

Land Evaluation of Eastern Suez Canal, Egypt Using Remote Sensing and GIS

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THE RAPID population growth in Egypt has accelerated desert reclamation to attain food security. The present work aimed at exploiting remote sensing and GIS for assessing land capability and crop suitability of soils located on the eastern side of Suez Canal, Egypt. The studied soils occupy 220.7 km² between longitudes 32° 24' 1" to 32° 29' 37" E and latitude 30° 29' 47" to 30° 42' 45" N. The sand sheet is the only landform covering the area, including three units; low, moderate and high. The soils are classified as Typic Tomipsamments, with sand being the dominant texture class. The land capability spatial model (LCSM) showed that the fair soils occupy an 208.7 km², representing 94.6% of the total area, while the poor soils occupy 12.0 km² and represent 5.4% of the total area. Soil texture is the limiting factor for land capability. The Applied System for Land Evaluation (ASLE) software was used for assessing land suitability for 12 crops; alfalfa, peanut, sugar beet, wheat, onion, tomato, watermelon, citrus, date palm, fig, grape, and olives. The clay content is the limiting factor. The soils would be suitable (S2) and marginally suitable (S3) for the selected crops. The most recommended crops would be peanut, tomato, and date palm, as the soils appeared suitable for their requirements.

Keywords: Land capability, Land suitability, Eastern Suez Canal, Remote sensing, GIS, ASLE.

One of the most significant indices determining agricultural progress is food security (Vink, 2012). The ability for securing food production will remain a global challenge for the next years due to the ever-increasing population and consumption growth that generate a fierce competition on land, water and energy (Godfray *et al.*, 2010). This is vital in the developing countries, where a large portion of the future population growth is expected (Byrnes and Bumb, 1998). Egypt is one of the most heavily populated countries in the world, where about 90 million people live on about 4% of the total area of the country (El-Ramady *et al.*, 2013). Nearly all of such area is arable land lying along the banks of the Nile and its Delta (Darwish *et al.*, 2013); and it is threatened by urbanization (Shalaby and Moghanm, 2015). Hence, the Egyptian government has adopted a policy of encouraging reclamation of desert lands to expand the area of arable land (Adriansen, 2009). Agriculture depends mainly upon adequate irrigation and suitable soils (Lawrence *et al.*, 2002). Thus, defining the proper land for a certain agricultural activity is needed to help decision makers in allocating highly suitable lands for such objective (Kalogirou, 2002).

Preservation of soil resources and optimal crop production requires devoting the most suitable land to a specific use (Sharififar, 2012). The process of assessing land performance over time when used for a particular purpose is known as 'land evaluation' (Bacic, 2008). It is a system of appraisal which facilitates sustainable management of land resources by

interpreting benefits and detriments of land use (FAO, 2007). Land capability is the fitness of a given type of land for a nonspecific kind of land use (de la Rosa and van Diepen, 2002). Land suitability as defined by the FAO Framework for Land Evaluation (FAO, 1976) is "the fitness of a certain type of land for a defined use". The high capacity for producing food, fiber, and other agriculture products remains the vital aim for agricultural expansion over barren lands (Mueller *et al.*, 2010). Crop production is a result of many factors including regional climate, land properties, socioeconomic resources, management, market, and other human activities (Li *et al.*, 2011). The current study was carried out on lands east of the Suez Canal, Egypt to assess their capability and suitability based on land resources and soil physiochemical properties. Such assessment would help decision makers in planning to achieve sustainable agriculture.

Materials and Methods

The studied area

The studied area covers 220.7 km² located east of Suez Canal (Fig. 1) between and 32° 24' 1" to 32° 29' 37" E and 30° 29' 47" to 30° 42' 45" N. The soils are young Aeolian Quaternary deposits of late Pleistocene to Holocene era, forming sand sheets and/or sand dunes physiographic units (Mohamed *et al.*, 2013). The total annual precipitation is 38.3 mm year⁻¹. Temperature reaches 36.22 °C in July and decreases to 8.0 °C in December with a mean annual value of 22.1 °C. The relative humidity ranges between 65.4% in December and 51.6% in May, with a mean value of 59.8%. The soil temperature regime is Hyperthermic and the soil moisture regime is Torric.

Remote sensing and GIS works

Landsat 8 satellite image (path 176, row 39) was acquired on 21-04-2016. The ENVI 5.1 software (ITT, 2014) was used for digital image processing. The image was geometrically corrected and rectification method (image for map) was followed. The geometric model used in the rectification process was second order polynomial, and the resampling method is the nearest neighbor method. The image was stretched, smoothly filtered, and its histograms were matched for its rectification and restoration according to Lillesand and Kiefer (2007). A digital elevation model (DEM), acquired from the Shuttle Radar Topographic Mission (SRTM) on 21-4-2016, was used as the source data for elevation heights of the study area (Fig. 2). The geomorphologic map was produced using the processed Landsat 8 image and the DEM. GIS works were performed to produce base, geomorphic, capability and suitability maps of the studied area using Arc GIS 10.2.2 software (ESRI, 2014).

Field and laboratory works

Fourteen soil profiles representing the studied area were made with a depth of 150 cm. The Global Positioning System (Garmin GPS 72 H) was used for identifying the exact locations of soil profiles in the field which were plotted on the map (Fig. 3). Morphologic features were described according to the FAO Guidelines (FAO, 2006). Forty-two soil samples were collected from the different horizons for analyses. The soil samples were air dried, crushed and passed through a 2-mm sieve. Chemical and physical analyses were performed according to the standard methods outlined by Estefan *et al.* (2013).

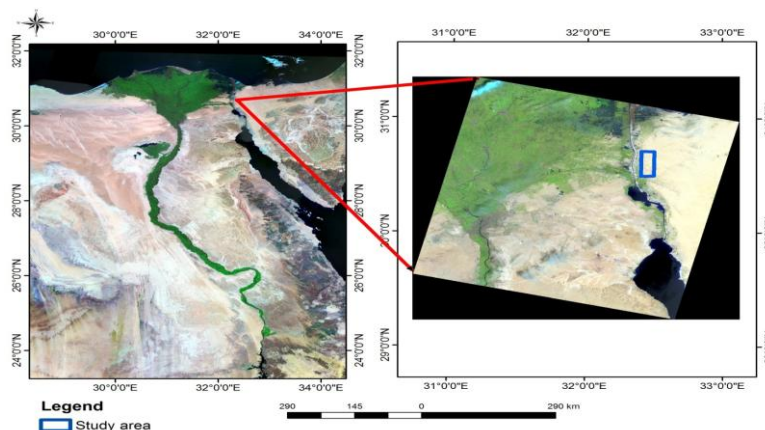


Fig. 1. Location maps of the study area.

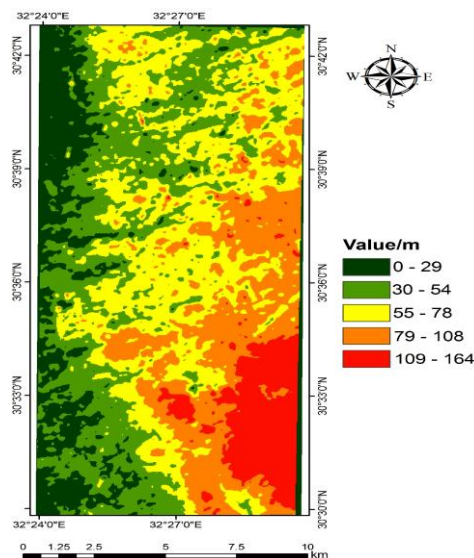


Fig. 2. Digital elevation model (DEM) of the studied area.

Land evaluation

This procedure was done using two systems. The first system is land capability classification based on the FAO Framework for Land Evaluation (FAO, 1976). Soil texture, soil depth, calcium carbonate status, gypsum content, EC, exchangeable sodium percent (ESP), drainage, and slope were inputted in the Arc GIS 10.2.2 software to design land capability model whereby capability map was produced. Also, the Applied System for Land Evaluation (ASLE) software which has been developed by Ismail *et al.* (2001) was used for classification based on soil properties as inputs. The second system is land suitability which was done using ASLE software based on the ratings of crop requirements proposed by Sys *et al.* (1993). Factors influencing land suitability for specific crop are the physical properties of clay content, profile depth, land form, level of surface and slope determine the soil-water relationship. The

chemical properties of pH, CaCO₃, gypsum, CEC, ESP and salinity determine fertility of soil. The capability and suitability classes are shown in Table 1.

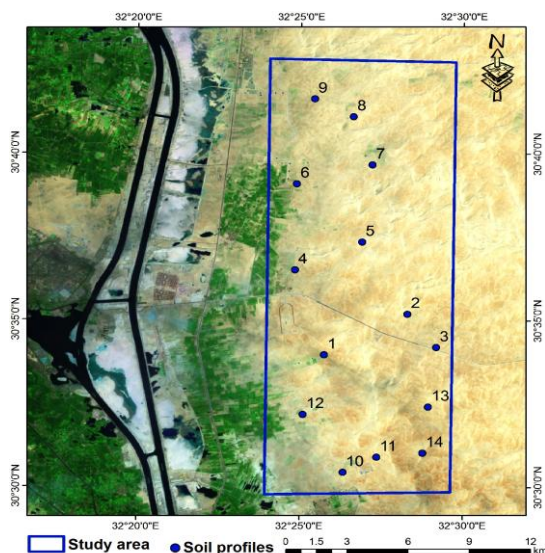


Fig. 3. Locations of soil profiles representing the study area.

TABLE 1. The ASLE capability and suitability indices and classes.

Capability index	Class	Description	Suitability index	Classes	Description
> 80	C1	Excellent	> 80	S1	Highly suitable
80 - 60	C2	Good	80 - 60	S2	Suitable
60 - 40	C3	Fair	60 - 40	S3	Moderately suitable
40 - 20	C4	Poor	40 - 20	S4	Marginally suitable
20 - 10	C5	Very poor	20 - 10	Ns1	Currently not suitable
< 10	C6	Non-agriculture	< 10	Ns2	Permanently not suitable

Results and Discussions

Geomorphology

Interpretation of satellite image and DEM is used to identify the geomorphologic features of an area. This procedure (which is the most common, economic and versatile advanced technology) offers the reality to the ground observation. Analyzing the main landscape which is extracted from the satellite image through the DEM and field survey enables recognizing and delineating the geomorphic units in the studied area. The results revealed that the main landform in the area is the sand sheet, which has been derived mainly from the Aeolian deposits that are scattered over the whole area. The sand sheet could be divided into three mapping unit (Fig. 4); low, moderate and high, covering 105.6, 103.1 and 12.0 km², respectively. Soil profiles Nos. 10, 11 and 13 were chosen as modal representative profiles for the three mapping unit; low, moderate and high sand sheet, respectively to be inputted in the Arc GIS 10.2.2 for soil mapping.

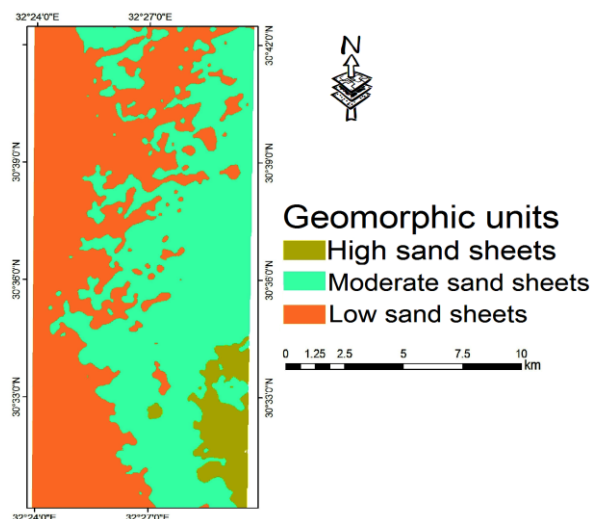


Fig. 4. Geomorphologic map of the study area.

Soils of the studied area

Table 2 shows the weighted mean values of soil characteristics and pH of the surface horizons. Soil pH varied between 7.83 and 8.53, indicating moderately to strongly alkaline reaction. Soil salinity varied from non-saline to slightly saline as EC values ranged from 0.79 to 6.14 dS m^{-1} . Organic matter content was low and did not exceed 1.10 g kg^{-1} due to the absence of natural vegetation and the aridity conditions. Values of calcium carbonate and gypsum contents varied between 0.62 - 1.12 for the former and 0.60 - 1.38 g kg^{-1} for the later. The CEC was low and ranged from 3.87 to 5.68 cmolc kg^{-1} due to low organic matter and clay contents. The soils remained within the safe level of sodicity since ESP was below 15, except for profile No. 12 with ESP of 15.16, indicating a slight hazard. According to the USDA (2014), the soils are Typic Torripsamments.

TABLE 2. Main characteristics for soils of the studied area.

Profile No.	pH	EC, dS m^{-1}	OM, g kg^{-1}	CaCO ₃ , g kg^{-1}	Gypsum, g kg^{-1}	CEC, Cmolc kg^{-1}	ESP	Texture, USDA triangle
1	8.09	1.36	0.53	0.62	0.72	4.38	5.72	Sand
2	8.53	1.32	0.93	0.68	0.74	3.87	5.36	Sand
3	8.24	1.17	0.76	1.06	0.60	4.27	4.14	Sand
4	8.06	1.27	0.67	0.77	0.74	4.43	5.32	Sand
5	8.00	1.39	0.82	0.92	1.09	4.59	5.08	Sand
6	7.85	3.30	1.10	1.10	1.11	4.79	12.17	Sand
7	8.06	0.79	0.77	0.95	0.98	4.32	2.66	Sand
8	8.17	6.06	0.76	0.90	0.64	4.80	12.14	Sand
9	8.49	4.08	0.50	0.62	0.84	4.32	12.24	Sand
10	7.86	2.83	0.83	0.74	0.65	5.28	2.67	Sand
11	8.15	1.36	0.77	0.75	0.65	4.87	2.10	Sand
12	7.83	6.14	0.84	0.90	1.09	5.68	15.16	Sand
13	8.21	2.07	1.00	1.12	1.38	4.80	5.11	Sand
14	8.40	0.95	0.44	0.62	0.67	4.31	1.44	Sand

Land capability classification

The land capability spatial model (LCSM) is designed for identifying capability classes for the studied area (Fig. 5). Soil properties were ranked and weighted in order to assess land capability. Thereafter, they were constructed and mapped in the geographic information system (GIS) environment. The spatial analysis was done on the GIS layers through running the LCSM to determine the capability classes and a soil capability map was produced. Based on the LCSM (Fig. 6 and Table 3), the soils belong to capability classes fair (C3) and poor (C4). The fair soils occupied an area of 208.7 km² (20870 ha), representing 94.6% of the total area while, the poor soils occupied an area of 12.0 km² (1200ha), representing 5.4% of the total area. The most limiting factor is soil texture (as the sand is dominant textural class). The significance of coarse soil texture is related to its implications on soil erosion susceptibility, low level of organic matter, low water holding capacity and low nutrient content and retention (Villas-Boas *et al.*, 2016). Based on the ASLE model (Fig. 7), the fair soils occupied 117.6 km², representing 53.3% of the total area, while the poor soils occupy 103.1 km², representing 46.7% of the total area. A trial was done to obtain a relation through correlation coefficient analysis for some measurements (areas/km²) of capability obtained from either GIS or ASEL model. After that, the data factors (y) and the correlation coefficient r were calculated as shown in Fig. 8. A positive correlation was observed between the GIS and ASLE models, and hence it could be estimated that capability area form ASLE = 5.18 GIS model.

TABLE 3. Land capability classes and areas based on the GIS and ASLE models.

Capability class	GIS model		ASLE model	
	Area (km ²)	%	Area (km ²)	%
Fair (C3)	208.7	94.6	117.6	53.3
Poor (C4)	12.0	5.4	103.1	46.7

Land suitability classification

The soils were evaluated for cultivating 12 crops, including field crops; alfalfa, peanut, sugar beet and wheat, vegetable crops; onion, tomato and watermelon, and fruit crops; citrus, date palm, fig, grape and olive (Fig. 9). The clay content is the limiting factor for crop cultivation. With slight salinity in few localities and sodicity (alkalinity) in soil profile No. 12, their occurrence could not pose a major problem. Excessive salt in such sandy soils is not concerned, where it could be leached easily (Barnard *et al.*, 2010). The soils belong to suitable (S2) and marginally suitable (S3) classes. Peanut, tomato and date palm would be the most suitable crops in the studied area (Table 4), as the soils appear suitable (S2).

Conclusion

Land evaluation plays a vital role in land use planning and helps decision makers in initiating a suitable management of agricultural resources. In the present work, an integration of GIS and ASLE software were performed for initiating more suitable land use planning of the area under investigation. The total area of 220.7 km² is located on the eastern side of Suez Canal belong to fair (C3) and poor (C4) capability classes. The soils of C3 represent 94.6% of the total area; meanwhile the remained area is occupied by soils of C4. The soils are suitable (S2) and marginally suitable (S3) for selected 12 crops. The most recommended crops would be peanut, tomato and date palm. In conclusion, the area would be promising lands for agricultural expansion to compensate the loss of arable land in Nile Delta.

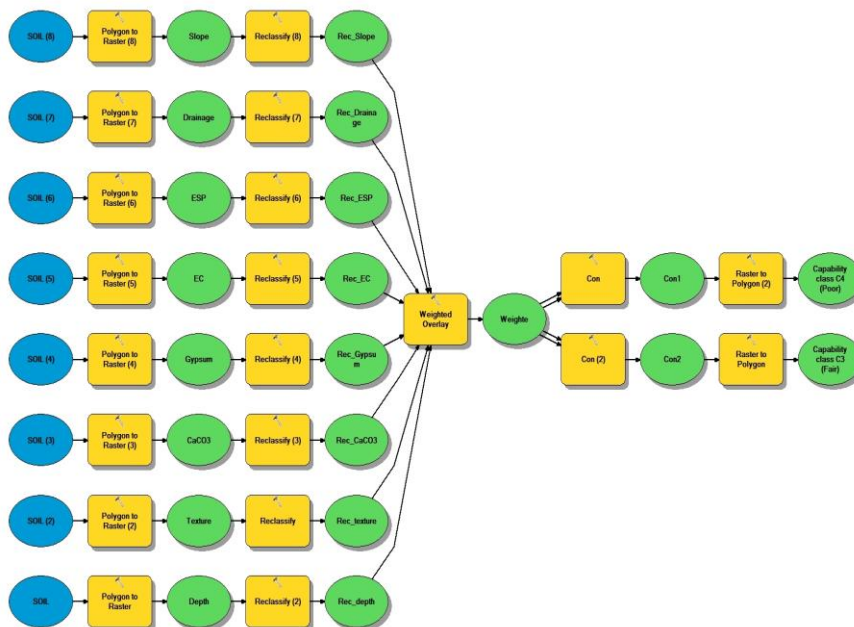


Fig. 5. Flowchart of the land capability classification spatial model.

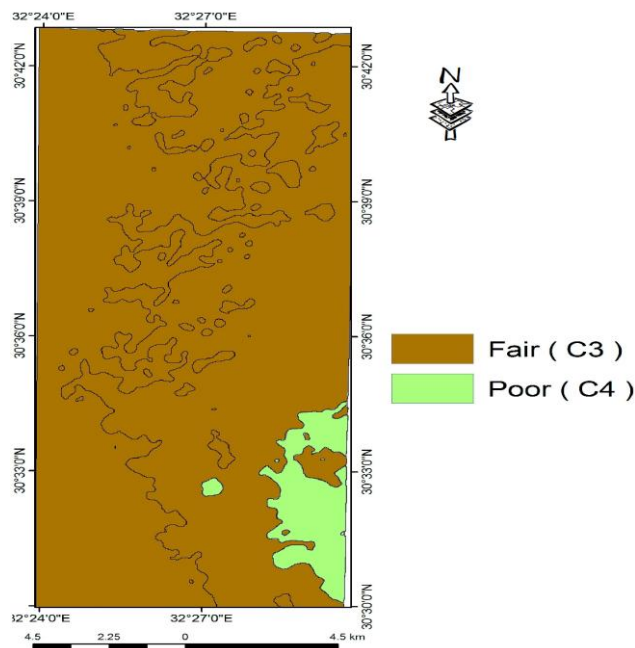


Fig. 6. Capability map based on the spatial model.

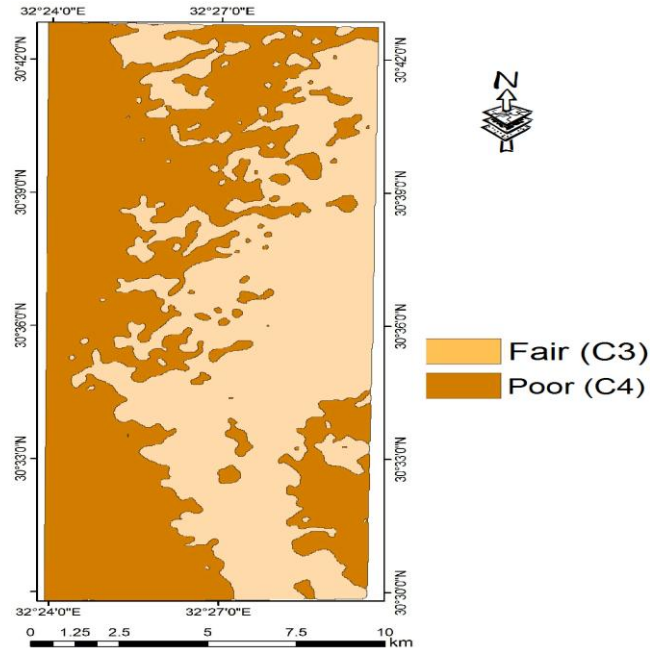


Fig. 7. Capability map based on the ASLE model.

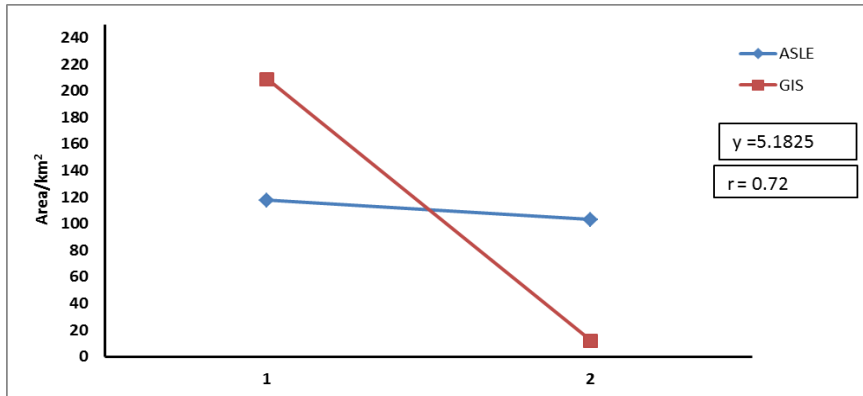


Fig. 8. Correlation between capability areas based on the GIS and ASLE models.

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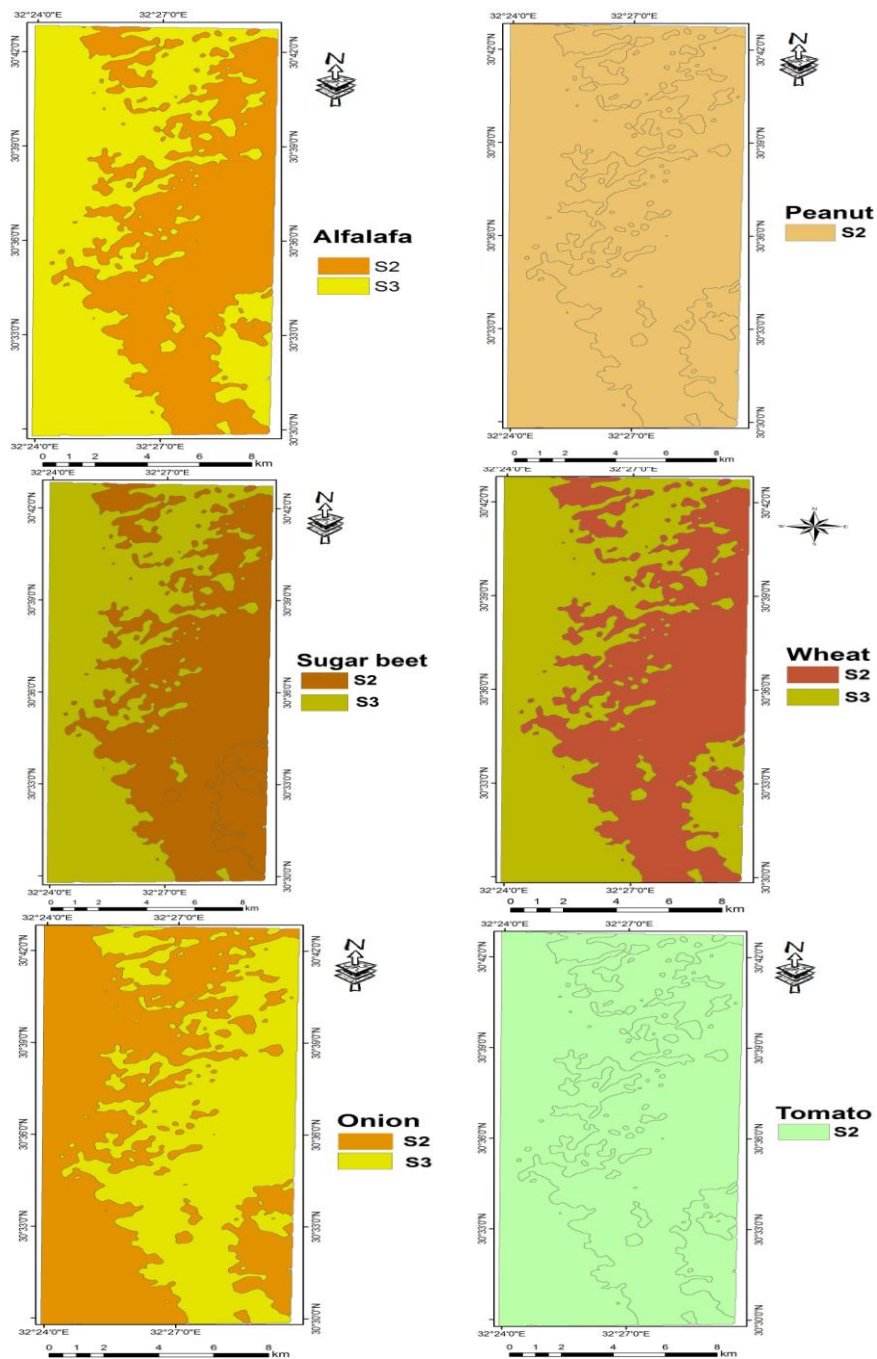


Fig. 9. Suitability maps for the selected crops in the study area.

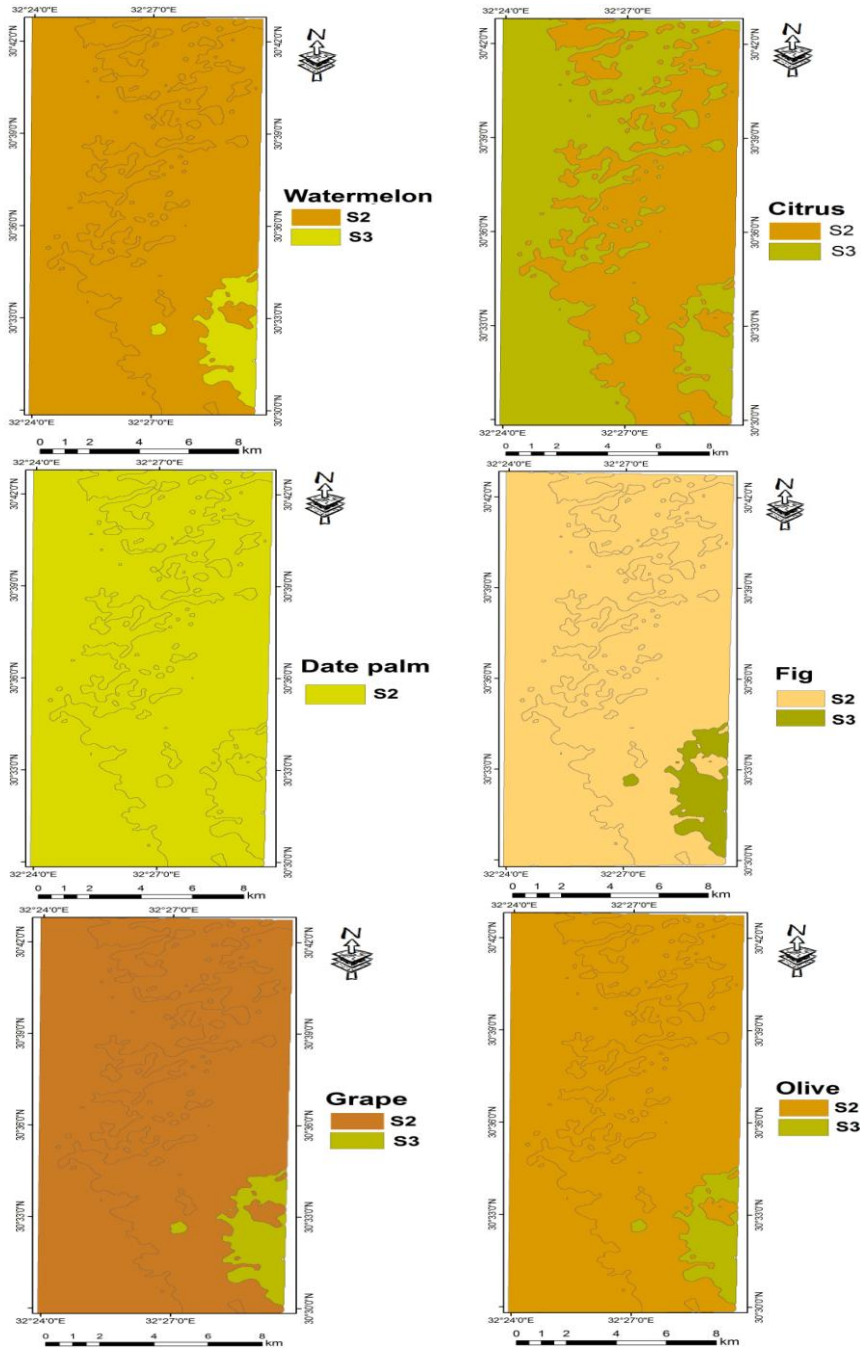


Fig. 9. Cont.

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تقييم الأراضي شرق قناة السويس - مصر باستخدام الإستشعار من البعد ونظم المعلومات الجغرافية

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تم استخدام بيانات الإستشعار من البعد ونظم المعلومات الجغرافية في تقييم مساحة قدرها ٢٢٠,٧ كم^٢ (٢٢٠,٧٠ هكتار) من الأراضي الواقعة شرق قناة السويس - مصر من حيث قدرة التربة ومدى ملائمتها لزراعة بعض المحاصيل. وجد من نتائج الجيومورفولوجية أن المنطقة المدروسة يوجد بها شكل أرضي واحد وهو الفرشلت الرملية Sand sheets. تنتمي التربة إلى تحت مجموعة Typic Torripsammments حيث أن القوام الرمل هو السائد في المنطقة. أوضح النموذج الفراغي لتقييم قدرة التربة أن ٩٤,٦% (٢٠٨٧٠ هكتار) من الأراضي المدروسة أراضي متوسطة القدرة (C3)، بينما ٥,٤% (١٢٠٠ هكتار) أراضي ضعيفة القدرة (C4). تم استخدام نظم التقييم الإلكتروني ASLE لتقييم ملائمة التربة لزراعة ١٢ محصول هي البرسيم الحجازي، الفول السوداني، بنجر السكر، القمح، البصل، الطماطم، البطيخ، الموالح، نخيل البلح، التين، العنب، والزيتون. وقد وجد أن الأراضي صالحة (S2)، وهلمشية الصلاحية (S3) للمحاصيل المختارة، وقد وجد أيضاً أن المحاصيل الموصى بزراعتها في المنطقة هي الفول السوداني، الطماطم، ونخيل البلح

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