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Using spatial data analysis for delineating existing mangroves stands and siting suitable locations for mangroves plantation

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ABSTRACT

Mangroves protect shorelines from waves and floods, help prevent coastal erosion by stabilizing sediments with their tangled root systems, serve as valuable nursery areas for fish and invertebrates. In addition, mangroves can play an important role in protecting the land from future seawater rise.

Small mangrove stands are distributed along the Red Sea coast in Egypt as small patches, rarely exceed few square kilometers. These stands have been rapidly destroyed in recent years due to the rapid development tourist activities and old running problem of over grazing and using the trees as fuel.

The current research aimed at delineating the existing mangroves stands within the area between El Quseir – Marsa Alam and finding the most suitable locations to plant mangroves trees. Sharm El-Bahari was found to be the healthiest mangroves stands in the area. By interpreting the satellite images and field survey the four environmental factors controlling the growing of mangroves: physical and chemical properties of seawater, soil properties and coastal geomorphology. These factors were measured at Sharm El-Bahari site and considered the best environmental boundaries suitable for mangroves growing in the study area. With these values in mind, the sites suitable for mangroves plantation were located where these environmental requirements were met. Six sites suitable for mangroves plantation were identified; these sites were ranked using Analytic Hierarchy Process (AHP).

1. Introduction

Mangroves play a vital role in supporting the surrounding environment; they are the most biodiversity wetland ecosystems on earth (Lugo and Sneaker, 1974). They are control erosion, protect the coastal areas, and maintain water quality and clarity. mangroves function as nursery and adult fishery habitat, fuelwood & timber, carbon sequestration, traps sediment, detoxifies pollutants, protection from erosion & disaster (Millennium Ecosystem Assessment, 2005). They are used as a building material fuel and for grazing in rural areas. Mangrove is the main Blue Carbon. It has very important role in carbon sequestration in its living parts and the rich carbon sediments.

The distribution of mangroves in both northern and southern Red Sea coast of Egypt is patchy and do not occur as a continuous forest. These stands have been threatened by rapid tourist development and grazing by Bedouins. The size and the number of these stands have been reduced and many of the stands have been destroyed (El-Juhany, 2009 and Asif Khan et al., 2010).

Therefore, the current study aimed at using spatial data like satellite images and GIS layers beside field survey to accurately map the existing mangroves stands and select the best suitable sites for mangroves plantation within the area extended between El Quseir and Marsa Alam on the Red Sea, Egypt (Fig. 1). Decision makers could use results of this research to develop a proper conservation plan to protect and increase the mangroves stands within the study area.

2. Methods

Selecting the best sites for mangroves plantation was carried out through the following steps (Fig. 2):

1. Mapping of the existing mangroves stands along the study area. Factors controlling the mangroves growing were measured at the healthiest mangroves stands.
2. To define the suitable sites for mangroves plantation, the study area went through four phases of site screening based on:
   a. Tide and wave systems.
   b. Chemical and physical properties of seawater.
   c. Flood potentiality of drainage basins.

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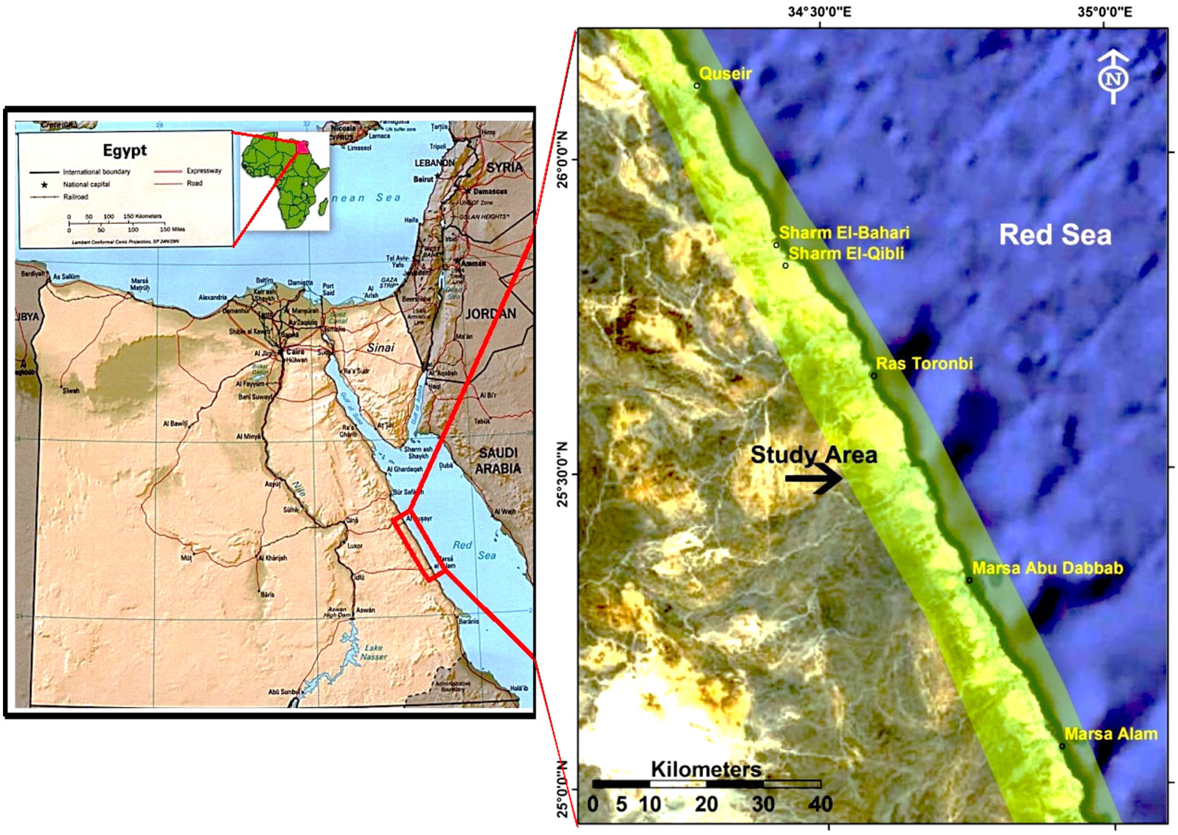

Fig. 1. Location of study area.

d. Soil rejuvenation capability, texture, physical and chemical properties.

3. Sites found to be suitable for mangroves plantation were ranked by using Analytic Hierarchy Process (AHP).

2.1. Mapping the existing mangroves and locating the healthiest mangroves stand

The inventory of mangroves in the study area aimed at: (1) evaluating the status of the existing mangroves stands, (2) defining the healthiest mangroves stand.

Both Normalized Difference Vegetation Index (NDVI) calculated out of RapidEye satellite images, and in-situ measurement of mangroves canopy cover using the Geographic Resource Solutions (GRS) Densitometer were used for the inventory of mangroves stands.

2.1.1. Using Normalized Difference Vegetation Index (NDVI) for canopy cover estimation

RapidEye satellite images have been chosen to map the mangroves of the study area because of its high 5 m spatial resolution and the availability of the red and infrared spectral bands required for vegetation mapping (Fig. 3). In addition, RapidEye is a low coast satellite images compared to satellite images with similar resolution. The RapidEye images were accurately ortho rectified using a set of Ground Control Points (GCPs) that cover the whole area.

NDVI was applied by using ERDAS imagine spatial modeler (Fig. 4). The built in NDVI model of the ERDAS imagine that designed for Landsat 7 images was modified to be compatible with RapiedEye image. The model based on the NDVI equation:

$$NDVI = \frac{(\mathrm{NIR} - \mathrm{VIS})}{(\mathrm{NIR} + \mathrm{VIS})}$$

where,

VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively.

Canopy cover is the ratio of vegetation to ground. Determination of canopy cover by using remote sensing technique gives the advantage of monitoring the changes in mangroves stands repetitively at low cost and time. In addition, Canopy cover is one indicator of the mangroves stand health.

The calculated NDVI image needs to be calibrated in order to use it for canopy cover estimation.

2.1.2. Calibrating NDVI image to inventory mangroves canopy cover

A Densitometer (GRS Densitometer, model 2008) was used for in-situ measurements of mangroves canopy coverage. In the current study we designed a new sampling plot pattern with a 30 by 30 meters' grid cell size to be suitable with the small size of mangroves stands at the study area (Fig. 5). Differential GPS techniques with sub-meter accuracy in addition to a traditional geological compass were used to define the plots boundaries (Fig. 6). This stand had been selected because it has most of the mangroves coverage densities expected to be found within the study area (Table 1). The average NDVI for each plot was estimated from the NDVI image.

The value of NDVI for each cell of the Abu Hamrah al Bahray sampling grid was plotted against its canopy cover measured by GRS Densitometer (Fig. 7). The strong linear relationship between the two variables is signifying the strong relation between NDVI and the mangroves canopy cover.

Here is the linear relation between NDVI and mangroves canopy coverage as calculated by the Origin software version 5.1:

$$\text{mangroves canopy\%} = (-5.29876) + (\text{NDVI}^{*}0.35835)$$