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Assessment of optimum land use and water requirements for agricultural purpose in some soils South Paris Oasis, Western Desert, Egypt

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Abstract The current work is aimed to realizing land suitability and water use efficiency and determining the optimum land use system. The main aims were to identify the physiographic futures and calculate the crop water requirements for specific crops. The study area was observed through a soil survey inventory in Paris Oasis, Western Desert, Egypt. Ten soil profiles plus a number of auger observations and mini pits were selected to represent the different mapping units. A fieldwork and morphological description were carried out, and soil samples were collected for demonstrating the physical and chemical soil properties. Based on satellite data that can integrate with GIS utility, field work, and laboratory analysis, the physiographic map was generated. The study found that the main land type units are plateaus, hills, dunes, and depression floor. Concerning the second aim, the main land qualities of different mapping units were rated and matched to obtain the current and potential land suitability using automated land evaluation system. This research concluded that the best crops adapted with the soil conditions and could be feasible for economic use are clover, wheat, beans, sugar beet, onions, maize, sunflower, tomato, potato, groundnut, pea, lentil, barley, sesame, and carrots. Crop water requirements were determined in variable rate according to the actual plant requirements using the aid of FAO–Cropwat model. Irrigation schedule and consumptive use of suitable crops were calculated and adopted. The crop water requirements for each selected crop were determined as follow: 828.0, 596.7, 410.3, 679.95, 409.52, 791.60, 712.2, 902.93, 456.55, 529.95, 231.4, 217.95, 303.93, 502.65, and 274.35 mm, respectively.

Keywords Consumptive use · Darb El-Arbean area · Geographic information system · Optimum land use

Introduction

Overpopulation and limited land in the Nile River flood plain and delta put pressure on the government to create and establish strategic plans for horizontal expansion in the Western Desert for food security. The study area is considered one of the promising areas of horizontal expansion in the Western Desert. The reclamation of this area aims to establish a channel system between the South Valley project and Al-Kharga Oasis and developing the areas around Darb El Arbaein road as well. The ongoing development plans include the reclamation of 11,500 acres and digging 85 ground wells of depth 150–500 m. The assessment of agricultural potentiality in such area requires concrete and actual evaluation of soil and water resources in terms of land capability and suitability for crops cultivation (ASRT 1989). Such expansion requires precise information to secure decision making process for investment in the concerned area. From an economic standpoint, two main parameters should be under detailed study and get more focus. Those parameters are soil suitability and water availability for crop cultivation and production. Land suitability assessment for agriculture is meant to evaluate the ability of a piece of land to provide the optimal ecological requirements of a certain crop variety. In other words, assessing the capability of land is enabling optimum crop development and maximum productivity. Without respect to economic conditions, a physical suitability evaluation indicates the degree of suitability for a land use; this result was later contradicted by Rossiter (1996). The suitability of soils for irrigated crops is an essential information need for land use planning; however, it

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is inadequate for making and supporting decisions concerning land use development. Therefore, all relevant land characteristics including soils, climate, topography, water resources, vegetation, and also socioeconomic behavior should be taken into consideration (FAO 1985), (Durbude and Venkatesh 2004).

Remote sensing (RS) is defined as the acquisition of information about an object without being in physical contact with it. Therefore, the intrinsic characteristics of agriculture make remote sensing an ideal technique for its monitoring and management (Zhongxin et al. 2004). Remote sensing techniques have been utilized in soil science for many years as a tool for soil surveyors that reduce the time and expense of sampling (Palacios-Orueta and Ustin 1998). Some soil properties can also be delineated from satellite images using the band combinations and computational indices depending on the particular reflectance of each soil category (Sharma et al. 2000). Nevertheless, remotely sensed data could enable to estimate large-scale moisture for the modeling purposes of two-way interaction between land and atmosphere, making it possible to understand the nature of global climate. In the last decade, satellite data shows effective use in soil sciences for estimating surface evaporation, salinity and water logging, and identification of soil suitability (Moran 1994; Palacios-Orueta and Ustin 1998; Amano and Salvucci 1999; Khaled and Abdalla 2013).

On the other hand, geographic information system (GIS) is considered as an organized collection of computer hardware, software, spatial, and nonspatial data that can help users for the efficient capture, storage, update, manipulation, analysis, and management of all geographically referenced information. RS in combination with GIS techniques proved to be effective in sustainability and planning studies (Rajitha et al. 2006). One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis; broadly defined land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity (Brail and Klosterman 2001; Collins et al. 2001). The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitant for animal and plant species, suitability of land for agricultural activities, landscape evaluation and planning, environmental impact assessment, and selecting the best site for the public and private sector facilities (Eastman et al. 1993; Church 2002; Adrian et al. 2010;). However, integration with GIS enables for the geographical analysis of all the soil information to generate soil suitability map.

The diversity of land-use suitability studies can be attributed to the different ways for tackling them. The term land use is defined by various applications and context that referee to its use. For example, it is likely that the urban planners and the agricultural experts would have different perception of the term. To this end, it is important to distinguish between two notions: land use and land cover. Broadly speaking, land cover describes the physical state of the earth's surface and immediate subsurface in terms of the natural environment (such as vegetations, soils, surfaces, and ground water) and the man-made structures. On the other hand, land use itself is the human employment of a land cover type. It involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation—the purpose for which the land is used (Briassoulis 2003). Furthermore, the term of land use may have different connotations depending on the spatial scale. At the large scales, it is typically considered as a resource and consequently land use means resource use. In contrast, at the urban scale, it is characterized in terms of the potential use of the land's surface for the location of various activities (Chapin and Kaiser 1979). This connotation of the term land use is implicit in the context of urban and regional planning. The description of land use, at a given spatial level and for a given area, usually involves specifying the mix of land use types, the particular pattern of these land use types, and the areal extent and intensity of use associated with each type.

In the context of land suitability analysis, it is important to differentiate between the site selection problem and site search problem (Cova and Church 2000). The aim of site selection analysis is to identify the best site for some activity given the set of potential (feasible) sites. In this type of analysis, all the characteristics (i.e., location, size, relevant attributes, etc.) of the candidate sites are know. The problem is to rank or rate the alternative sites based on their characteristics, so that the best site can be identified. If there is not a predetermined set of candidate sites, the problem is referred to as site search analysis. The characteristics of the sites (their boundaries) have to be defined by solving the problem. The aim of the site search analysis is to explicitly identify the boundary of the best site. Both the site search problem and land suitability analysis assume that there is a given study area; thus, the area is subdivided into a set of basic unit of observations such as polygon or raster. The land suitability analysis problem involves classification of the units of observations according to their suitability for a particular activity. The analysis defines an area in which a good site might exist. The explicit site search analysis determines not only the site suitability but also its spatial characteristics such as its shape, contiguity, and/or compactness by aggregating the basic units of observations according to some criteria (Aerts 2002).

Experts' estimates that demand for food crops will double during the next 50 years. With limited land and water resources, farmers need to increase their output from existing cultivated areas to satisfy the food demand of increasing population. Irrigation systems will be essential to enhance crop productivity in order to meet future food needs and ensure food security. However, the irrigation sector must be revitalized to unlock its potential by introducing innovative management practices and changing the way it is governed. Developments in irrigation are often instrumental in achieving high rates of agricultural goals, but proper water management must be given due weightage in order to effectively manage water resources (Dawoud 2013). Better management of existing irrigated areas is required for growing the extra food to fulfill the demand of increasing population (Allen et al. 2005).

Irrigation systems are essential component to minimize water losses and improving crop yield productivity in order to meet the future overgrowth of food needs. However, the irrigation sector must be revitalized to unlock its potential by introducing innovative management practices and changing the way it is governed. Developments in irrigation are often instrumental in achieving high rates of agricultural goals, but proper water management must be given due weightage in order to effectively manage water resources. Better management of existing irrigated areas is required for growing the extra food to fulfill the demand of increasing population (Brough 1986).

The practical well-known method of estimating crop water requirements is always based on meteorological parameters utilizing the Penman–Monteith formula. The Penman–Monteith value is calculated from weather data utilizing internationally agreed procedures and has the major advantage that climatic factors influencing plant growth are taken into account (Monteith 1965). This mathematical formula produces the potential evapotranspiration (Eto) which has to be scaled by crop coefficient to the potential crop evapotranspiration (Doorenbos and Pruitt 1977; Jensen and Allen 2000). Although this empirical equation has been tested and approved worldwide, it requires accurate meteorological data ideally measured in the field, although in most parts of the world, the latter is often not available.

Remote sensing techniques have rapidly developed in the last two decades, as the sensors that capture the data have been developed giving improved spectral and spatial resolutions of the images. Remote sensing data are primary sources extensively used for change detection in recent decades (Lu et al. 2004; Matinfar et al. 2013). Remote sensing has been identified as a powerful tool producing information in spatial and temporal domain, instead of point measurement, with high resolution. The efficiency of remote sensing applications has rapidly evolved, providing information with varying degrees of success and accuracy on land use/cover classification, irrigated area, crop type, and crop evapotranspiration (Anderson et al. 1976; Nualchawee 1984; Granger 1989; Foody 1995; Bastiaanssen et al. 1998; Bastiaanssen 2000; Nirala and Venkatachalam 2000; Prakash et al. 2000; Su 2000).

Considering the estimation of crop water use, i.e., evapotranspiration, several methodologies are available. Many are based on the determination, through the use of thermal infrared bands, of radiometric surface temperature and then employed in solving simplified energy balance equations (Kustas and Norman 1996). This type of approaches has been developed into more sophisticated procedures, integrating remotely sensed data into vegetation–atmosphere transfer models Allen et al. (2005). However, these methods effectively lead to the estimation of a “snapshot” of the actual evapotranspiration at the moment of satellite overpass, at best extended to daily values and needing interpolation procedures for the estimation of monthly or seasonal values. In this respect, two alternative strategies are used, both adopting the Food and Agriculture Organization (FAO) approach (Allen et al. 1998). It leads to the estimation of evapotranspiration of crops under optimal agronomic conditions, i.e., in the absence of any biotic or a biotic stress, which is not realistic under the current farming practice. Moreover, it has been shown that crop coefficients are site specific and should be determined locally, implying the need of dedicated experimental activities. Therefore, the accuracy of the estimates decreases whenever farming or environmental factors cause limitations to crop growth and where local data on crop coefficients are missing. However, this inaccuracy can sometimes cause inconveniences when the method is used for irrigation management or scheduling. The considered FAO approach can be considered adequate for planning purposes or deriving indications on the spatial and temporal evolution of crop water requirements. The simplest method available for the spatial estimation of evapotranspiration following the FAO approach is to derive through remote sensing a crop classification map. Consequently, monthly crop coefficient (Kc) values are associated to each crop class and a reference evapotranspiration map, e.g., derived from meteorological data, and are used in order to estimate crop evapotranspiration in a GIS environment (Stehman and Milliken 2007). Abdel Kawy and Abou El-Magd (2012) studied the crop water requirements of soils in the South El Farafra Oasis, Egypt. They found that the most suitable crops for the studied area were clover, wheat, beans, sugar beet, onions, maize, sunflower, tomato, potato, groundnut, pea, lentil, barley, sesame, and carrots. Darwish and Abdel Kawy (2012) investigate the land use changes in the areas west of Nile Delta, Egypt. They proved that the most suitable crops to grow in the study area according to the crop suitability results were maize, melon, potato, sunflower, onion, garlic, olive, and date palm in the order indicated. It is found that the main limitation factors for land suitability are the excess of salts, shallow soil depth, and inadequate drainage conditions.

Knowledge of evaporation demand is essential to define irrigation water requirements. Satellite imagery offers a valued source of information that could effectively resolve this problem. For example, optical satellite imagery has been used to estimate surface temperature and soil evaporation (Choudhury

1994; Eymard and Taconet 1995; Amano and Salvucci 1999). The existence of multiple spectral channels of visible and thermal infrareds gave the opportunity to calculate surface temperature and soil evaporation which are used later to extract the evapotranspiration (Moran 1994). The wide range of the sensor recording bands made the computational indices between these bands that give a logarithmic relationship between crop water stress index (Jackson et al. 1977) and soil moisture (Yu and Tian 1997; Kondo et al. 1998).

Remote sensing techniques offer solution to the limitations and shortcomings of conventional methods for estimating crop evapotranspiration by providing near real-time information on the daily crop water use as influenced by development pattern of the crop, the crop coverage, local atmospheric conditions, and field spatial variability (Hunsakar and Pinter 2003). Remotely sensed data can, therefore, give a near real-time mean of instantaneous estimation of energy balance and therefore the crop evapotranspiration, together with the percent of the crop stand. Sensible heat flux methodology (Bastiaanssen et al. 1998; Bastiaanssen 2000; Abo El-Magd and Tanton 2005) using the optical satellite imagery is found to be efficient to estimate the crop evapotranspiration as a residual of the latent heat flux.

This study aimed to evaluate the agricultural potentiality of in the study area's soils using remotely sensed data and GIS technologies. In addition, one of the targets is to determine the most appropriate land use type and then assessing the water requirements for the qualified suitable crops.

Materials and methods

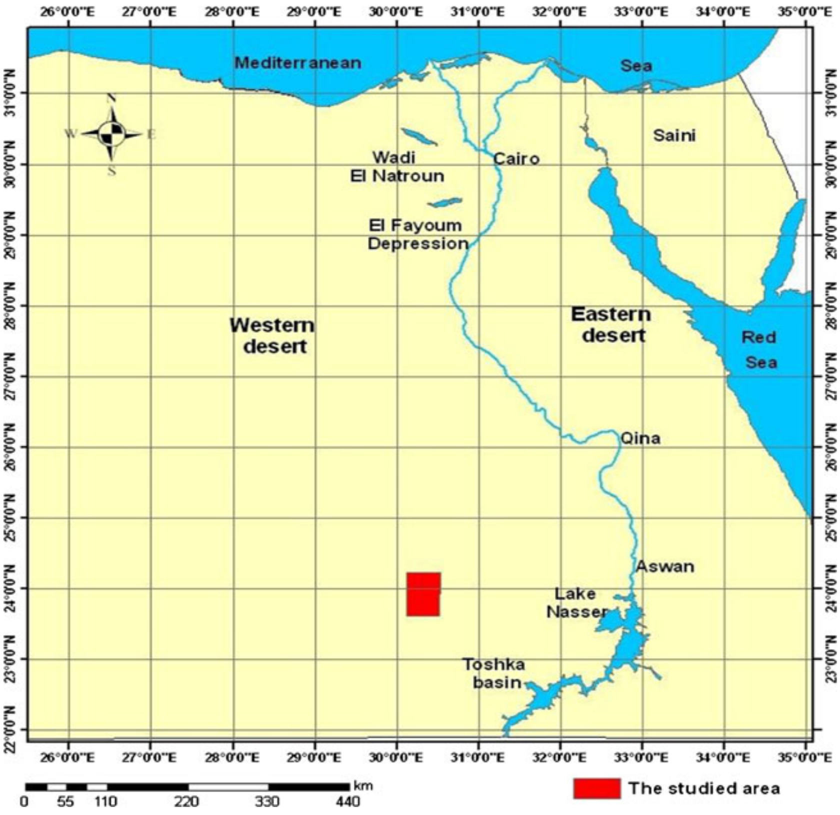
Location and description of study area

The studied area located between latitudes 23°36 and 24°14′N and longitudes 30°09 and 30°32′E, and occupying an area of 685,440 acres (Fig. 1).

Concerning the climatic conditions of the study area, according to EMA (1996) and Climatologically Normal for Egypt (2011) and the American Soil Taxonomy (USDA 2010), the soil temperature regime of the studied area could be defined as hyperthermic, while the soil moisture regime is torric.

From the geology point of view, the studied area belongs mainly to Pleistocene sediments. The surface of the area is essentially occupied by Upper Cretaceous Nubian Formations made up of cross-bedded sandstones with interbedded shale. The extrusive rocks, which belong to the Precambrian age, are exposed in scattered patches. On the limestone plateau, Tertiary Eocene and Paleocene limestone and shale overlie the Nubian Formation, which is locally intruded by basalts

Fig. 1 Location map of the studied area



believed to be of late Tertiary or Early Pleistocene age (Said 1993; UNDP/UNESCO 2001).

In regard to the area geomorphology, El-Shazly (1976), ASRT (1989), and UNDP/UNESCO (2001) demonstrated that the geomorphologic features displayed in this area are (1) the elevated plateau, (2) the foothill slopes, and (3) the Kharga Oasis depression. The latter includes hills, ridges, lacustrine deposits, local marshes, crescentic sand dunes, and sand sheets.

In regard to the water resources in the study area, Ezz El Deen (1996) reported the hydrogeology of the Nubian aquifer south of the studied area and showed that the succession was overlain by variegated shale bed (cap rock) and underlain by the basement complex. The whole thickness varies from about 230 m in the south to more than 750 m in the north. This wide variation of thickness could be attributed to the general configuration of the basement, which in turn controlled by the geological structures. The depth to water varies from 35 m below ground surface at south to 16 m at north, so the piezometric water level varies from 72 to 26 m from south to north. This indicates that the general trend of groundwater movement tend to be from south to north. However, the productive layers in the past were generally exploited under artesian flowing condition. At present, pumping is necessary where all wells have stopped flowing due to over pumping and the consequent formation of regional cones of depression.

Soil data collection

Total of 10 soil profiles and ground truth data were conducted in the depression floor territory; besides, 60 mini pits were carried out to check the accuracy of mapping boundary.

Soil physical analyses

Particle size distribution (by hydrometer method) was determined according to Klute (1986), Blake and Hartge (1986a), and (1986b).

Soil chemical analyses

Electric conductivity (EC), soluble cations and anions, calcium carbonate, organic matter, pH, exchangeable Na+, macronutrients, and cation exchange capacity (CEC) were determined according to USDA (2004).

Water samples analyses

Three water samples (pH, EC, total dissolved solids, and sodium adsorption ratio (SAR) were carried out using the soil survey laboratory methods manual USDA (2004). Suitability of water for irrigation was determined according to the limitations outlined by FAO (1985).

Remote sensing data and image processing

Two Landsat ETM+ images of the study area (path 176–row 43 and path 176–row 44) were used for image analysis in this research. The digital image processing for Landsat ETM+ satellite images with spatial resolutions of 28.50 m acquired in year 2010 was executed using ENVI 4.7 software (ITT 2009). Digital image processing included gap filling of ETM+ SLC-off images, in which all missing image pixels in the original SLC-off image have been replaced with estimated values based on histogram-matched scenes. Data were calibrated to radiance using the inputs of image type, acquisition date, and time. Images were stretched using linear 2 %, smoothly filtered, and their histograms were matched according to Lillesand and Kiefer (2007). Satellite image was rectified (geometrically). The false color composite of the image was performed using the normally used band combination for agricultural analysis purposes of bands (7, 4, and 2) (Fig. 2).

Geomorphology and soils mapping using geographic information system

Geomorphologic mapping was carried out using digital image processing of Landsat ETM+ images (path 178, rows 43 and 44), 2010, executed using ENVI 4.7 software ITT, (2009). Image was stretched using linear 2 %, smoothly filtered, and their histograms were matched according to Lillesand and Kiefer (2007) (Fig. 2).

Image was atmospherically corrected using FLASH module ITT, (2009). The different landforms were initially determined and delineated from the satellite image, digital elevation model from shuttle radar topography mission (NCSA 2005), and the available contour map, following the methodology developed by Dobos et al. (2002) and Kalogirou (2002) (Fig. 3).

Ten soil profiles and 30 min pits were conducted in the depression floor territory (Fig. 4). The morphological descriptions of the soil profiles were carried out using ISRIC (1991) and FAO (2006). Keys of soil taxonomy USDA (2010) was used to classify the different soil profiles. ArcGIS 9.3.1 and its spatial analyst extension (ESRI 2009) were used for mapping soil variables.

Land evaluation and land suitability assessment

Land quality classes were defined according to Gary (1988) and USDA (2005). The guideline for “land evaluation for irrigated agriculture” after FAO (1985) was used for assessing the water quality. The land suitability for crops was carried out according to Sys (1985) and Allan (2004). The main land qualities of the different mapping units

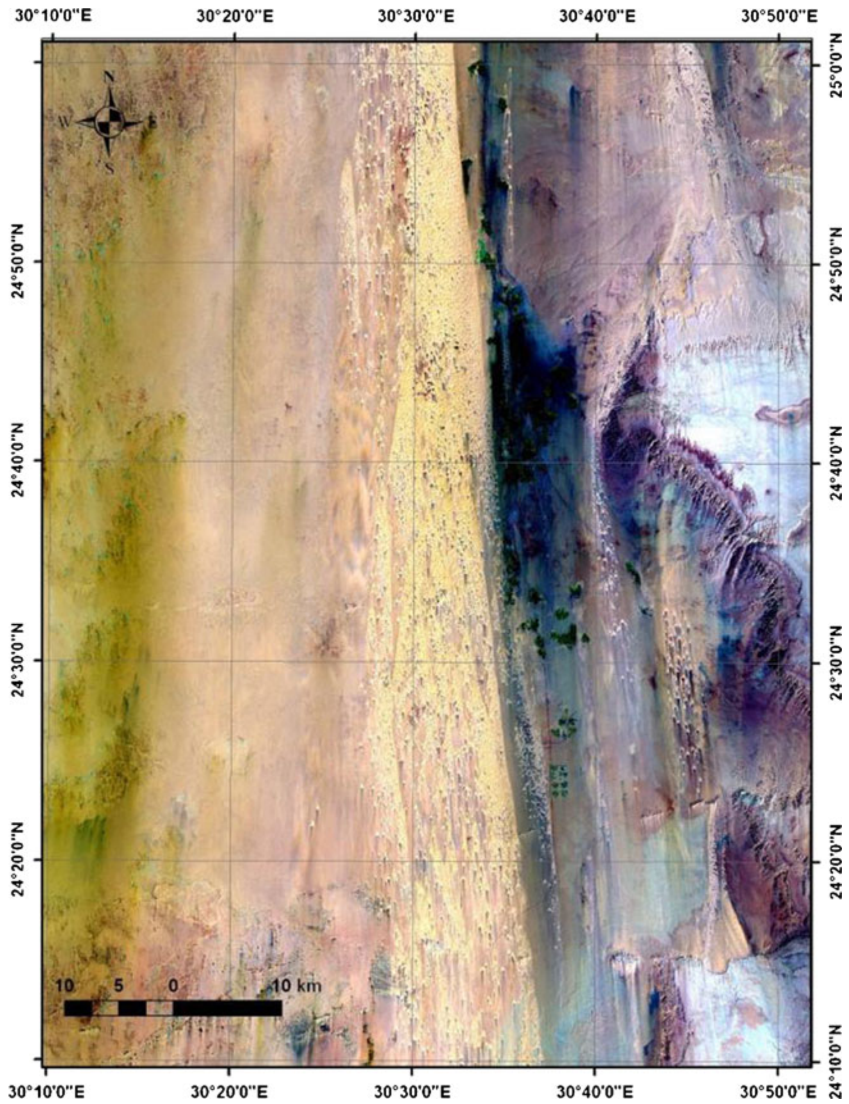


Fig. 2 Landsat ETM+image of the studied area

and the crop requirement were rated and matched to obtain the current and potential land suitability, which was carried out using automated land evaluation system (ALES) 4.1 software (Rossiter and Wambeke 1997); (Rossiter 2003) depending on soil rating after Sys et al. (1993) and Sideruis (1984; 1989).

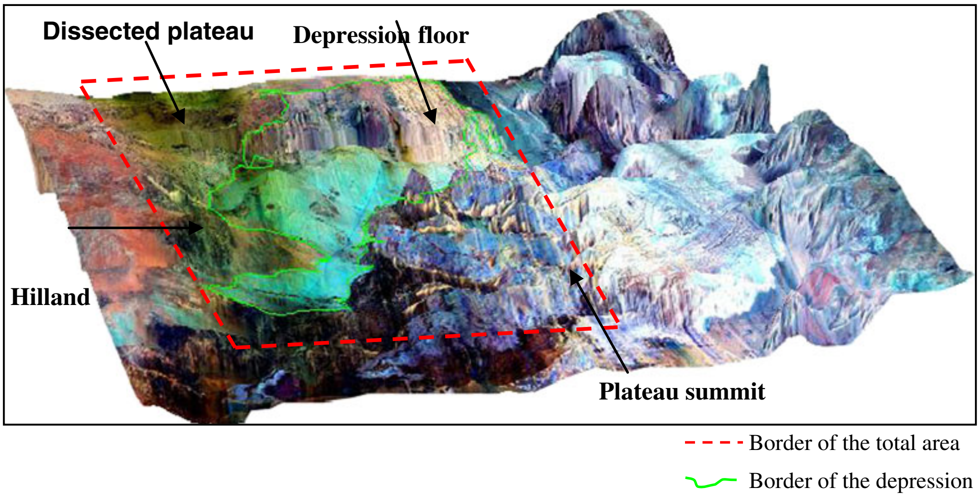


Fig. 3 Digital elevation model of the studied area

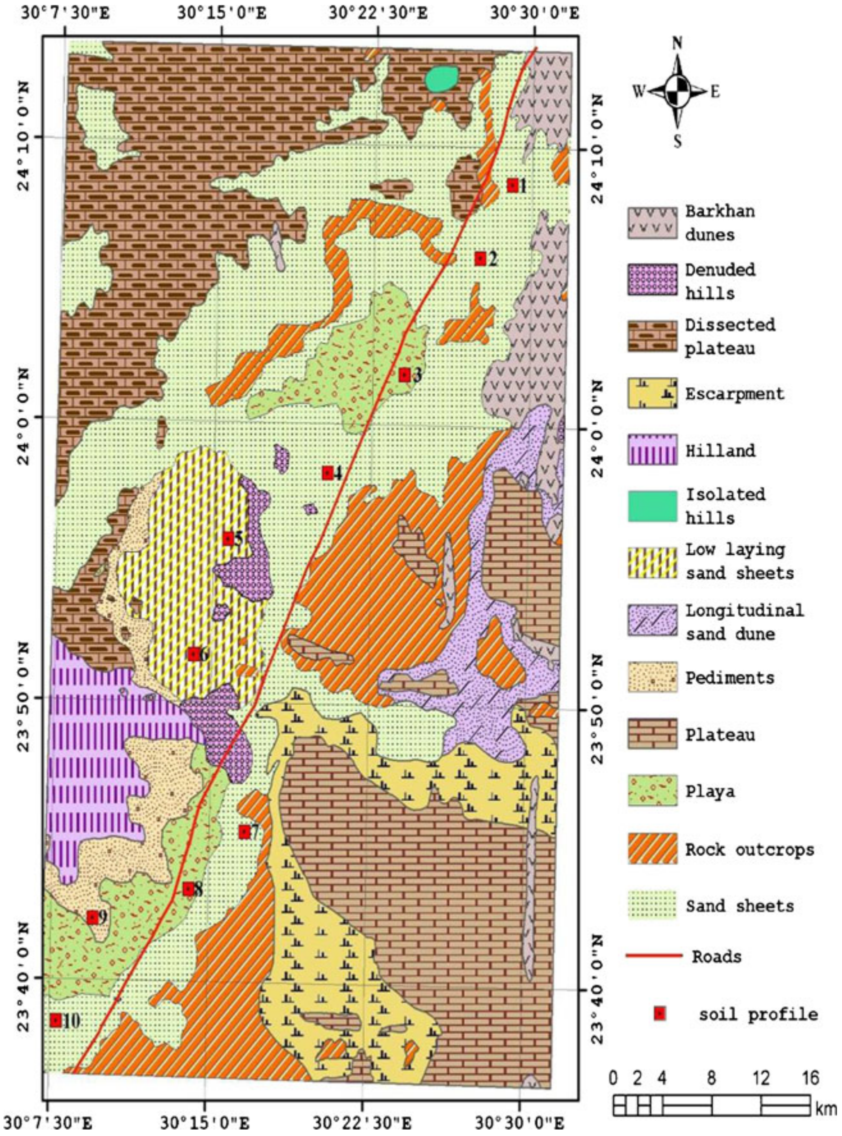


Fig. 4 The main landforms of the studied area

Corp water requirement

The crop water requirements were calculated using CROPWAT 8.0 for Windows program. The program determines ETO using Penman–Monteith method (Allen et al. 1998). The climatic data of the studied area is extracted from EMA (1996) and Climatologically Normal for Egypt (2011).

Results and discussion

Geomorphology and soil of the studied area

Using the digital elevation model integrated with satellite images, it was verified that the study area includes three main physiographic units, i.e., plateaus (339,993.54 acres), hills (59,998.86 acres), and the depression floor (285,447.60 acres) as shown in Fig. 3. Through this model, it is possible to separate the depression units; then the land forms of the depression floor were delineated as shown in Fig. 4. The obtained data indicate that the depression floor include the landforms of sand sheets (188,055.09 acres), low laying sand sheets (23,474.50 acres), playa (43,946.69 acres), denuded hills (9,688.72 acres), and pediments (20,282.60 acres).

The landforms of the depression floor were represented by ten soil profiles; some physical and chemical properties are shown in Table 1. The data indicate that the soils of the depression floor are characterized by sandy to gravelly sand texture in the successive layers of the soils profiles. The soil depth varies between 60 and 140 cm; the EC and exchangeable sodium percentage values differ from 0.50 to 13.83 dS/m and 4.10 to 12.80 %, respectively. The high values of salinity were found in playas, while low values characterized the sand sheet landforms. CEC in general is low in the different soil profiles; it is located in the range of 4.79 to 14.11 mEq/100 g soil. The values of available nitrogen, phosphorous, and potassium are

Table 1 Physical and chemical analyses of the studied soil profiles

Profile	Depth (cm)	Particle size distribution %							Texture class	pH	O.M. %	$CaCO_3$ %	EC dS/m	CEC mEq/ 100 g soil	ESP %	Available macro-nutrients (in the surface layer) (ppm)		
		> 2 mm	2–1 mm	1–0.5 mm	0.5–0.25 mm	0.25–0.125 mm	0.125–0.063 mm	<0.063 mm								N	P	K
1	0–20	9.3	28.94	16.00	31.20	17.82	2.43	3.61	S	7.9	0.10	7.4	11.84	8.21	9.9	0.5	1.0	6.7
	20–30	11.4	25.24	21.33	26.17	24.11	3.15	2.17	S	7.8	0.04	6.2	6.16	9.11	8.5	–	–	–
	30–100	2.6	34.65	18.48	21.09	19.00	4.18	2.60	S	7.9	0.01	9.8	4.29	10.24	9. 0	–	–	–
2	0–30	14.3	20.38	18.12	26.00	26.00	5.20	4.11	S	7.8	0.10	6.9	8.71	8.00	10.0	0.4	0.8	8.0
	30–60	26.2	17.66	17.42	21.30	30.30	7.14	6.28	GS	7.8	0.02	6.0	8.16	10.21	9.1	–	–	–
3	0–20	16.0	36.01	26.01	21.89	11.16	3.23	1.70	S	7.7	0.10	10.1	13.83	5.8	4.1	0.6	1.2	7.5
	20–80	3.1	43.39	16.22	19.10	15.00	4.10	2.19	S	7.7	0.03	3.3	11.19	7.0	6.2	–	–	–
	80–130	1.7	32.74	10.15	17.00	37.47	1.71	0.39	S	7.9	0.01	4.6	6.24	8.1	7.5	–	–	–
4	0–30	–	11.69	30.27	34.66	18.75	4.10	0.46	S	7.7	0.16	10.7	3.80	4.79	5.9	0.5	1.4	7.8
	30–60	–	10.00	21.12	43.99	21.47	2.25	1.17	S	7.8	0.07	7.6	4.11	6.33	7.4	–	–	–
	60–130	–	19.16	19.00	39.72	19.10	1.67	1.35	S	7.8	0.02	8.0	2.18	8.10	9.1	–	–	–
5	0–15	6.3	18.68	20.36	31.20	26.30	2.16	1.30	S	7.6	0.18	4.7	3.17	7.14	10.1	0.7	1.6	8.5
	15–40	–	21.18	29.42	21.17	25.13	3.10	0.60	S	7.7	0.10	5.1	2.82	8.20	9.3	–	–	–
	40–100	–	19.23	40.49	18.15	19.00	1.24	1.89	S	7.8	0.04	7.2	4.16	9.67	9.0	–	–	–
6	0–20	12.4	11.82	48.89	23.33	13.45	1.79	0.72	S	7.6	0.16	3.8	7.30	8.5	8.3	0.5	1.3	7.5
	20–60	16.3	13.15	44.55	21.12	18.63	1.42	1.13	GS	7.9	0.10	2.7	6.41	11.4	10.2	–	–	–
	60–120	7.6	35.66	26.07	18.51	17.17	2.11	0.48	S	7.8	0.04	1.8	5.00	12.4	11.1	–	–	–
7	0–20	16.3	21.68	37.38	21.43	17.91	1.18	0.42	GS	7.6	0.17	14.6	5.42	7.2	7.8	0.7	1.7	9.2
	20–40	13.2	20.71	39.40	20.22	18.00	1.00	0.67	S	7.8	0.09	8.6	6.81	10.1	9.1	–	–	–
	40–110	22.8	27.42	32.64	19.18	19.16	1.00	0.60	GS	7. 6	0.03	1.8	8.29	7.4	11.0	–	–	–
8	0–30	–	23.42	34.55	23.65	16.18	1.10	1.10	S	7.9	2.6	2.6	11.71	11.24	8.5	0.5	1.3	7.4
	30–80	7.6	30.11	22.81	24.18	17.19	3.40	2.31	S	7.6	1.1	1.6	6.18	10.00	9.0	–	–	–
	80–140	–	28.10	27.49	20.10	20.25	2.61	1.45	S	8.1	1.7	1.7	7.10	7.19	9.0	–	–	–
9	0–15	2.6	24.10	30.10	21.85	18.13	3.18	2.64	S	8.1	1.3	1.3	8.18	9.16	7.6	0.6	1.5	7.0
	15–35	1.0	25.00	31.06	19.17	21.30	1.65	1.82	S	7.6	1.4	1.4	0.50	11.80	10.4	–	–	–
	35–100	0.7	19.00	37.47	10.12	29.16	1.00	3.25	S	7.7	1.0	1.0	7.14	14.11	8.00	–	–	–
10	0–20	–	14.18	40.84	31.18	11.82	0.70	0.80	S	8.1	1.6	1.6	6.18	11.26	8.18	0.5	1.4	6.5
	20–60	–	10.32	46.11	28.00	14.16	0.82	0.71	S	7.9	2.8	2.8	7.33	13.18	10.18	–	–	–
	60–110	–	11.06	44.53	24.25	19.00	1.10	0.34	S	7.8	1.3	1.3	11.20	11.00	12.84	–	–	–

low, as it not exceeds 0.7, 1.7, and 9.2 ppm, respectively. The soils of the depression floor are classified to the sub-great groups as Typic Torripsamments (profiles 1, 2, 4, and 10) and Typic Torriorthents (profiles 3, 5, 6, 7, 8, and 9).

Water quality

Water plays an important role in land use especially irrigation water, which is considered the decisive factor of salinization. Table 2 illustrates some chemical analyses of the collected water samples. The data indicate that the EC is low in the collected samples as it ranges between 0.60 and 1.36 dS/m. The values of SAR in general are less than 4.50 in the different samples. The pH values ranges between 7.0 and 7.4. Therefore, water quality is fit optimum into the quality requirements scope of most crops.

Land quality assessment

The assessment of land quality in this study were based on several factors, i.e., slope percentage, drainage class, texture/structure, coarse fragments percentage, soil depth, $CaCo_3$ percentage, erosion vulnerability, CEC, availability of nutrients, soil salinity, and exchangeable sodium percentage (Table 3). The data obtained indicate that the windblown, CEC, and availability of nutrients are the main limiting factors as they reduced the land qualities in the studied soil profiles. Texture and structure are moderate to marginally capable, where the slope percentage, drainage condition, coarse fragments percentage, soil depth, $CaCo_3$ percentage, soil salinity, and exchangeable sodium percentage are high to moderately capable in the different soils of the depression floor.

Land suitability classification

Actual and potential suitability deals with land qualities coupled with crop requirements calculated by using the ALES. The selections of the most promising crops to be evaluated according to their suitability for the investigated area were based on the following parameters: sustaining the natural resources, national strategic plans, and economic viability. Regarding the last mentioned factor, fairly traditional crops are proposed for the studied area. The main selected crops are (clover, wheat, beans, sugar beet, onion, maize, sunflower, tomato, potato, groundnut, pea, lentil, barley, sesame, and carrot), suitability of the studied crops.

Table 2 Chemical composition of the water samples

Well no.	Location		pH	EC dS/m	TDS ppm	SAR
	Latitude	Longitude				
1	24°06′50″	30°28′35″	7.3	0.84	537.6	1.99
2	24°04′20″	30°25′58″	7.1	0.76	486.4	2.70
3	23°59′26″	30°24′43″	7.4	0.80	512.0	2.38
4	23°57′18″	30°18′30″	7.2	1.20	768.0	3.91
5	23°55′02″	30°18′27″	7.0	0.62	396.8	2.28
6	23°50′54″	30°18′48″	7.3	1.36	870.4	4.22
7	23°43′50″	30°16′07″	7.1	0.60	384.0	2.23
8	23°40′36″	30°13′22″	7.2	0.73	467.2	2.67

Current and potential land suitability for crops

The current land suitability classes of the second new introduced land utilization type LU2 are shown in Table 4; the obtained data indicate that the land uses of beans, maize, groundnut, and pea are currently not suitable in the studied area. The most limiting factors of these crops are windblown, cation exchange capacity, salinity, and nutrients availability. The current suitability of potato, tomato, sunflower, lentil, sesame, and carrot are marginally suitable in most of the studied soil profiles.

With moderate to high input, the potential suitability of these soils can be moderate (S2) for the selected field crops (LU2), as the needed land improvements include controlled fertilizing system, special method for irrigation, removing gravels, and establish wind breaks.

Current and potential land suitability for fruits

The current land suitability of the selected fruit (LU3) are shown in Table 5, the obtained data show that the studied soils are currently marginal suitable for citrus, date palm, and olives, while it is currently not suitable for apples, bananas, and grapes. The most limiting factors are windblown, CEC, soil depth, and nutrients availability. Under high input, the potential suitability of these soils can be moderate for the selected fruit trees. It is proposed to use the system of organic agriculture with such crops.

Crop water requirements

The ETO from January to December were 33, 36, 49, 64, 77, 86, 88, 90, 73, 56, 43, and 33, respectively. The crop water requirements for the selective crops were calculated using CROPWAT 8.0 for Windows program. The calculated values were as follow: clover=828.0 mm, beans=596.7 mm, wheat=410.3 mm, sugar beet=679.95 mm, onion=409.52mm, maize=791.60 mm, sunflower=712.2 mm, tomato=902.93 mm, potato=456.55 mm, groundnut=529.95mm, pea=231.4 mm, lentil=217.95 mm, barley=303.93 mm, sesame=502.65 mm, and carrot=274.35 mm, respectively. This is clearly shown in Table 6.

Table 3 Land quality classes of the studied soil profiles

Factors		Soil profiles									
		1	2	3	4	5	6	7	8	9	10
Slope	A	2	2	1	2	1	1	1	2	2	2
Drainage condition	B	2	3	2	2	2	2	2	2	2	2
Texture/structure	C	3	3	3	3	3	3	3	3	3	3
Coarse fragments	D	2	2	3	1	1	2	3	1	1	1
Soil depth	E	2	3	1	1	2	2	2	1	2	1
CaCo$_3$	F	1	1	1	2	1	1	2	1	1	1
Wind erosion vulnerability	G	3	3	3	3	3	3	3	3	3	3
CEC	H	4	4	4	4	4	3	4	4	3	3
Nutrients availability	I	4	4	4	4	4	4	4	4	4	4
ECe	J	3	2	3	1	1	2	2	3	2	2
ESP	K	1	1	1	1	1	1	1	1	1	1
Limitation to class 3	–	B, G, J	B, C, G	C, D, G ,J	C, G	C, G	C, G, H	C, D, G	C, G, J	C, H	C, H
Limitation to class 4	–	H, I	H, I	H, I	H, I	H, I	H, I	H, I	H, I	H, I	H, I

1 Highly suitable, *2* moderately suitable, *3* marginally suitable, *4* currently not suitable

Conclusion

Results based on the present work demonstrate that the investigated area is facing numerous constrains such as soil productivity, social acceptability, and economic viability which could hinder the agricultural sustainability in the region. A number of factors were considered when selecting cropping patterns, including physical factors, financial factors, socioeconomic factors, and traditional factors.

Table 4 Land suitability for some field crops (LU2)

Land use (LU)	Soil profiles									
	1	2	3	4	5	6	7	8	9	10
Beans	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4
Clover	S1	S2	S2	S1	S1	S2	S3	S1	S1	S2
Maize	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4
Onion	S3	S3	S4	S3	S3	S3	S3	S3	S3	S3
Potato	S4	S2	S4	S4	S3	S4	S4	S4	S2	S3
Sunflower	S3	S4	S4	S4	S3	S3	S4	S4	S2	S4
Tomato	S3	S4	S4	S3	S3	S4	S4	S4	S3	S4
Sugar beet	S3	S3	S4	S3	S3	S3	S3	S3	S3	S3
Wheat	S2	S3	S4	S2	S3	S3	S3	S3	S2	S3
Groundnut	S3	S4	S4	S4	S4	S4	S3	S4	S2	S4
Pea	S4	S4	S3	S4	S2	S4	S4	S4	S4	S2
Lentil	S2	S4	S3	S4	S4	S3	S4	S2	S4	S4
Barley	S3	S3	S4	S3	S3	S3	S3	S3	S3	S3
Sesame	S4	S2	S3	S4	S2	S4	S4	S4	S3	S4
Carrot	S3	S4	S2	S4	S2	S4	S4	S3	S4	S2

The physical factors normally include the environmental natural elements, i.e., water, soil, climate, and topography. On the other hand, the financial factors normally include financial returns, risks, and labor requirements. In addition, socioeconomic factors officially include economic returns, food production, and employment. Nevertheless, the traditional factors can oscillate between two factors, i.e., past experience and practice.

Based on these factors, fairly traditional crops and rotations are proposed for the studied area. The main crops selected are summer crops and vegetables that include maize, sunflower, groundnut, tomato, and sesame. The water requirements of the last mentioned crops and vegetables ranged between 502.65 and 902.93 mm per season.

On the other side, winter crops and vegetables can include clover, wheat, beans, sugar beet, onions, potato, pea, lentil, barley, and carrots. It is found that these types of winter crops and vegetables have water requirements ranging from 217.95–828.0 mm per season.

Table 5 Land suitability for some fruit trees (LU3)

Land use (LU)	Soil profiles									
	1	2	3	4	5	6	7	8	9	10
Apples	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4
Bananas	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4
Citrus	S3	S4	S3	S3	S3	S3	S3	S3	S3	S3
Date palm	S3	S4	S4	S3	S3	S3	S3	S3	S3	S3
Grapes	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4
Olives	S3	S4	S3	S3	S3	S3	S3	S3	S3	S3

Table 6 Crop water requirements (mm/growing season) for the suitable crops examined in the studied area

Month	ETo mm/ 10 days	Clover (210 days)			Wheat (180 days)			Beans (130 days)		
		KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month
Jan	33	1.00	33.0	99.0	0.90	29.7	99.0	1.10	36.3	108.9
	33	1.00	33.0		1.00	33.0		1.10	36.3	
	33	1.00	33.0		1.10	36.3		1.10	36.3	
Feb.	36	1.00	36.0	108.0	1.10	39.6	118.8	0.90	32.4	57.6
	36	1.00	36.0		1.10	39.6		0.70	25.2	
	36	1.00	36.0		1.10	39.6				
Mar.	49	0.90	44.1	132.3	1.10	53.9	161.7			
	49	0.90	44.1		1.10	53.9				
	49	0.90	44.1		1.10	53.9				
Apr.	64	0.90	57.6	172.8	0.70	32.2	83.4			
	64	0.90	57.6		0.50	32.0				
	64	0.90	57.6		0.30	19.2				
May	77									
	77									
	77									
June	86									
	86									
	86									
July	88									
	88									
	88									
Aug.	90									
	90									
	90									
Sep.	73									
	73									
	73									
Oct.	56	0.50	28.0	100.8						56.0
	56	0.60	33.6					0.50	28.0	
	56	0.70	39.2					0.50	28.0	
Nov.	43	0.80	34.4	116.1	0.50	21.5	64.5	0.50	21.5	83.85
	43	0.90	38.7		0.50	21.5		0.65	27.95	
	43	1.00	43.0		0.50	21.5		0.80	34.4	
Dec.	33	1.00	33.0	99.0	0.60	19.8	69.3	0.95	31.35	103.95
	33	1.00	33.0		0.70	23.1		1.10	36.3	
	33	1.00	33.0		0.80	26.4		1.10	36.3	
Total ET crop (mm)		828.0			596.7			410.3		
Month	ETo mm/ 10 days	Sugar beet (200 days)			Onions (140 days)			Maize (110 days)		
		KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month
Jan	33	1.10	36.3	108.9	0.95	31.35	94.05			
	33	1.10	36.3		0.95	31.35				
	33	1.10	36.3		0.95	31.35				
Feb.	36	1.10	39.6	118.8	0.80	28.8	54.0			
	36	1.10	39.6		0.70	25.2				
	36	1.10	39.6							
Mar.	49	0.85	41.65	124.95						
	49	0.85	41.65							

Table 6 (continued)

	49	0.85	41.65							
Apr.	64	0.60	38.4	76.8						
	64	0.60	38.4							
	64									
May	77									
	77									
	77									
June	86							0.40	34.4	137.6
	86							0.50	43.0	
	86							0.70	60.2	
July	88							0.90	79.2	272.8
	88							1.10	96.8	
	88							1.10	96.8	
Aug.	90							1.10	99.0	279.0
	90							1.10	99.0	
	90							0.90	81.0	
Sep.	73							0.70	51.1	102.2
	73							0.70	51.1	
	73									
Oct.	56	0.50	28.0	84.0	0.50	28.0	84.0			
	56	0.50	28.0		0.50	28.0				
	56	0.50	28.0		0.50	28.0				
Nov.	43	0.50	21.5	77.4	0.62	26.66	83.42			
	43	0.60	25.8		0.75	19.35				
	43	0.70	30.1		0.87	37.41				
Dec.	33	0.80	26.4	89.1	0.95	31.35	94.05			
	33	0.90	29.7		0.95	31.35				
	33	1.0	33.0		0.95	31.35				
Total ET crop (mm)		679.95			409.52			791.6		

Month	ETo mm/ 10 days	Sunflower (100 days)			Tomato (120 days)			Potato (150 days)		
		KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month
Jan	33									
	33									
	33									
Feb.	36									
	36									
	36									
Mar.	49									
	49									
	49									
Apr.	64									
	64									
	64									
May	77	0.40	30.8	123.2			61.6			
	77	0.50	38.5		0.40	30.8				
	77	0.70	53.9		0.40	30.8				
June	86	0.90	77.4	266.6	0.55	47.3	187.48			
	86	1.10	94.6		0.73	62.78				
	86	1.10	94.6		0.90	77.4				

Table 6 (continued)

July	88	1.10	96.8	268.4	1.05	92.4	294.8			
	88	1.10	96.8		1.15	101.2				
	88	0.85	74.8		1.15	101.2				
Aug.	90	0.60	54.0	54.0	1.15	103.5	297.0	0.15	13.5	40.5
	90				1.15	103.5		0.15	13.5	
	90				1.00	90.0		0.15	13.5	
Sep.	73				0.85	62.05	62.05	0.50	36.5	109.5
	73							0.50	36.5	
	73							0.50	36.5	
Oct.	56							0.60	33.6	103.6
	56							0.60	33.6	
	56							0.65	36.4	
Nov.	43							1.10	47.3	141.9
	43							1.10	47.3	
	43							1.10	47.3	
Dec.	33							0.65	21.45	61.05
	33							0.60	19.8	
	33							0.60	19.8	
Total ET crop (mm)		712.2			902.93			456.55		
Month	ETo mm/ 10 days	Groundnut (120 days)			Pea (120 days)			Lentil (110 days)		
		KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month
Jan	33				0.25	8.25	24.75	0.20	6.6	19.8
	33				0.25	8.25		0.20	6.6	
	33				0.25	8.25		0.20	6.6	
Feb.	36									
	36									
	36									
Mar.	49	0.15	7.35	22.05						
	49	0.15	7.35							
	49	0.15	7.35							
Apr.	64	0.65	41.6	124.8						
	64	0.65	41.6							
	64	0.65	41.6							
May	77	1.10	84.7	254.1						
	77	1.10	84.7							
	77	1.10	84.7							
June	86	0.50	43.0	129.0						
	86	0.50	43.0							
	86	0.50	43.0							
July	88									
	88									
	88									
Aug.	90									
	90									
	90									
Sep.	73									
	73									
	73									
Oct.	56				0.15	8.4	35.2			16.8

Table 6 (continued)

	56				0.15	8.4		0.15	8.4	
	56				0.15	8.4		0.15	8.4	
Nov.	43				0.60	25.8	77.4	0.60	25.8	77.4
	43				0.60	25.8		0.60	25.8	
	43				0.60	25.8		0.60	25.8	
Dec.	33				0.95	31.35	94.05	1.05	34.65	103.95
	33				0.95	31.35		1.05	34.65	
	33				0.95	31.35		1.05	34.65	
Total ET crop (mm)		529.95			231.4			217.95		
Month	ETo mm/ 10 days	Barley (130 days)			Sesame (120 days)			Carrots (120 days)		
		KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month	KC	ET crop mm/ 10 day	ET crop mm/ month
Jan	33	0.2	6.6	13.2				0.85	28.05	84.15
	33	0.2	6.6					0.85	28.05	
	33							0.85	28.05	
Feb.	36									
	36									
	36									
Mar.	49									
	49									
	49									
Apr.	64				0.15	9.6	28.8			
	64				0.15	9.6				
	64				0.15	9.6				
May	77				0.65	50.05	150.15			
	77				0.65	50.05				
	77				0.65	50.05				
June	86				1.05	90.3	270.9			
	86				1.05	90.3				
	86				1.05	90.3				
July	88				0.20	17.6	52.8			
	88				0.20	17.6				
	88				0.20	17.6				
Aug.	90									
	90									
	90									
Sep.	73			21.9						
	73	0.15	10.95							
	73	0.15	10.95							
Oct.	56	0.50	28.0	84.0				0.15	8.4	25.2
	56	0.50	28.0					0.15	8.4	
	56	0.50	28.0					0.15	8.4	
Nov.	43	0.65	27.95	83.85				0.55	23.65	70.95
	43	0.65	27.95					0.55	23.65	
	43	0.65	27.95					0.55	23.65	
Dec.	33	1.02	33.66	100.98				0.95	31.35	94.05
	33	1.02	33.66					0.95	31.35	
	33	1.02	33.66					0.95	31.35	
Total ET crop (mm)		303.93			502.65			274.35		

**KC* crop coefficient, **ETo* evapotranspiration, **ET crop* consumptive use

Recommendations

In order to access the optimum land utilization and overcome agricultural development constrains, strategic farming management, well-planned infrastructure, and socioeconomical services should be improved to reach the standards of agricultural sustainability throughout by (1) improving land and water resources following the marketing advanced techniques of conservation and land management, (2) developing awareness levels on the sustainable issues of environmental resources exploitation, (3) persuading governors and policy decision makers to adopt monitoring and flexible mechanisms, and (4) innovations in the production's materials and methods of production and appropriate technological interventions.

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