impacted both land use and land cover characteristics. Satellite images were processed to identify the dominant land use/cover classes (from 1990 to 2014) and GIS techniques spatially analyzed and quantified the rate of changes. Five dominant classes were identified and their changes monitored against the unprecedented human activities. Results demonstrated a significant rate of land forms transformation within the last 25 years, in favor of developing of fish farming (+13%) and urban (+22%). Such development of these land use classes was unfortunately at the expense of the agricultural land (−15%), coastal dune and barren land (−13%) and water bodies (−7%). In addition, the coastal processes have made significant changes in the shoreline creating areas of erosion (maximum of 24–36 m/year) and others of accretion (a total accreted area of 3.14 km^2) with an overall retreat of 2.7 km^2 along the shoreline. The expected changes in climate and sea level rise will worsen the erosion rate and the general status of the coastal zone. Based on the IPCC scenarios (i.e. the 59 cm sea level rise by the end of this century) and the proposed land subsidence (2.5 mm/year), one fifth of the Nile Delta will be seriously vulnerable to inundation.

Introduction

Deltaic environment often support large populations preferably concentrated along the coastal zone (Syvitski and Saito, 2007). This is aligned with the global tendency of thousands

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of cities that are geographically located in the low elevation coastal zones of less than 10 meters below the sea level (wetland areas) (UN-Habitat, 2008). This is mainly due to the wealth of the natural resources that existed at this coastal zone (e.g. freshwater, flat fertile soils, recreation places, mineral resources, fish farming opportunities) according to various authors (e.g. El-Demerdash et al., 1990; Mashaly et al., 1991).

It is common that deltaic regions are highly vulnerable due to its physical characteristics of low topography with high flood probability, significant land erosion and high sensitivity to climatic changes (Milliman et al., 1989). Nile Delta coast is a highly dynamic landscape due to various earth surface processes that control the formation of various landforms (Zuidam et al., 1998; Abou El-Magd and Hermas, 2010). These processes include both coastal and hydrodynamic processes and eolian processes (Allen, 1997). The coastal and hydrodynamic processes produce several coastal landforms (e.g. sand beaches, coastal plains, salt marshes, wetlands, water bodies, etc.). However, the eolian processes produce several varieties of sand dunes (e.g. barchan sand dune, longitudinal sand dunes, and the star dunes) (Masselink and Hughes, 2003).

Since the construction of High Aswan Dam in 1964 the Nile Delta has seriously been impacted due to the changed load of water and sediment flow. It was recorded that the average sediment load and freshwater arriving to the Mediterranean coast was 134 Million tons and 55 Billion m^3 (before the construction of High Aswan Dam), respectively (Abu-Zeid and El-Shibini, 1997; Sharaf El Din, 1977). This has created a significant deterioration of the coastal lagoons (Aleem, 1972; Nixon, 2004), and also negatively affected on the quality of the agricultural soils (Tortajada et al., 2012). It has cumulatively led to extensive land use changes including loss of some wetland areas as well as other areas that served as shelter or habitats for birds and other kinds of animals.

On the other hand, the excessive increase in population, civilization and the accompanied developments during the last few decades accelerated the demand of the Nile Delta region and fostered extensive developmental projects to exist. Despite its negative environmental impacts, it has made some socio-economic acceleration through the creation of new job opportunities and improved the local income (Abou El-Magd and Hermas, 2010).

Furthermore, the coastal zone of the Nile Delta is undergoing severe erosion caused by natural coastal processes. It is anticipated that climate changes have been worsening the level of erosion at the Nile Delta coast of Egypt. In low-lying deltas, rising sea levels would, in all areas, bring the risk of inundation, higher rates of erosion and increased saline intrusion into rivers and fresh water aquifers (El-Nahry and Doluschitz, 2010). The Egyptian Government has recently shown an interest and commitment toward coastal environmental and coastal management issues.

Some earlier studies have focused on studying geomorphic and land uses changes; for example, Frihy et al. (1994), Sadek et al. (1993), who have paid special attention to coastal environments and addressed some shoreline changes that occurred in the Nile Delta. In addition, Haggag (1994) and Zaghloul et al. (1992) have focused on studying soil characteristics at the coastal area. Most of these earlier studies are either limited in time (represent short period of time) or area (cover small area of the coastline) or both. The main objective of this research is to bridge the gaps of the earlier studies by expanding the area of study along the Nile Delta coast to cover a wider area (from Alexandria to Port Said of about 250 km long) and extending the period of study to present the last 25 years (from 1990 to 2014). The study focuses on the coastal changes that occurred at the Nile Delta coast in Egypt identifying the different land forms; land use and land cover classes at this highly dynamic part using multi-temporal satellite images together with field observations.

In addition, mapping the dynamicity of these classes and its relation to the socio-economic values would help in developing a projection model of these categories by 2040 using the IPCC universal scenario (IPCC, 2007). This would simulate the changes would occur and the implications of coastal processes on re-shaping the Delta coastline and hence develop a model scenario with the proposed shape of the Delta coastal shoreline by 2040. Results of this study would serve as base line information to the national planners and decision makers that ensure their better understanding of the coastal zone management. In turn this might help in planning of such an area at minimum risks or reduced harms of the environment.

Study area

The study area occupies the northern coastal zone of the Nile Delta between 29° 45′E to 32° 15′E and 30° 45′N to 31° 30′N with a total area of about 18,738 km^2. The area is bounded from the east by the Suez Canal and the Sinai Peninsula, from the west by the western desert, from the south by the rest of the agricultural land of the Nile Delta and by the Mediterranean Sea from the north (Fig. 1). It includes big cities such as Alexandria to the West, Port Said to the East, and in between there are Damietta and Rosetta cities. The study area governed by 5 local governorates, which are; from the east to the west; Port Said, Damietta, Kafr El-Shiekh, El-Beheira, and Alexandria.

The climatic condition of this area is almost the climate of the Mediterranean Basin with a minimum temperature of 10 °C in winter and a maximum temperature of 40 °C in summer. The area is characterized by different landforms such as sand dunes, beaches, wetlands, and salt marshes. However, the area is highly populated (around 8 Million capita representing 10% of Egypt total population – CAPMAS "Central Agency for Public Mobilization and Statistics", 2013) with several man-made activities (e.g. agriculture, fishing and others).

Methods

The methods used in this research include:

Satellite images data and processing

Satellite images covering the last 25 years (1990–2014) were processed to monitor and determine the natural and man-made changes in the coastal zone of the Nile Delta. The used images were freely downloaded from the USGS website (www.glovis.usgs.gov). Table 1 lists the technical specifications of these satellite images.

Both images (for 1990 and 2014) were geometrically corrected to the Universal Transverse Mercator (UTM) projection, Zone 36 North and the WGS84 datum. The images were then corrected radiometrically and converted to irradi-