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Mapping and evaluating land suitability using a GIS-based model

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ABSTRACT

Wheat is considered the most important crop in Egypt; however, not all of the land in Egypt is equally suitable for growing wheat. The main objective of this study was to develop a spatial model for land suitability assessment for wheat crop integrated with geographic information system (GIS) techniques. Organic matter, N, P, K, Zn, drainage, texture, depth, topography, surface stoniness, hard pan, hydraulic conductivity, water holding capacity, salinity, ESP, $CaCO_3$ and pH were recognized as factors affecting land suitability for wheat crop in the study area. Three thematic indicators were used in assessing land suitability, soil fertility, chemical and physical properties quality indices. The results of the proposed model were compared with the Square root and Storie methods. The results from the proposed model showed that most of the units fall within the highly suitable class and the moderately suitable class which together represent 71.44% of the total area. About 29% of the study area was marginally suitable and unsuitable for wheat crop and those areas correspond to the adverse physical and chemical properties of the soil. The comparison of the results of the three approaches used showed that the present model has a high level of agreement with the Square root method, whereas all land units have the same classes of suitability with the exception of one unit. The present model allows obtaining results that seems to be corresponded with the current conditions in the area.

1. Introduction

Agriculture is one of the largest sectors of the Egyptian economy and provides 20% of gross domestic product, 34% of the total exports and employs 32% of the total labor force (CAPMAS, 2012). Land resources in Egypt face pressures from continuing land degradation and increasing number of people. The population in Egypt is growing very rapidly as its density has doubled during the last three decades (Hamza and Mason, 2004). Therefore, the efficient management of natural resources in Egypt is essential for ensuring food supplies and sustainability in agricultural development.

In order to manage land resources properly, land suitability assessment is often conducted to determine which type of land use is most appropriate for a particular location (Bodaghabadi et al., 2015). Land suitability analysis is a method of land evaluation, which allows identifying the main limiting factors of a particular crop production (Halder, 2013). At the same time it enables decision makers to develop a crop management system for increasing land productivity (Chen, 2014). Land suitability assessment is a planning approach to avoid environmental conflicts by the segregation of competing land uses (FAO, 1976; Rossiter, 1990; FAO, 1991; Al-Mashreki et al., 2011; Ashraf and Normohammadan, 2011). Land suitability evaluation can be either qualitative or quantitative. Qualitative approach is used to assess land potential on a broad scale and the results are given in qualitative terms. Quantitative approach involves more detailed land attributes by using parametric techniques which allow various statistical analyses to be performed. The land suitability evaluation procedure in the quantitative approaches involves many simulation modeling systems (Van de Graaff, 1988; Shields et al., 1996) to quantify the potential of land for specific uses. FAO guidelines on land evaluation system (FAO, 1976 &1985) and physical land evaluation methods (Sys et al., 1991) were widely used for land suitability assessment.

Remote sensing and Geographic Information Systems (GIS) hold great promises for improving the convenience and accuracy of spatial data, more productive analysis and improved data access. These technologies have been used to assess the criteria required to define the suitability of land (Booty et al., 2001; De la Rosa and Van Diepen, 2002; Darwish et al., 2006; Mokarram et al., 2010; El Baroudy, 2011; Hamzeh et al., 2014; Mishelia and Zirra, 2015) and were also adopted for the present study.

In Egypt, the main field crops are maize, rice and cotton during the summer season and wheat, clover and bean during the winter season. Cereal production represents about 50% of the value of field crops, occupying about 2.72 million ha of the whole cropped area. Wheat occupies approximately 1.26, maize 0.88, rice 0.59, sorghum 0.15 and barley 0.19 million ha (FAO, 2005). Wheat is considered the most important crop and the Egyptian Government gives priority to wheat production providing farmers with varieties which tolerate different types of stress. The main objective of this research is to prepare land suitability

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evaluation maps for wheat crop using a GIS-based and to compare it with Square root and Storie methods for areas in the northern part of the Nile Delta.

2. Materials and methods

2.1. Description of the study area

The study area is a coastal region adjacent to El-Manzala Lake in the northern part of the Nile delta. The geographical location is in UTM zone 36 (30° 58′ 30″–31° 31′ 20″ N; 31° 16′ 20″–32° 12′ 15″ E) covering 4190 km^2 (Fig. 1). The soil temperature regime of the studied area is "Thermic" and the soil moisture regime as "Torric" according to the US Soil Taxonomy System (USDA, 2010). The study area is characterized by a Mediterranean climate with a little rain in winter and a hot arid in summer. The amount of annual rainfall is very low and mostly falls in winter. The maximum rainfall is recorded in January, reaching about 40 mm in Damietta station. Temperatures are high during the summer months and relatively low in winter. The hottest temperature is recorded in August, reaching about 31 °C and the coldest month is January, reaching about 18 °C. Potential evaporation is low (3.2 mm/day) in December and January when the temperature is comparatively low. Potential evaporation values are high (5.4 mm/day) between June–September when the temperature is comparatively high. The area was formed in the latter part of the Miocene and the beginning of Pliocene periods and the surface of the area is essentially occupied by formations form the Quaternary and Holocene (Said, 1993). The main cultivated crops in the studied area are cotton, rice, corn, clover, barley and beans, meanwhile the common cultivated orchards are citrus, guava, banana, and date palm trees. Vegetables represent small-scattered areas including tomatoes, eggplant, potatoes, watermelon and others (Belal, 2001).

2.2. Digital image processing and physiographic map

Digital image processing for Landsat ETM + satellite image (path 176, row 38) with a spatial resolution of 30 m acquired during 2013 was performed using ENVI 5.1 software. The original scan line corrector (SLC-off) image has been replaced with estimated values based on histogram-matched scenes to improve the utility of the SLC-off data. According to Lillesand and Kiefer (1979), the image was stretched using linear 2%, smoothly filtered, and their histograms were matched. Image was atmospherically corrected using FLAASH module (ITT, 2009). The ETM + image was geometrically corrected using a rectification method (image to map). Two topographic maps with scale of 1:50,000 (Egyptian General Survey Authority) were digitized and converted to DXF format and the coverage was topologically processed in UTM projection, Zone 36 and WGS-84 datum. Elevation contour lines and points were used to generate raster Digital Elevation Model (DEM) (10 × 10 m) using Arc-GIS 10.1 software. The physiographic units were defined from the satellite image and DEM, classified into groups and the map legend was established according to Zinck and Valenzuela (1990).

2.3. Fieldwork and laboratory analyses

Field studies and ground truth were carried out to identify the physiographic units and to examine the reality of the interpretation. A total of 90 observation points were taken to check the accuracy of mapping units. Twenty seven soil profiles were taken from the different physiographic units. A detailed morphological description of the studied soil profiles was elaborated on the basis outlined by FAO (2006). Representative 103 soil samples have been collected from the soil profiles and analyzed for physical and chemical characteristics using the standard analytical methods as described below.

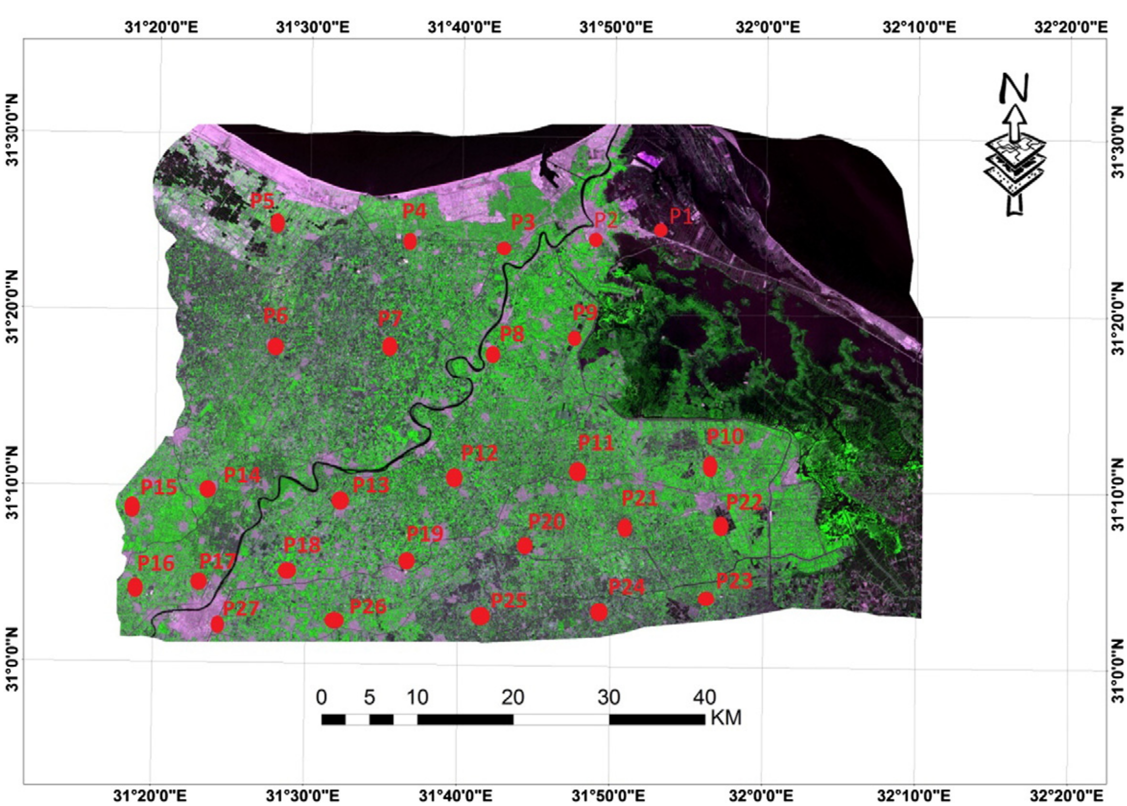

Fig. 1. Location of the study area and soil profiles.