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Assessment of Soil Capability for Agricultural Use in Some Areas West of the Nile Delta, Egypt: an Application Study Using Spatial Analyses

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Abstract: The main objective of soil capability assessment for agriculture is to predict future conditions after development has taken place. It is necessary to forecast the benefits to farmers and the national economy and whether these will be sustained. The current study deals with spatial analyses techniques to evaluate the agricultural land capability in some areas west of the Nile Delta. The land surveying data, Digital Elevation Model (DEM) and satellite image were used in a Geographic Information System (GIS) to delineate the landforms of the area. The attribute data of erodability, surface slope, $CaCO_3$ content, texture class, soil depth, salinity, alkalinity and drainage condition were linked with the landform units of the area. The thematic layers of the attribute data were created in Arc-GIS 9.2 software using the spatial analyses function, and then these layers were matched together to produce the soil capability map. The results indicate that the soils of very high, high, marginal, low and very low capability classes for agriculture represent 7.26, 22.45, 43.62, 21.11 and 5.56 % of the studied area respectively. The low capability classes in the area are mainly due to the shallow soil depth, coarse texture, poor drainage and the salts accumulation. Therefore, action measures of land management are essential for sustaining the agricultural land uses in this area.

Keywords: Soil capability, landforms, GIS, spatial analyses, west of Nile Delta.

INTRODUCTION

Most of the newly developed lands in the 1960s (420000 ha) were situated along the fringes of the Nile Delta. The West Delta region received the highest share of the land reclamation program 170000 ha[1]. By the year 1997 the total cultivated area in the West Delta fringes reaches to 445200 ha[2]. The cost of reclamation of such regions varies from LE 7,000 to LE 23,000 per hectare of crop area for canals, pumping stations, main roads, electricity transmission facilities, utilities and related buildings[3]. The soil capability mapping for this area is therefore, an essential action in order to maintain the sustainable development of effort and investment as well as the sustainable usage of the soils. The study area includes both old cultivation and newly reclaimed soils, extending between longitudes 30° 31′ 30″ and 30° 58′ 30″ east, and latitudes 30° 12′ 20″ and 30° 40′ 02″ north (Figure 1). This area includes different landforms i.e. river terraces, levees, flood plain and alluvial windborne deposits[4]. The Pleistocene deposits (sand and gravel) in this area are of assorted size bordering the cultivated areas; they form a series of various elevation terraces[5].

Land evaluation is a vital link in the chain leading to sustainable management of land resources. It is assigned the indispensable task of translating the data on land resources into terms and categories, which can be understood and used by all those concerned with land improvement and land use planning. The different types and procedures in land evaluation are gradually being developed. Interpreting soil qualities and site information for the agricultural use and management practices is integrated using geographical information system[6,7].The land quality is a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use[8], it is the ability of the land to fulfill specific requirements for the land utilization type[9].

The spatial analysis was used in this study, it can be defined as the analytical techniques associated with the study of locations of geographic phenomena together with their spatial dimensions and their associated attributes[10]. Spatial analysis is useful for evaluating suitability, for estimating and predicting, and for interpreting and understanding the location and distribution of geographic features and phenomena. The use of spatial analyses techniques in evaluating the land capability, allow producing multi-thematic maps and outlining the limiting factors, accordingly suitable suggestions could be attained to understanding how to deal with these soils for sustainable agricultural use.

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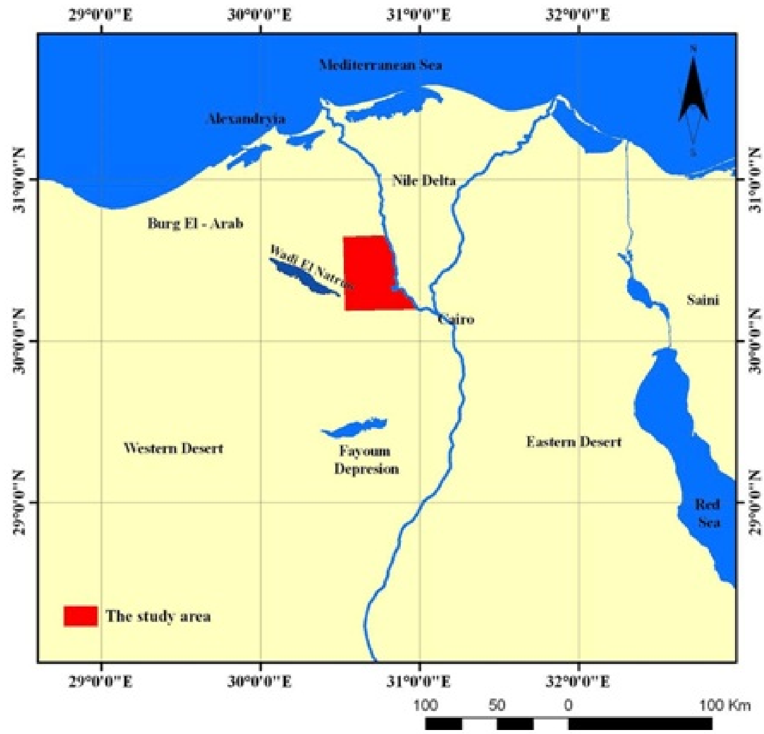

Fig. 1: Location of the study area

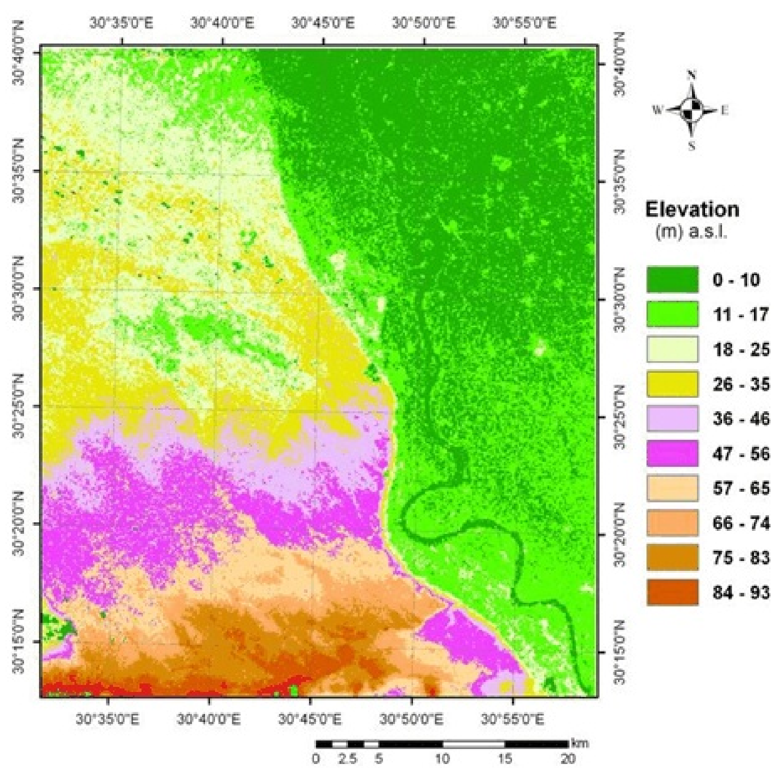

Fig. 2: Digital elevation model of the study area

MATERIALS AND METHODS

Digital Elevation Model (DEM) of the study area has been generated from the vector contour lines (Figure 2); Arc- GIS 9.0 software was used for this function. Landsat ETM+ images (Figure 3) and Digital Elevation Model (DEM) were grouped and processed in ERDAS Imagine 8.7 software to define the different landforms of the studied area[11,12]. The extracted of data generates a preliminary geomorphologic map which was checked and completed through field observation. A semi detailed survey was done throughout the investigated area in order to gain an appreciation on the soil patterns, the land forms and characteristic landscape. Fourteen soil profiles were taken to represent different mapping units; the morphological description of these profiles was carried out according to the guidelines edited by FAO[13]. Representative disturbed soil samples have been collected and analyzed using the soil survey laboratory methods manual[14]. The obtained data were imported in a GIS database; the digital geomorphologic map was used as base map in the database. The spatial analyses function in ArcGIS 9.0 was used to create the thematic layers of erodability, surface slope, CaCO3 content, texture class, soil depth, salinity, alkalinity and drainage condition. The thematic layers were matched to produce the soil capability map; the land capability classes were defined using the rating and procedure after FAO[7,8].

RESULTS AND DISCUSSIONS

Base Map: The landforms of the studied area were delineated by using the digital elevation model, Landsat ETM^+ and ground truth data of the studied area. The produced map, represents the landforms of the studied area, was imported in a Geo-database and considered as a base map (Figure 4). The obtained data indicate that the area includes the following:

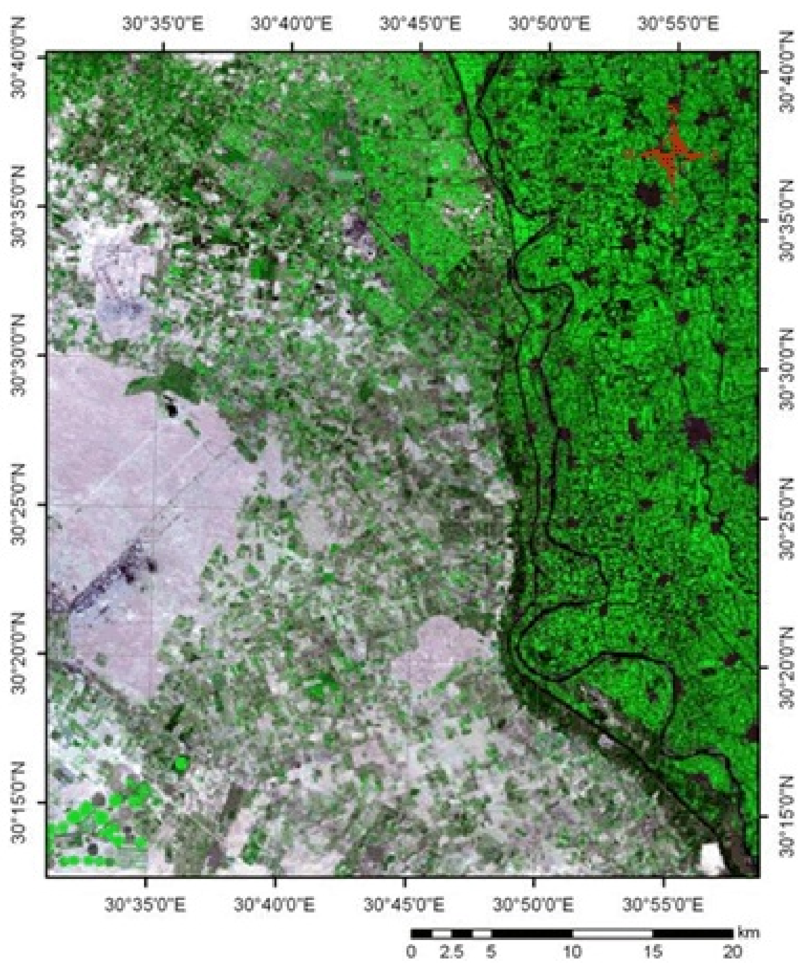

Fig. 3: Landsat ETM+ image of the studied area

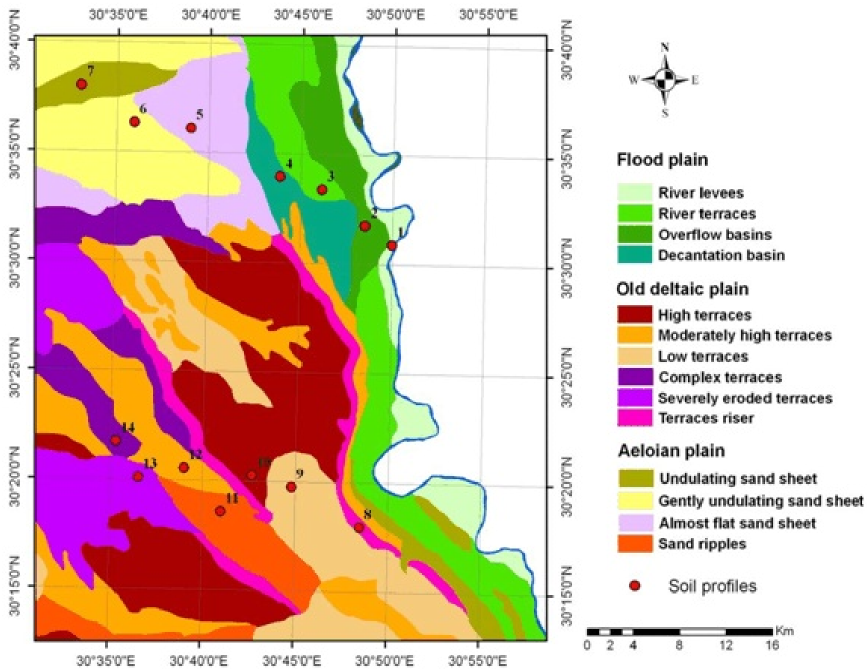

Fig. 4: Geomorphologic units of the studied area

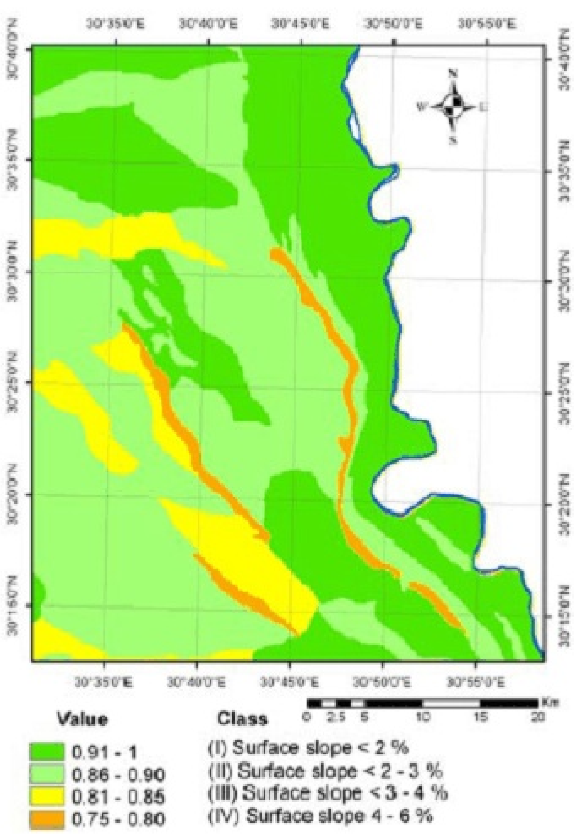

Fig. 5: Spatial distribution of erodability.

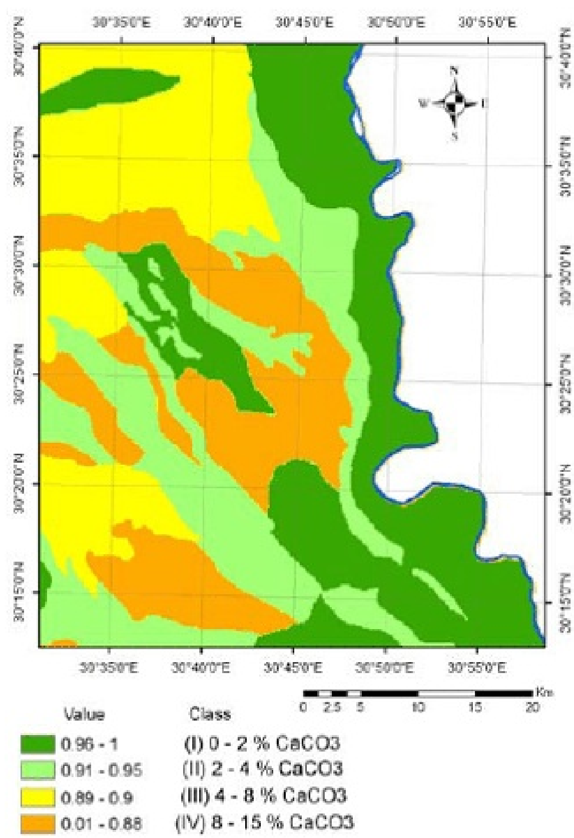

Fig. 6: Spatial distribution of surface slope.

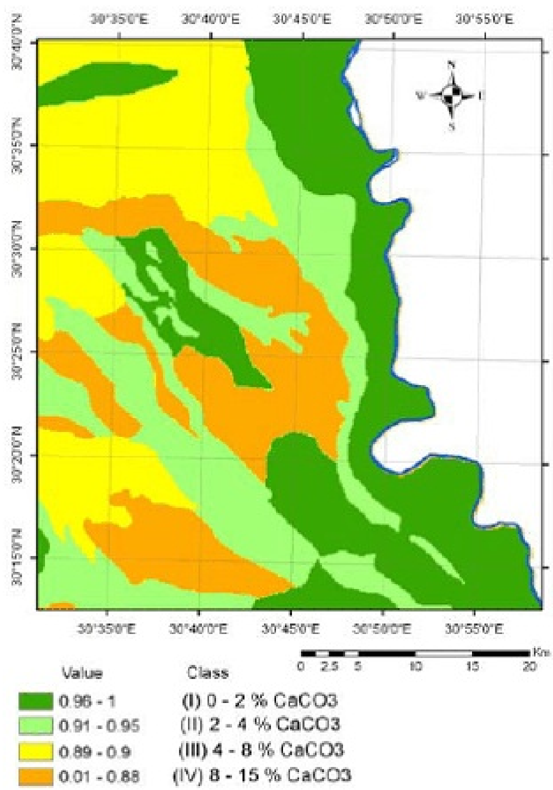

Fig. 7: Spatial distribution of $CaCO_3$ content.

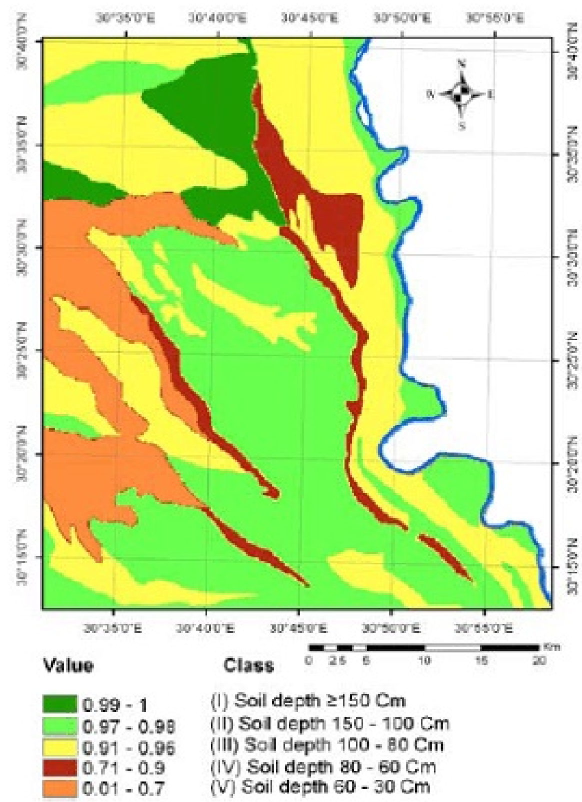

Fig. 9: Spatial distribution of soil depth.

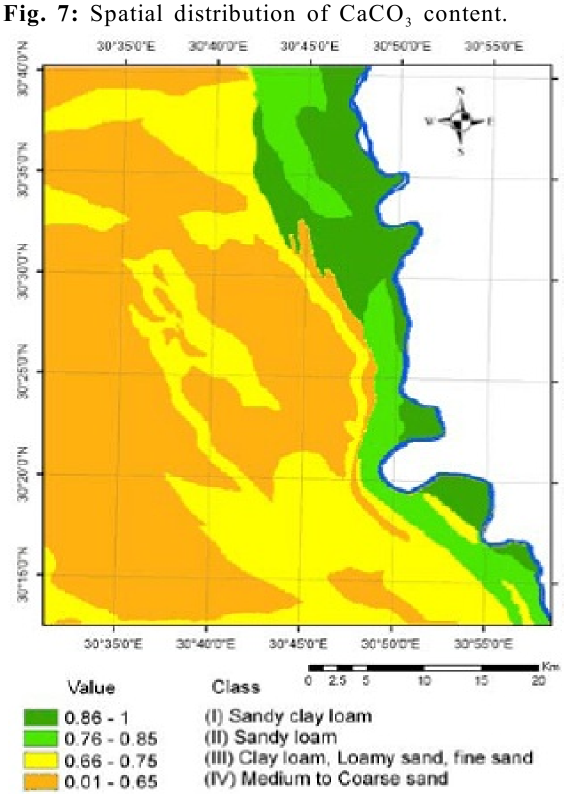

Fig. 8: Spatial distribution of soil texture.

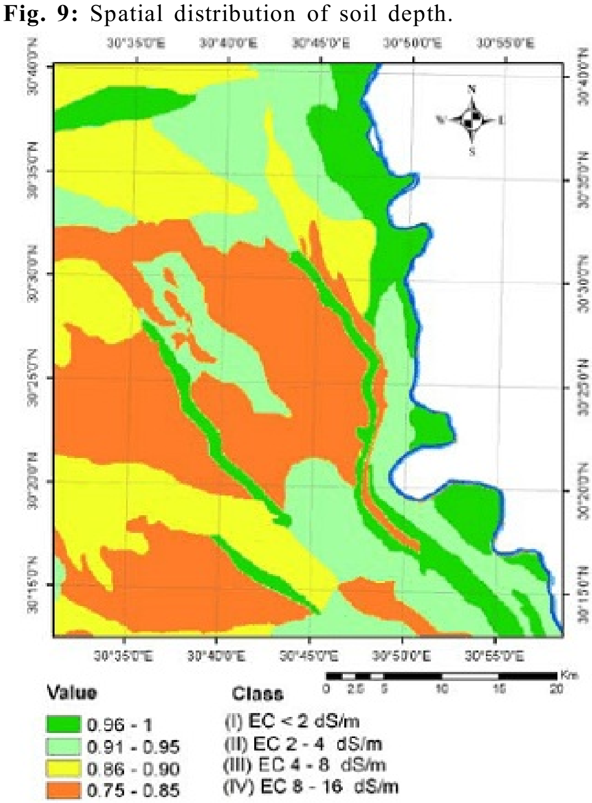

Fig. 10: Spatial distribution fo drainage condition.

Table 1: Main land characteristics of the studied area

Profile no.	Depth (cm)	Slope %	Erosion	Texture class	Drainage class	$CaCO_3$ %	EC dS/m	ESP
1	120	1.4	Non to Slight	SCL	Well	2.32	1.42	11.31
2	110	1.6	Non to Slight	SL	Well	0.91	0.86	12.82
3	100	2.1	Non to Slight	CL	Moderate	2.66	3.45	14.54
4	90	2.3	Non to Slight	SL	Moderate	6.84	7.39	14.83
5	150	3.3	Moderate	S	Well	8.31	3.52	16.31
6	100	2.7	Moderate	GS	Well	9.52	5.73	15.52
7	120	3.5	Moderate	S	Well	2.66	1.55	17.70
8	90	6.6	Moderate	S	Moderate	3.94	1.58	15.81
9	130	2.8	Slight to moderate	S	Well	1.57	3.69	11.44
10	120	3.4	Slight to moderate	SG	Well	12.76	9.56	19.53
11	130	4.2	Slight to moderate	S	Well	3.35	7.82	18.58
12	100	3.2	Moderate	SG	Moderate	5.14	9.62	18.15
13	60	3.4	Moderate	SG	Imperfect	8.12	6.41	19.86
14	45	4.6	Slight to moderate	GS	Imperfect	12.8	11.51	14.63

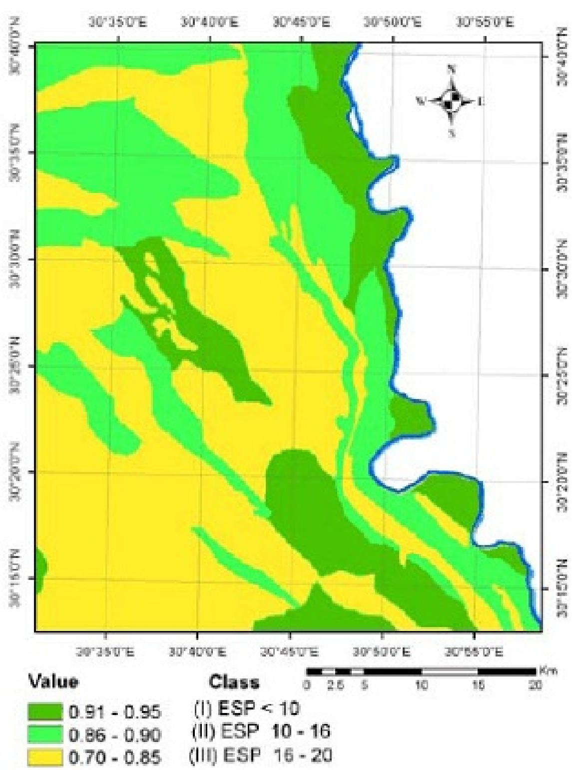

Fig. 11: Spatial distribution of soil alkalinity.

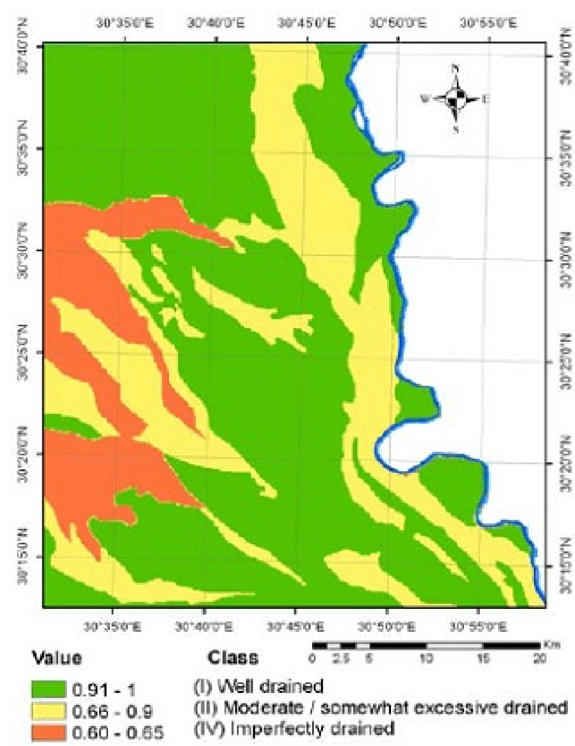

Fig. 12: Spatial distribution of drainage condition.

Flood Plain: This landscape exhibit an area of 336.56 Km^2, representing 19.83 % of the total area; it includes the landforms of river terraces of various elevation (145.36 Km^2), river levees (62.86 Km^2), overflow basin (59.19 Km^2) and decantation basin (50.99 Km^2). River stream and islands exhibit an area of 18.16 Km^2 (i.e. 1.08 % of the studied area).

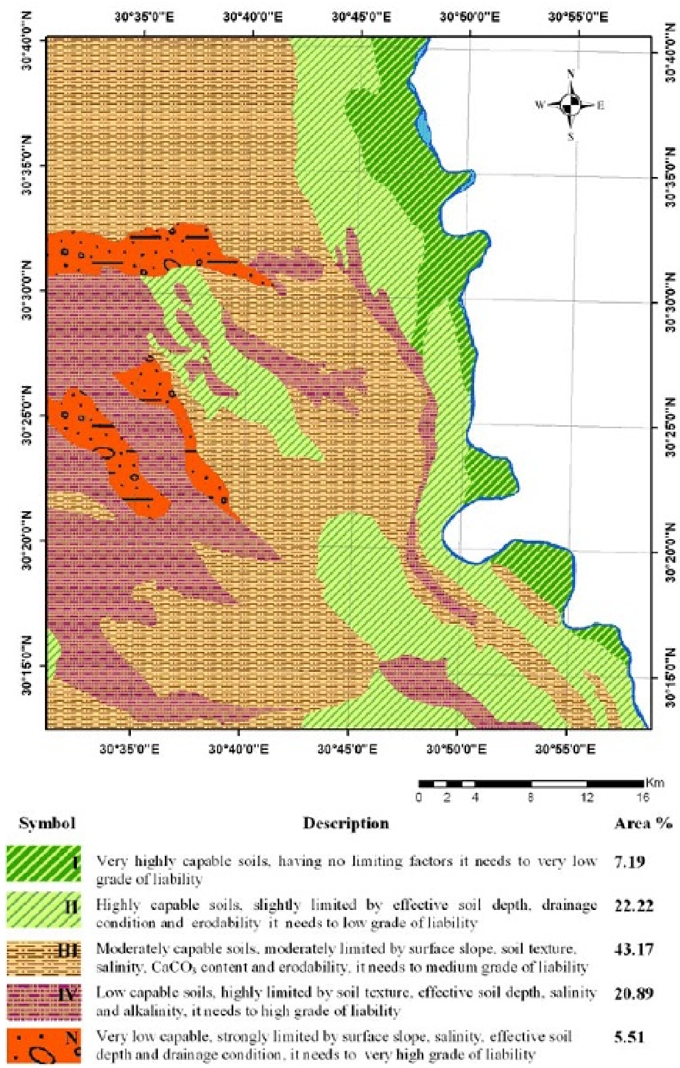

Fig. 13: Land capability classess of the studied area.

Aeolian Plain: This landscape covers an area of 393.92 Km^2, representing 23.19 % of the total area. It includes the landforms of almost flat sand sheet (108.06 Km^2), gently undulating sand sheet (143.56 Km2), undulating sand sheet (64.99 Km2) and sand ripples (77.31 Km^2).

Old Deltaic Plain: This landscape covers an area of 967.81 Km^2; representing 56.98 % of the total area. The main landforms in this landscape are high terraces (277.38 Km^2), moderately high terraces (226.98 Km^2), low terraces (180.82 Km^2), complex terraces (93.48 Km^2), severely eroded terraces (127.62 Km^2) and terraces riser (61.53 Km^2).

Thematic Layers: The attribute data of erodability, surface slope, $CaCO_3$ content, texture class, soil depth, salinity, alkalinity and drainage condition (Table 1) were compiled into the units of the digital geomorphologic map in a geographic information system. The incorporated attributes were used to obtain the thematic layers of spatial distribution of the above mentioned characteristics (Figures 5; 6; 7; 8; 9; 10 and 12). The produced layers include information on the rating value, capability subclass, and distribution for each soil characteristics. The obtained data from the thematic layers indicate that the soils of flood plain having no limiting factors, except some areas in the basins and river terraces which have a slight limitation due to soil depth and drainage condition. The soils of aeolian plain have moderate to high degree of limitation related to the erodability, $CaCO_3$ content, texture, and salinity. High to very high degree of limitation related to erodability, soil texture, slope,

$CaCO_3$ content, soil depth, salinity and drainage condition exhibit the different landforms of old deltaic plain. These results are of great importance as they show the distribution of the constraints of productivity all over the region. This is particularly important when planning for optimal land uses, also it benefits the existing land users in determining the most appropriate management practices.

Soil Capability Assessment: The soil capability of the area has been identified from the thematic layers (Figure 13). The soil capability was divided to five categories according the rating values (ranges from 0 to 1), whereby the soil capability tend to increase when the rating value is closed to 1. It became clear that the very high capable soils (class I) represent 7.19 % of the total area; it is associated with the river terraces and levees. The high capable soils (class II) dominate the decantation and overflow basins in the flood plain and low terraces of old deltaic plain, representing 22.22 % of the total area. The moderately capable soils (class III) are associated with the aeolian plain landforms and high terraces and sand ripples in the old deltaic plain, representing 43.17% of the area. The soils of terrace risers, moderate high terraces and severely eroded terraces have a low capability class (class IV) representing 20.89 % of the total area. The very low capable soils are associated mainly with the landforms of complex terraces in the west of the area, representing 5.51% of the total area. Suitable land management is essential for sustaining the agricultural land uses of 64.06 % (classes III & IV) of the studied area.

Conclusion: The use of spatial analyses allows producing multi thematic layers of land characteristics, which offer a great source of data for the land use planners. The spatial distribution represents the correlation between the soil characteristics and landforms, with more detailed data, that can be use in extrapolation of soil characteristics in the different landforms. The spatial distribution of soil capability in the area indicates that soil of old deltaic plain have low capability classes compared with those of aeolian and flood plain. An area of 5.51 % of the total area is currently not suitable for agricultural use, while 64.06 % of the area needs to high grade of liability for sustaining the agricultural land uses.

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