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Full Length Research Paper

Crop water requirements in selective wetland areas, West Suez Canal, Egypt

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The present research aims to generate a geometrical corrected physiographic map with a scale (1:50,000) and calculating crop water requirements for the suitable crops in this area. To fulfill these requirements, eight soil profiles were chosen to represent the different mapping units. Morphological description was carried out and soil samples were collected for the physical and chemical analyses. Based on satellite ETM+ images of the area and the geographic information system integrated with field work and laboratory routine analyses data, the physiographic soil map was produced. In this study, two main landscape units were identified, named: Coastal plain (the Fluvio Marine deposits) and Young sub-deltaic deposits. Subsequently, the main land qualities of different mapping units with the corresponding crop requirement were rated and matched to obtain the current and potential land suitability using automated land evaluation system (ALES). In this study, it is found that the most suitable crops for the study area in regard to its crop water requirements were: Clover, wheat, beans, onion, maize, sunflower, tomato and potato.

Key words: Soil mapping, water requirements, West Suez Canal, East Delta.

INTRODUCTION

Experts' estimates that demand for food crops will be doubled during the next 50 years with limited land and water resources, therefore an output increase from existing cultivated areas to satisfy the food demand of increasing population is a must. 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 followed, due weight-age 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. The water requirements that were determined by indirect methods had similar values with those specified by the method of the soil water balance, and this confirms that these reference methods also can be used for forecasting and warning of soil watering. The practical method of crop water requirements is based on atmospheric demand utilizing the Penman-Monteith calculated evapotranspiration of field crops as evaporation (it is similar in principle to the well-known procedure based on the use of the A-pan). 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. It was considered that remote sensing would offer several advantages for such a task. Its potential for monitoring water resources is well known and there are a large number of successful applications in operative contexts in the last decades (FAO, 1995;

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Figure 1. Location of the studied area.

Belmonte et al., 1999; Shultz et al., 2000; D'Urso, 2001; Stehman and Milliken, 2007). A review of available remote sensing approaches to water resources estimation was provided by (Schmugge et al., 2002).

Considering the estimation of crop water use, that is 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 (Moran et al., 1990; Sugita and Brutsaert, 1992; Kustas and Norman, 1996).This type of approaches have been developed into more sophisticated procedures, integrating remotely sensed data into vegetation–atmosphere transfer models (Bastiaanssen et al., 1998; Allen et al., 2005). However, these methods effectively lead to the estimation of a 'snap shot' 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 FAO approach (Allen et al., 1998), in which crop evapotranspiration is obtained by multiplying reference crop evapotranspiration by a specific crop coefficient (Kc). It should be noted that although the FAO approach has been universally accepted and widely applied following its original proposition more than 30 years ago (Doorenbos and Pruitt, 1977), it leads to the estimation of evapotranspiration of crops under optimal agronomic conditions, that is 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 (Hanks, 1985) 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. While this inaccuracy can sometimes cause inconveniences when the method is used for irrigation management or scheduling, the 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. Then monthly crop coefficient (Kc) values are associated to each crop class and a reference evapotranspiration map, e.g. derived from meteorological data, is used in order to estimate crop evapotranspiration in a geographic information system (GIS) environment (Stehman and Milliken, 2007).

MATERIALS AND METHODS

The study area is located in the eastern part of the Nile Delta, it is extended between longitudes, 32° 02´ 00´´ and 32°09´ 30´´ E and latitudes, 30° 49´ 20´´ and 30° 58´ 25´´ N (Figure 1). Based on the Keys to Soil Taxonomy (USDA, 2010) the soil temperature regime of this area could be defined as Thermic and the soil moisture regime as Torric, where the arid climatic conditions dominate the area.

This area has a good agricultural potentiality and the major constraints determining the present low production capacity of the soil are salinity, sodicity, poor internal drainage and impervious compact soil structure. Two main landscapes characterize this area, the fluvoi-marine plain and the river terraces, both of them originated from fluvial and deltaic origin. Between these two landscapes, there is a wide transitional zone, strongly affected by wind action and consisting of nearly flat plains, gypsiferous sandy soils, and windblown sand soils, with dunes or hummocky relief and small strip of transitional soils. The area in general has fairly flat relief except the river terraces and sand dunes, which have an undulating or hummocky relief. The northern and eastern parts of the study area include young fluvio-marine deposits, which were originally transported and deposited by both the river and the sea, and which are composed of clay and silty clay inter-layered with lenses of quartz sand, and highly enriched with salts. The southern parts of the area include young Aeolian deposits, which are distributed as sand sheets developed into hummocks or sand dunes of variable size. While the western parts include Sub-deltaic deposits which are composed of medium and fine quartz sand.

Field work and laboratory analyses

A semi detailed survey was done throughout the investigated area in order to gain an appreciation on the soil patterns, the land forms and land use/land cover. Eight soil profiles were selected from thirty profiles to represent different land forms; the morphological description of these profiles was carried out according to the guidelines edited by (FAO, 2006). Representative disturbed soil samples have been collected and analyzed.

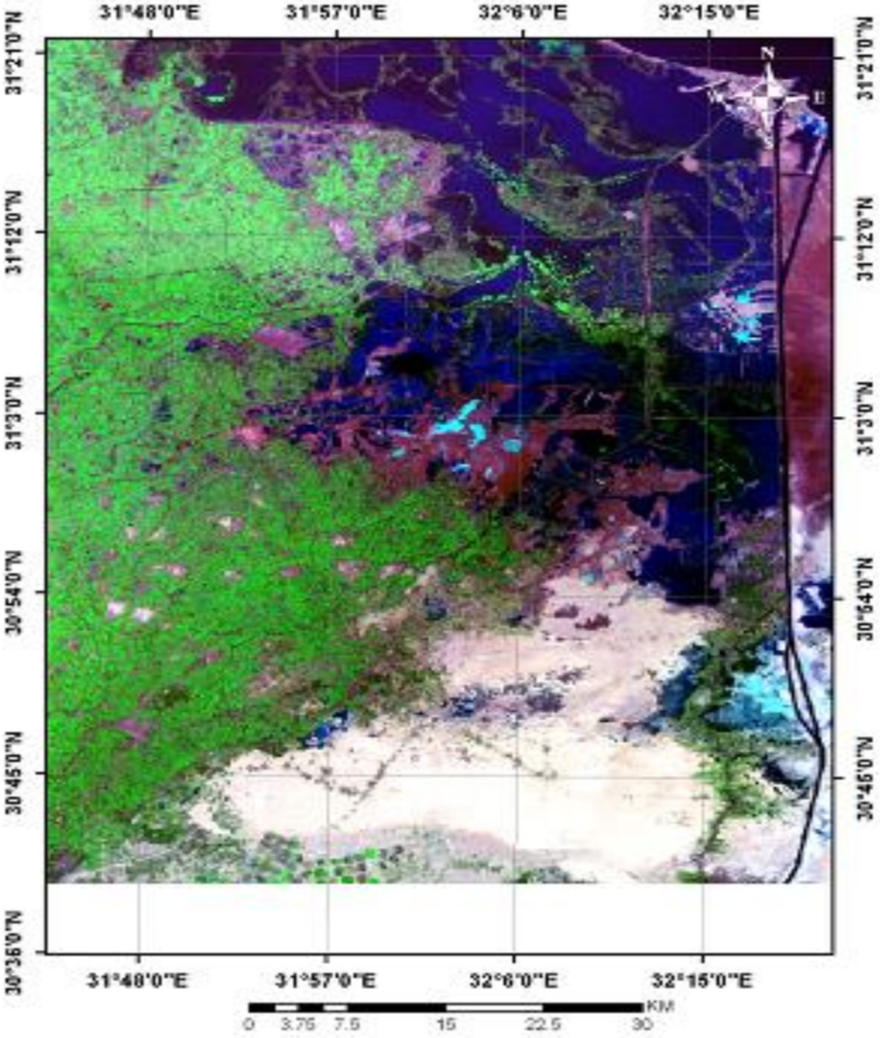

Figure 2. ETM+ Image of the study area.

Physical analysis

Particle size distribution was determined according to Klut (1986).

Chemical analysis

Electrical conductivity (EC), soluble cations and anions, total calcium carbonate ($CaCO_3$), organic matter (O.M), pH, exchangeable sodium Na^+, macro nutrients and cation exchange capacity (CEC), were determined according to (USDA, 2004).

Geomorphology and soils mapping using geographic information system (GIS)

Geomorphologic map was produced using digital image processing of Landsat 7 ETM+ image dated to the year 2010 (Figure 2), which was 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). Image was atmospherically corrected using FLAASH module.

The different landforms were initially determined from the satellite image and the digital elevation model was extracted from the contour map, following the methodology developed by (Dobos, 2002). Keys to soil taxonomy (USDA, 2010) were used to classify the different soil profiles. ArcGIS 9.3.1 and its spatial analyst extension (ESRI, 2009) were used in soil mapping and soil variables.

Land suitability

Actual and potential suitability were estimated by using the automated land evaluation system (ALES) after (Rossiter and Wambeke, 1995) and based on soil rating after (Sideruis, 1984,1989).

Corp water requirement

The crop water requirements were calculated using cropwat program. The program determines ET_O using Penmon-Monteith method (Allen et al., 1998). The climatic data of the studied area were extracted from (EMA, 1996).

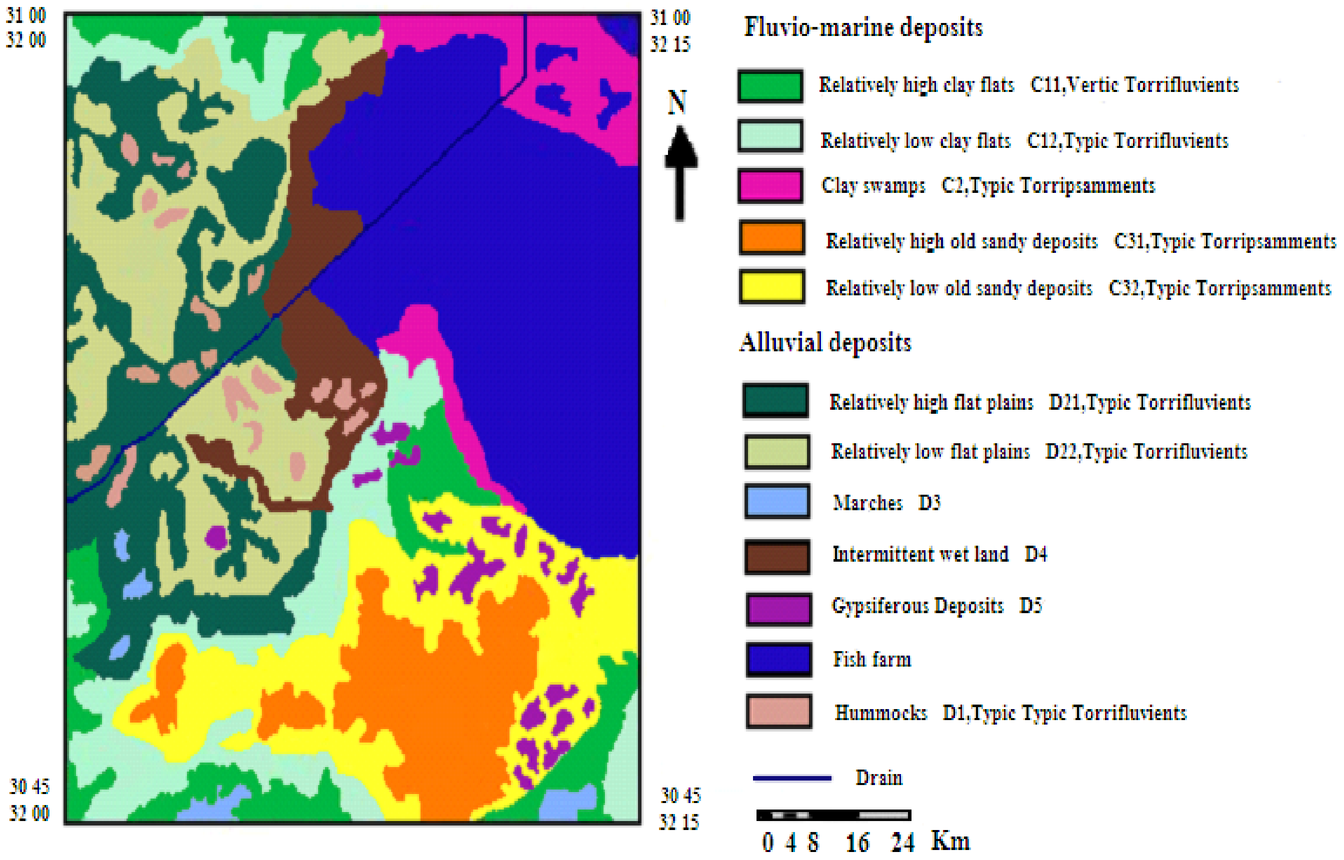

Figure 3. Geomorphology and soils of the investigated area.

RESULTS

Landforms of the studied area

The landforms of the studied area were delineated by using the digital elevation model, Landsat ETM+ and ground truth data. Figure 3 and Table 1 represent the main landforms of the study area.

The obtained data indicated that the western side of the area included the landforms of Flat plains (55.19 km^2) and Hummocks (1.88 km^2). These landforms are exhibited by alluvial deposits of the Nile River. The eastern side was dominated by Fluvio-marine deposits including the landforms of Clay flats (43.62 km^2), Clay swamps (7.86 km^2), Marches (3.01 km^2), Intermittent wet land (4.83 km^2), Gypsiferous deposits (2.12 km^2) and Fish pond (80.15 km^2). The south east corner of the area is occupied by the aeolian deposits which included old sand deposits (37.45 km^2) landforms.

Soils of the studied area

The obtained results indicate the following:

Soils of coastal plain: (Fluvio- marine deposits)

This plain was low lying and almost flat. It was originally affected by the Nile then the sea and later by the wind as soil forming factors. Soils of this landscape mainly occured on three main sub-land types, that is clay flats, clay swamps and old sand deposits. These soils were found in mapping units C11, C12, C2, C31 and C32 and were represented by soil profiles 1, 3 and 5.

The particle size distribution was characterized by alternative pattern of sedimentation as the texture was clayey for the different layers of profiles 1 and 3 and sandy clay loam in the upper layer, sandy in the second layer of profile 5. The structure was massive. The consistence was extremely firm, very sticky, and very plastic. There were few or many shells along the profile depths. The compaction of the second horizon was slight to high. There were common fine to medium pores. The effervescence with HCl was slight to moderate, the boundary between soil profile layers were clear. EC values of the soil paste varied between 15.3 and 19 dS/m; pH value is 8.6–8.8; Organic matter content ranged

Table 1. Physiographic and soil map legend of the Investigated area.

Landscape	Relief	Lithology/origin	Land form	Mapping unit	Rep. profiles	Soil subgroup class	Soil sets
Coastal plain	Gently undulating	Fluvio-marine deposits.	*Clay flats relatively high relatively low	C11	1	Vertic Torrifluvents	Cons.
				C12	2	Vertic Torrifluvents	Cons.
			*Clay swamps	C2	3	Typic Aquisalids	Cons.
			*Old sandy deposits. remnants. Relatively high relatively low	C31	4	Typic Torripsamments	Cons.
				C32	5	TypicTorripsamments	Cons.
Young sub-deltaic deposits	Flat to almost flat	Alluvial deposits	*Scattered small hills (hummocks)	D1	6	Typic Torrifluvents	Cons.
			*Flat plains. relatively high relatively low	D21	7	Typic Torrifluvents	Cons.
				D22	8	Typic Torrifluvents	
			*Marches	D3	-	-	-
			*Intermittent wet land.	D4	-	-	-
			*Gypsiferous deposits	D5	-	-	-

between 1.2 and 1.9%, the high values of O.M. content may be due to the common humified and fresh residuals of organic materials (fish ponds) and irrigation water of Bahr El-Bakar Drain which was very rich in decomposed organic residuals. Calcium carbonate varied between 6.8 and 11.7%; the high percentage of $CaCO_3$ is due to shells fragments. CEC ranged between 2.2 and 68.9 meq/100 g soil. ESP ranged between 16.4 and 20.2. The macro nutrients analyses indicated that available nitrogen was of 21.3 – 91.1 ppm, available phosphors was of 24.6 – 31.4 ppm and available potassium is 100.2 – 290.2 ppm.

Soils of recent sub-deltaic deposits (alluvial deposits)

These soils represented the recent sub-deltaic plain, which was of recent age. Throughout the successive periods of the river terraces formation, immense quantities of gravel and sand had been carried by the Nile into the sea, where they spreadd out around the river's mouth in the form of Delta. As the relative level of the sea fell, the less compacted sandy and gravelly deposits were disintegrated by water action and the materials were again redistributed, where the more resistant portions remained in situ and formed Islands, these soils are called "Turtle backs" or "Hummocks".

These soils are found in mapping units D1, D21, D22, D3, D4 and D5 and were represented by profiles 6, 7and 8. The texture was clayey for different layers. The structure was massive. The consistence was extremely firm, very sticky, and very plastic. There were few to many shells along the profiles. The compaction of the second layer was slightly to highly compacted. There were common fine to medium pores. The effervescence with HCl was slight to moderate. The boundaries between soil profile layers were gradual to clear. EC values of the soil paste varied between 8.7 and 11 dS/m; pH value ranged between 8.5 and 8.6. Organic matter content ranged between1.1 and 1.6% and calcium carbonate varied between 10.4 and 13.5%. CEC ranged between 47.8 and 56.3 meq/100 gm soil and ESP ranged between 15.5 and 16.3%. The macro nutrients analyses indicated that available nitrogen content was in the range of 81.6- 91.9 ppm, available phosphorus 26.7 –27.80 ppm and available potassium 208.4- 210.4 ppm.

DISCUSSION

Soil classification

According to the Keys To Soil Taxonomy (USDA, 2010), the soils of the identified mapping units

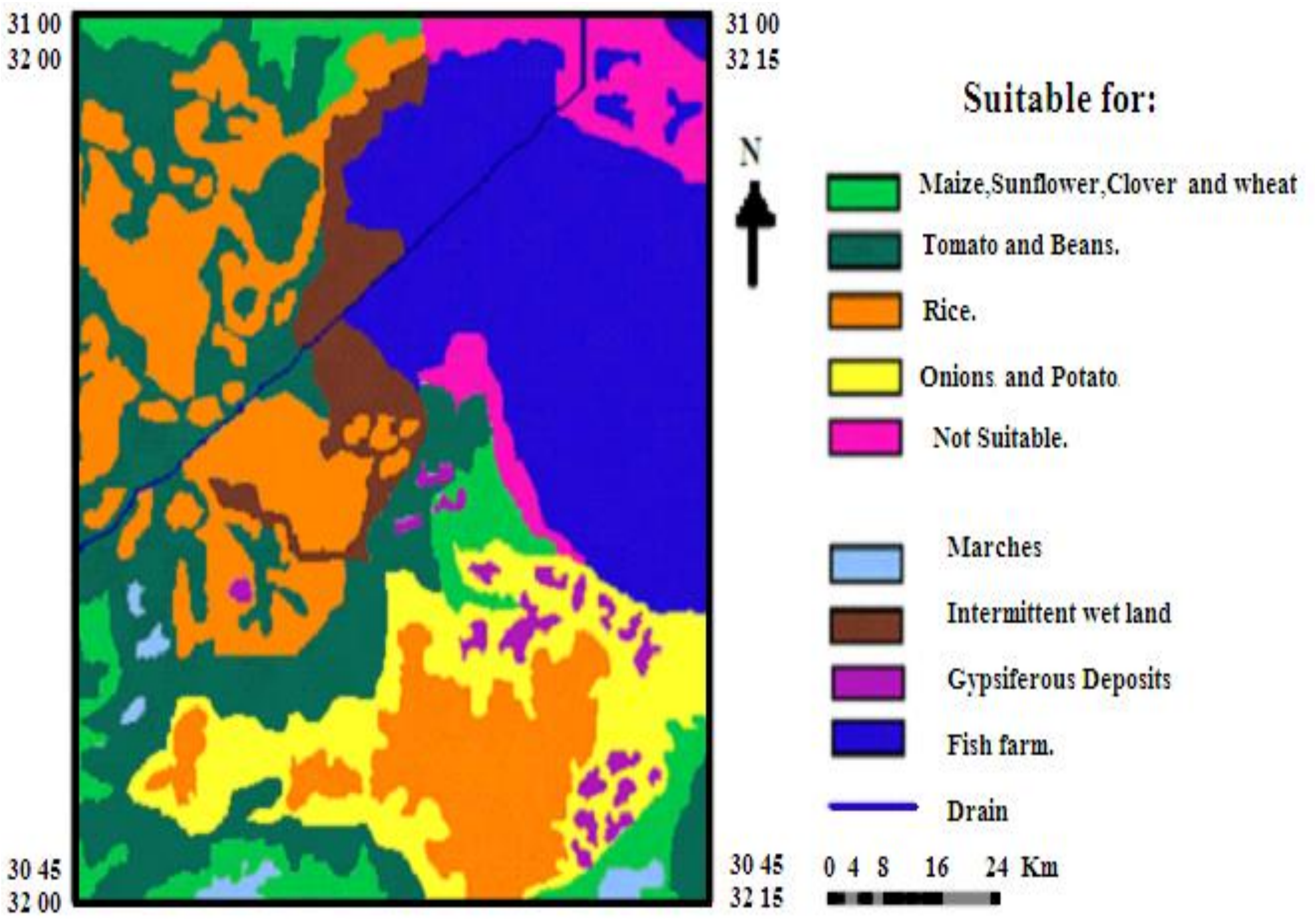

Figure 4. Land suitability of the investigated area.

could be classified as follows:

Vertic Torrifluvents C11 and C12,
Typic Aqusalids C2,
Typic Torripsamment C31 and C32, and
Typic Torrifluvents D1, D21 and D22.

Land suitability classification

Actual and potential suitability deals with land qualities coupled with crop requirements calculated by using the automated land evaluation system (ALES) after (Rossiter and Van Wambeke, 1995), depending on soil rating after (Sideruis, 1984). 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 these factors, fairly traditional crops are proposed for the studied area. The main selected crops are (clover, wheat, beans, onion, maize, sunflower, tomato and potato). Figure 4 represents the land suitability map of the studied area.

Crop water requirements

The crop water requirements were calculated by using (CropWat) program. The ET_0 was estimated using (Penman-Monteith) method, after (Allen et al., 1998) the ET0 from January to December were 25, 28, 39, 52, 68, 76, 79, 81, 61, 45, 33 and 23, respectively. The crop water requirements of clover, wheat, beans, onion, maize, sunflower, tomato and potato are 643.10, 477.50, 309.10, 320.40, 703.00, 614.15, 803.88 and 362.65 mm respectively, as shown in Figure 5 and Table 2.

Conclusion

A number of factors were considered when selecting cropping patterns including: 1) physical factors: water, soils, climate, and topography; 2) financial factors:

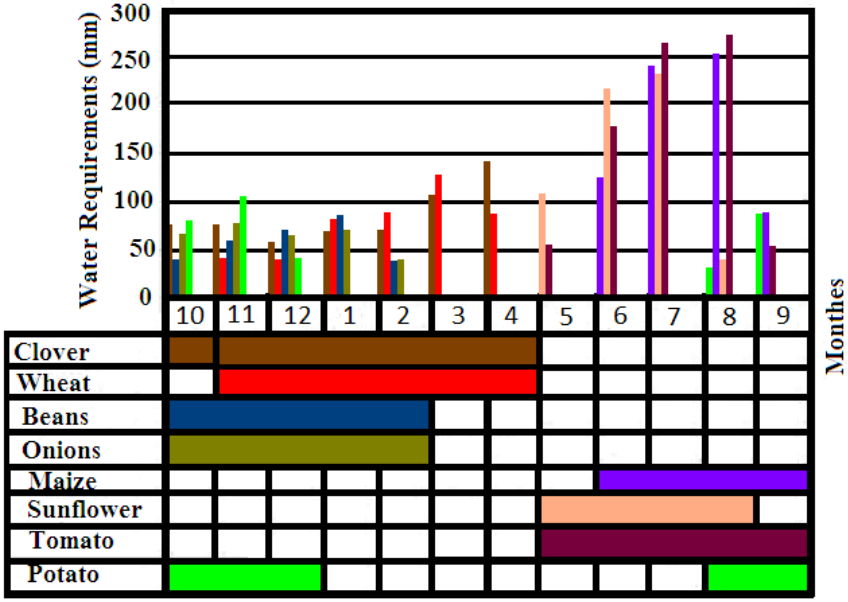

Figure 5. Crop water requirements for suitable crops of the studied area.

Table 2. Crop water requirements for suitable crops in the studied area

Crop	Month												Total ET crop (mm)
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	
Clover (210 days)	75.00	84.00	105.30	140.40						81.00	89.10	69.00	643.10
Wheat (180 days)	75.00	92.40	128.70	88.40							49.50	43.20	477.50
Beans (130 days)	82.50	44.80								45.00	64.30	72.50	309.10
Onions (140 days)	71.30	42.00								67.50	74.10	65.60	320.40
Maize (110 days)						121.60	244.90	251.10	85.40				703.00
Sunflower (100 days)					108.80	215.80	240.90	48.65					614.15
Tomato (120 days)					54.40	165.70	264.70	267.20	51.85				808.88
Potato (150 days)								36.50	91.50	83.20	108.90	45.55	362.65

financial returns, risks and labor requirements; 3) socio-economic factors: economic returns, food production and employment; 4) traditional factors: past experience and practice.

Based on these factors, fairly traditional crops and rotations are proposed for the studied area. The main crops that selected are: i) summer corps and vegetables: maize, sunflower and tomato, having a water requirements ranged from 614 to 804 mm per season and ii) winter corps and vegetables: clover, wheat, beans, onions and potato, having a water requirements ranged from 309 to 643 mm/ season. Other non-agricultural uses are suggested as fish farming.

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