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Land evaluation of north east El Baharya oases area, Egypt using GIS and remote sensing techniques

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***Abstract*---**The North East area of El Baharya Oases represents one of the highest priority areas for future agricultural development in Egypt. The study area is located between longitudes 29° 9' 28.354" , 29° 27' 38.264" East and latitudes 28° 47' 26.562" , 29° 3' 17.531" North and covers an area of about 101294 feddans. A physiographic map was produced to present the mapping units of the study area. The area was classified into two landscapes, i.e., plateau represents 23.77 % of the total study area and plain which covers an area of about 77212.3 feddans (76.23 % of the total study area). Land capability was used to evaluate the soils of the study area. The study area was classified into four capability subclasses, i.e., S_{2x}, $S_{3x,n}$, $S_{3x,d}$ and $N_{1x,d,n}$ .The soils of S_{2x} (69.26 % of the total area) have moderate limitations for agricultural crops, whereas texture is the most limiting factor. The area of $S_{3,x,n}$ (18.52 %) whereas texture and salinity are limiting factors while the soils of S_{3xd} (5.64 % of the total study area) whereas the texture and depth are limiting factors. On other, hand the soils of $N_{1x,d,n}$ (6.58 % of the total study area) whereas the texture, depth and salinity are the main limiting factors for agriculture. Four crops were selected to assess their soil suitability for cultivation in the study area, i.e., wheat,

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barley, tomato and olive. The results indicated that olive was the best crop for growing in such soils.

Keywords---capability, suitability, mapping, GIS, RS.

Introduction

Desert and uninhabited land represents approximately 95% of the total area of Egypt. Consequently, the majority of the population is concentrated around the Nile valley and in the Nile Delta. This unbalanced distribution of inhabitants causes serious social and economic problems, as the over-increasing population has resulted in a decrease in agricultural area per capita from 0.12 ha. in 1950 to 0.06 ha. In 1990 (Suliman 1991) and 0.04 ha. In 2009 (CAPMAS 2009). Land evaluation is an important step in the process of land use planning where resources are limited. Land evaluation is concerned with the assessment of land performance when used for specified purposes (FAO, 1976). Although several land evaluation models have been developed to provide a quantified procedure to match land with various actual and proposed uses, there is no single or unified land evaluation modeling approach (Rossiter, 2003).

Computer based decision support model have been developed towards land evaluation (shim et al 2002). Land evaluation through map analysis techniques has been accomplished using geographic information system (Baja et al 2002, Kalogirou, 2002). The potential of the integrated approaches using GIS and RS data provides useful tools for quantitative land evaluation (Martin and Saha 2009). The land evaluation and mapping for North East El Bahariya Oasis area are essential actions in order to maintain the sustainable development of effort and investment as well as the sustainable usage of the soils. The present study aims at producing physiographic soil map using sentinel data, field work and soil analytical data; evaluate the soils of the study area to assess the soil limitations and constraints and assess the soil suitability for cultivation for wheat, barley, tomato and olive.

Materials and Methods

Location

The study area is located North East El Baharya Oases - Giza Governorate. It covers an area of about 101294 feddans. It is far from Cairo city about 215 Km, and October Al-Wahat Road passes inside the study area (Figure 1).

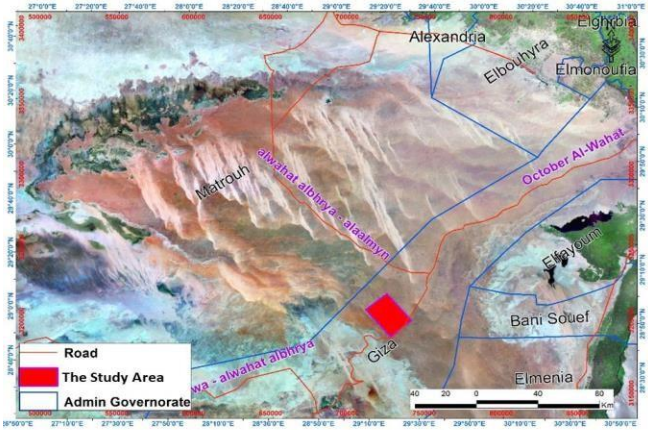

Figure 1. Location map of the study area

Satellite data

Data of sentinel 2 dated in August 2021 with spatial resolution of 10 m and spectral resolution of the false color composite (FCC) bands 8, 4 and 2 was used for unsupervised classification and delineating the different mapping units.

Digital Elevation Model (DEM)

The geo-statistical analysis techniques were used to create Digital Elevation Model (DEM) using the semi-variogram parameters (Stein, 1998) of contour lines and spot heights (Figure 2).

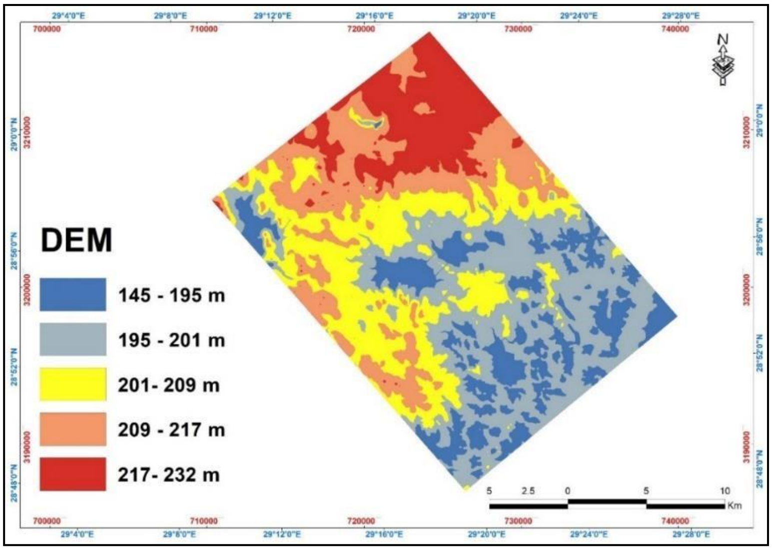

Figure 2. Digital Elevation Model (DEM) of the study area

Spectral classification

Unsupervised classification based on statistical discriminate analysis (Daels, 1986). The iso-data method is commonly used and utilized in the present analysis. The spectral classification was performed using Erdas Imagine software version 14.0. A base map is produced through the integration between DEM, Geology and unsupervised classification of multispectral image for the study area based on analysis methods according to Zinck (1988).

Field Work

Seventy soil profiles and 82 minipits were collected to represent the soils of the study area. Morphological descriptions of soil profiles were described according to FAO, (2006).

Physiographic map

The minipits from the field work were used to confirm, correct and modify the mapping unit boundaries. In the process, the base map was developed to physiographic map (Zinck, 1988). Physiographic soil map was produced in GIS by using the physiographic map and all soil properties (Stein, 1998).

Laboratory Analyses

The collected soil samples were air dried, crushed and prepared for laboratory analyses, to determine soil chemical (pH, EC, soluble cations and anions, calcium carbonate , gypsum, cation exchange capacity and exchangeable sodium percentage) and physical (texture and soil profile depth) properties according to USDA (2004).

Land Capability

Land capability for agriculture was assessed according to the method of Land Capability techniques (Sys and Verheye (1978) and Sys et al. (1991)) using the rating tables of FAO (1985),. The method of land evaluation used according to the following equation:

$$Ci = \frac{t}{100} \times \frac{x}{100} \times \frac{d}{100} \times \frac{l}{100} \times \frac{y}{100} \times \frac{n}{100} \times 100$$

Where:
Ci = Capability index (%),
t, x, d, I, y, and n are rating of Slope, Texture, Soil depth, $CaCO_3$, Gypsum, Salinity, alkalinity, respectively.

Capability classes according to the value of the index (Sys, 1991) as follows:

Capability class	Land capability index (Ci) %	Definition of the class
S_1	> 75	Soils are highly suitable for agriculture.
S_2	75-50	Soils are moderately suitable for agriculture
S_3	50-25	Soils are marginally suitable for agriculture
N	< 25	Soils are not suitable for agriculture

Land evaluation assessment for certain crops:

The assessment of land suitability for four different land use types has been conducted for soil units (Sys et al, 1993) by implementing the FAO Framework for Land Evaluation (FAO, 1976). Soil characteristics of the different mapping units were matched with the requirements of each crop.

Results and Discussion

Physiographic map of the study area

Using sentinel-2 image taken during August 2021, and Based on digital elevation model (DEM), the topography and field check, the physiography of the study area has been identified. Two landscape units were delineated, i.e., Plateau (Pl) and Plain (Pa), (Figure 3 and Table 1).

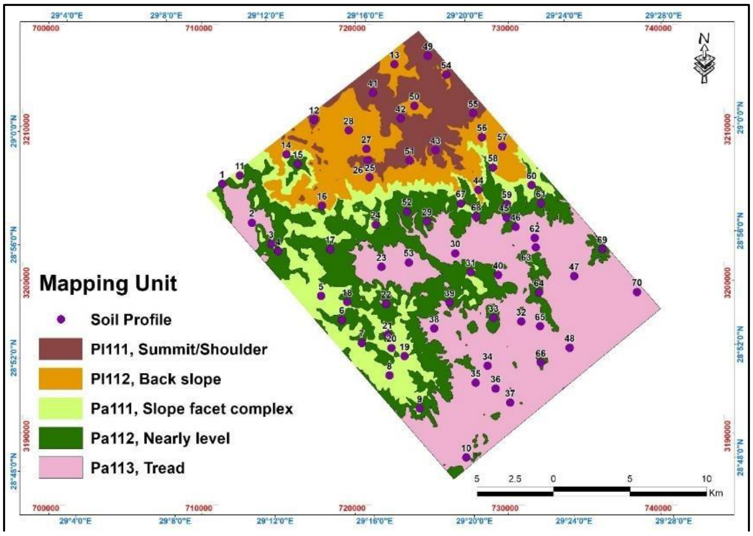

Figure 3. The Physiographic map of the study area

Table 1
Legend of the physiographic map

Landscape	Relief	Lithology	Landform	Symbol	Area Fed.	%
Plateau	Undulating	Moghra	Summit/Should	Pl111	10039.8	9.91

(Pl)	ng (Pl1)	Formation	er			
			Back slope	Pl112	14041.9	13.86
Plain (Pa)	Undulating (Pa1)	Gable Qatrani formation	Slope facet complex	Pa111	14791.9	14.60
			Nearly level	Pa112	24878.5	24.56
			Tread	Pa113	37541.9	37.07
Total					101294.0	100.00

Fed. = 4200 m^2

Soil Properties of mapping units
Mapping Unit Pl111, Summit/Shoulder

The soils are moderately deep to very deep as the depth ranged from 90 to 150 cm. The soil texture varies between Loamy Sand and Sandy Loam; pH values range between 7.7 and 8.38. $CaCO_3$ ranges between 6.4 and 19.45 % with mean is 10.6 and standard deviation is 4.3. The soils of this unit are moderately saline to very highly saline (EC value in dS m^{-1} ranged from 5.9 to 26.1). Soil gypsum content ranged from 0.1 to 10.76 % with mean 4.13 % and standard deviation is 3.08. The soils are not sodic as ESP ranged from 7.64 to 13.14 with mean 10.8 % and standard deviation is 1.8. (Table 2).

Mapping Unit Pl112, Back slope

The soils are very deep as the depth is more than 150 cm. The soil texture vary between Loamy Sand and Sandy Loam. The soils are alkaline in reaction as pH values are more than 7. $CaCO_3$ ranges between 4.4 and 10.54 % with mean is 7.9 and standard deviation is 1.7. The soils of this unit are slightly saline to highly saline (EC value in dS m^{-1} ranged from 2.9 to 13.5). Soil gypsum content ranged from 0.1 to 6.91 % with mean 2.4 % and standard deviation is 2.3. ESP ranged from 7.45 to 15.68 with mean is 11.3 % and standard deviation is 2.7. (Table 2).

Mapping Unit Pa111, Slope facet complex

The soils are moderately deep to very deep as the depth ranged from 60 to 150 cm. The soil texture vary between Sand and Sandy Loam. The soils are alkaline in reaction as pH values ranged from 7.1 to 8.8. $CaCO_3$ ranges between 7.3 and 13.0 % with mean is 10.12 and standard deviation is 1.85. EC value in dS m^{-1} ranged from 5.0 to 68.6 whereas the soils of this unit are moderately saline to extremely saline. Soil gypsum content ranged from 0.09 to 10.0 % with mean 2.35 % and standard deviation is 2.65. The soils are not sodic as ESP ranged from 4.76 to 17.27 with mean 11.6 % and standard deviation is 3.4 (Table 2).

Table 2
Range of some chemical and physical properties for surface layers of the study mapping units

Mapping Unit	Depth cm	Texture	$CaCO_3$ %	Gypsum %	pH	ECe	ESP
Pl111	90 to 150	LS - SL	6.4 -19.45	0.1 – 10.7	7.7 – 8.3	5.9 - 26.1	7.64 -13.14
Mean	121		10.6	4.1	8.2	10.3	10.8
SD	23		4.3	3.0	0.2	6.3	1.8
Pl112	150	LS - SL	4.4 -10.5	0.1 – 6.9	7.9 – 8.7	2.9 – 13.5	7.45 -15.68

Mean	150		7.9	2.4	8.3	6.6	11.3
SD	0.0		1.7	2.3	0.2	3.2	2.7
Pa111	60 to 150	S - SL	7.3 -13.0	0.1 – 10.0	7.1 – 8.8	5.0 -68.6	4.76 -17.27
Mean	129.6		10.1	2.3	8.2	19.8	11.6
SD	30.7		1.8	2.6	0.4	16.9	3.4
Pa112	70 to 150	S - SL	5.5 -16.8	0.1 – 4.4	7.7 – 8.8	4.02 -29.8	6.88 -18.75
Mean	133.8		9.7	1.2	8.2	13.5	11.0
SD	29.6		3.2	1.3	0.3	7.8	3.1
Pa113	60 to 150	S - SL	2.75 -15.4	0.06 - 5.9	7.3 – 8.2	1.58 - 29.0	3.22- 16.86
Mean	135.4		8.0	1.9	8.2	9.7	10.5
SD	27.3		2.8	2.8	0.3	6.8	3.0

SL = Sandy Loam, LS = Loamy, S = Sand and SD= Standard Deviation

Mapping Unit Pa112, Nearly level

The soils are moderately deep to very deep as the depth ranged from 70 to 150 cm. The soil texture varies between Sand and Sandy Loam; pH values range from 7.7 to 8.87. $CaCO_3$ ranges between 5.5 and 16.8 % with mean is 9.75 and standard deviation is 3.21. EC value in dS m^{-1} ranged from 4.02 to 29.8 whereas the soils of this unit are moderately saline to very highly saline. Soil gypsum content ranged from 0.11 to 4.4 % with mean 1.26 % and standard deviation is 1.38. ESP ranged from 6.88 to 18.75 with mean 11.0 % and standard deviation is 3.1 (Table 2).

Mapping Unit Pa113, Tread

The soils are moderately deep to very deep as the depth ranged from 60 to 150 cm. The soil texture vary between Sand and Sandy Loam. The soils are alkaline in reaction as pH from 7.3 to 8.2. $CaCO_3$ ranges between 2.75 and 15.4 % with mean is 8.02 and standard deviation is 2.81. EC value in dS m^{-1} ranged from 1.58 to 29.0 whereas the soils of this unit are slightly saline to very highly saline. Soil gypsum content ranged from 0.06 to 5.9 % with mean 1.47 % and standard deviation is 1.73 except profile No. 64 whereas gypsum content is 13.0 %. ESP ranged from 3.22 to 16.86 with mean 10.5 % and standard deviation is 3.0 (Table 2).

Current land capability assessment

The aim of parametric system (Sys and Verhey,1978) Sys et al. (1991) and Sys et al. (1993) is to provide a method that permits evaluation for agricultural propose. This is based on the standard groundmetrical and physiochemical characteristics of soil profile. A land capability model was built using Arc GIS 10.4 software (database) and the resulting tables were imported into Arc GIS to produce the capability map. Based on superimpose between all soil properties to produce land capability map according to Sys, 1991 as follows (Figure 4 and Table 3). Land capability of the study area was classified into three current capability classes which reflect the limitation factors, i.e., S_2 (moderately suitable), S_3 (marginally suitable) and N_1 (temporary not suitable) (Table 3). The soils of S_2 have moderate limitations for agricultural crops, as texture is the main limiting factor. It covers an area of 70159.8 feddans (69.26 % of the total area). The capability index value ranged from 54.0 to 67.2 %. The soils are of marginally suitable S_3 occupies an area of 24468.9 feddans (24.16 %) where texture and salinity are the limiting factors in 18.52 % of this class. The capability index value ranges between 37.8

and 49.0 %. While Texture and depth are the limiting factors in 5.64 % of this class area with capability index value range from 34.47 to 44.89 %. On other, hand the soils of N_1 have severe limitations of texture, salinity and depth. It represents an area of about 6665.2 feddans (6.58 %). The capability index value ranges between 21.77 and 24.68 %.

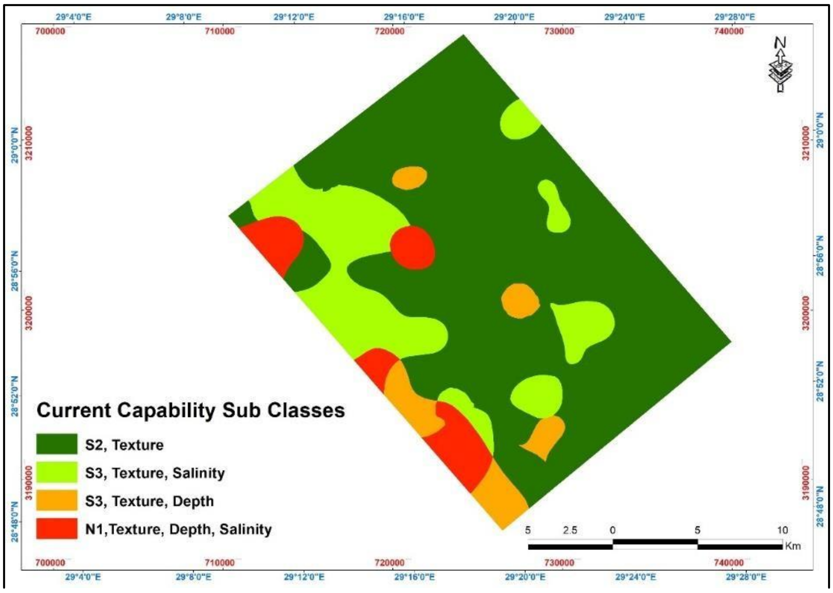

Figure 4. Current Land capability map for agriculture of the study area

Table 3
Current Sub classes of capability for agriculture (Sys et al., 1991)

Sub Class	Limitation factors	Area feddans	%
S_{2x}	Texture	70159.8	69.26
$S_{3x,n}$	Texture, Salinity	18760.8	18.52
$S_{3x,d}$	Texture, Depth	5708.2	5.64
$N_{1x,d,n}$	Texture, Depth, Salinity	6665.2	6.58
Total		101294.0	100.00

Potential land capability assessment

For this purpose, the land utilization is applicable after executing specified major land improvements as proposed in the current study according to their necessity.In the study area, land improvements is required to management the severity of limitations exiting in the area under consideration such as; modern irrigation systems such as drip and sprinkler to save irrigation water and prevent the formation or the rise of ground water table. Leaching of salinity and, adding organic fertilizers, green manures and soil conditioners to increase soil fertility and improve the physical and chemical soil properties. The leaching requirements for reclamation (LRR) to maintain soil salinity at a minimum level (< 6 dS/m) are calculating using the equation proposed by Hoffman (1980).

$$\frac{Di}{Ds} * \frac{ECs}{ECo} = 0.1$$

Where:
Di = Depth of required water irrigation,
Ds=Depth of soil;
ECs= salinity of soils after leaching and
ECo=salinity of soils before leaching

Potential land capability of study soils as illustrated in Table (4) and shown in Figure (5) indicated two sub classes ($S_{2Texture}$, and $S_{3Texture,\ Depth}$) as follows: This capability sub class of S_{2x} covers an area about 88920.6 feddans represents 87.78 % of the total area. The capability index value ranges from 50.3 to 67.2. $S_{3x,d}$ covers 12373.4 feddans (12.22 %of the total area). The capability index value ranges between 26.44 and 44.89 %.

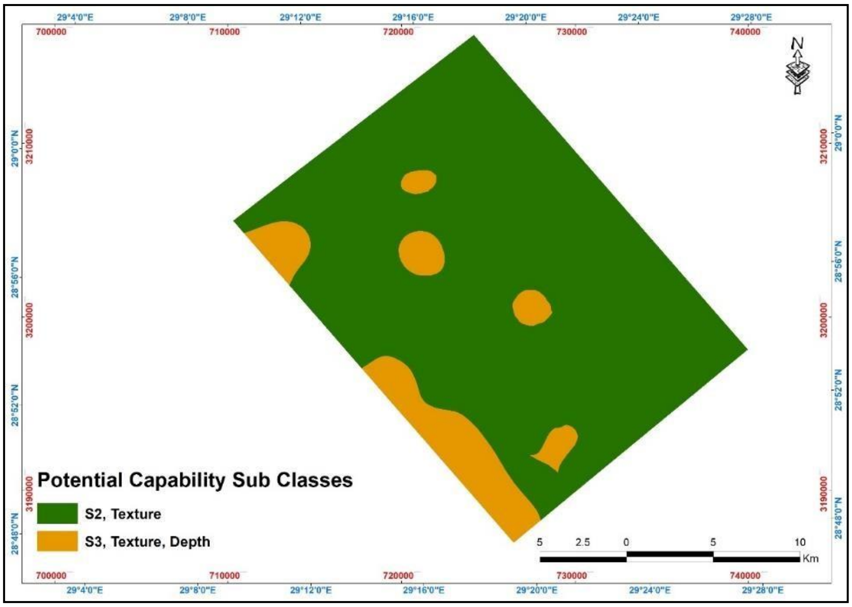

Figure 5. Potential Land capability map for agriculture of the study area

Table 4
Potential Sub classes of capability for agriculture (Sys et al., 1991)

Sub Class	Limitation factors	Area feddans	%
S_{2x}	Texture	88920.6	87.78
$S_{3x,d}$	Texture, Depth	12373.4	12.22
Total		101294.0	100.00

Land suitability for certain crops

Land suitability for four different crops, i.e., wheat, barley, tomato and olive was tested for the soils using Arc GIS 10.4 software. The results were imported to Arc

GIS to display maps. Soil characteristics of the different mapping units were matched with the crop requirements of each crop (FAO, 1976). The matching led to the current and potential suitability for each crop using the parametric approach and land index as mentioned by Sys et. al. (1993).

Current suitability

The data in Table 5 and Figures 6, 8 and 10 show the current suitability classes for the selected study crops. These data indicate that 87.78 % of the study area was moderately suitable (S_2) for olive, and 69.26 % of the study area was marginally suitable (S_3) for wheat and barley.

Potential suitability

From the previous discussion, the main limiting factors were soil, texture and salinity, which can be improved using good management practices such as salt leaching, use organic matter amendments, construction a good drainage system and follow good agriculture practices for crops. These improvements will develop the potential suitability. The results in Table 5 and Figures 7, 9 and 11 showed that about 87.78 % of the study area was highly suitable (S_1) for olive. While about 74.9 % of the study area was moderately suitable (S_2) for tomato. On other hand, about 69.26 % of the study area was moderately suitable (S_2) for wheat and barley.

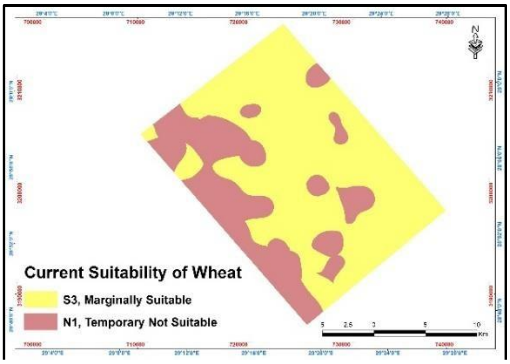

Figure 6. Current Land suitability map of Wheat and barley

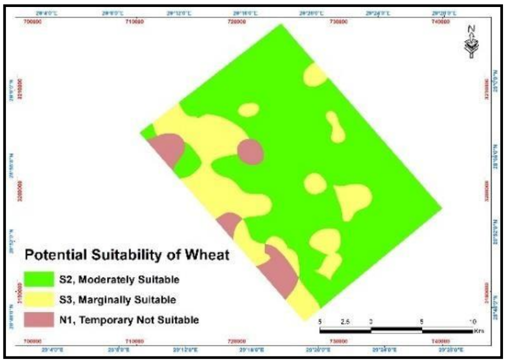

Figure 7. Potential Land suitability map of Wheat and barley

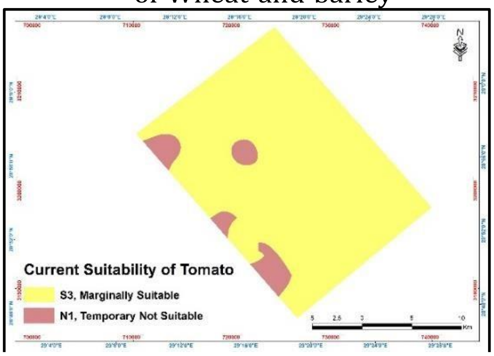

Figure 8. Current Land suitability map of Tomato

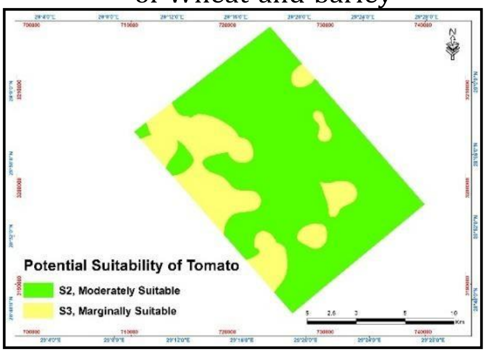

Figure 9. Potential Land suitability map of Tomato

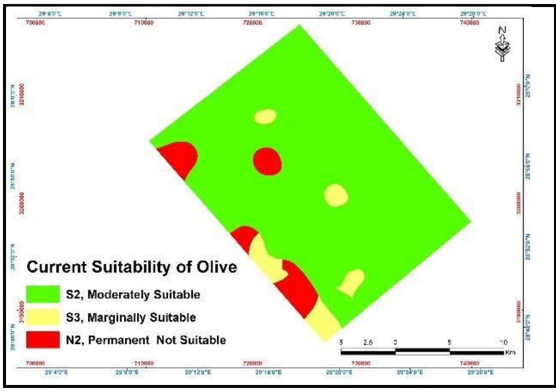

Figure 10. Current Land suitability map of Olive

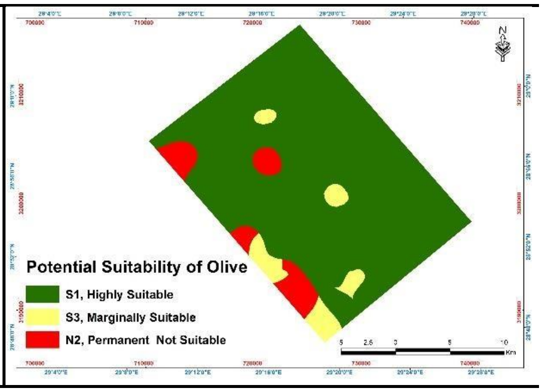

Figure 11. Potential Land suitability map of Olive

Table 5
Current and potential suitability classes and areas % for growing crops in the study area

Suitability Class**	Wheat & Barley		Tomato		Olive	
	Current	Potential	Current	Potential	Current	Potential
S_1	---	---	---	---	---	87.78 %
S_2	---	69.26 %	---	74.9 %	87.78 %	---
S_3	69.26 %	24.16 %	93.42 %	25.1 %	5.64 %	5.64 %
N_1	31.74 %	6.58 %	6.58 %	---	---	---
N_2	---	---	---	---	6.58 %	6.58 %
Total	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %

* * S_1 = Highly suitable, S_2 = Moderately suitable
N_1 = Currently not suitable S_3 = Marginally suitable N_2 = Permanent not suitable

Conclusion

The soils of the study area are suitable for agriculture specially the soils of moderately suitable which represents an area of about 70159.8 feddans (69.26 % of the total area). the texture and salinity are the main limiting factors for agriculture. The fruit crops such as olive were the best crop with drip irrigation system for growing in such soils.

References

Baja, S., Chapman, D.M. And Dragovich, D. (2002). A conceptual model for defining and assessing land management units using a fuzzy modeling approach in GIS environment. Environmental Management, 29, pp. 647–661.

CAPMAS. (2009). Statistical Year Book, Annual Report July 2009, Cairo, Egypt: Central Agency for Public Mobilization and Statistics (CAPMAS).

Daels, L. (1986). Remote sensing fundamentals. Gent. State Univ., Gent., ITC. J., pp.1-19.

Darmadi, N. M. ., Semara, D. G. ., & Kawan, I. M. . (2020). Tongkol (Euthynnus affinis) fermentation on organoleptics and its biochemistry. International Journal of Life Sciences, 4(3), 41–49. https://doi.org/10.29332/ijls.v4n3.503

FAO. (1976). A Framework for Land Evaluation. FAO Soil Bulletin, 32. Rome, Italy.

FAO. (1985). Guidelines: Land Evaluation for irrigated Agriculture. FAO Soils Bulletin No. 55, Rome, Italy.

FAO. (2006). Guidelines for soil description "fourth edition, FAO, Rome, ISBN 92-5-105521-10.

Hoffman, G.J. (1980). Guideline for Reclamation of Salt Affected Soils. Proc. Int. American Salinity and Water Magt. Tech. Conf., Juarez, Mexico, 230 p.

Kalogirou, S. (2002). Expert systems and GIS: an application of land suitability evaluation. Computers, Environment and Urban Systems, 26, pp. 89–112.

Kumar, V. K., & Singh, A. (2022). A stability indicating RP-HPLC method for related impurities of dexamethasone in tobramycin and dexamethasone otic suspension. International Journal of Health Sciences, 6(S6), 119–132. https://doi.org/10.53730/ijhs.v6nS6.9177

Martin, D. and S.K. Saha. (2009). Land evaluation by integrating remote sensing and GIS for cropping system analysis in a watershed. Current Science. 96 (4): 569-575.

Rossiter, D. G. (2003). Biophysical models in land evaluation. In: Encyclopedia of Life Support Systems (EOLSS), Theme 1.5 Land Use and Land Cover (ed W.H. Verheye), Oxford: EOLSS publishers developed under the auspices of UNESCO. Article 1.5.27. pp: 1–16.

Shim, J.P., Warkentin, M., Courtney, J.F., Power, D.J., Sharda, R. and Carlsson, C.(2002). Past, present and future of decision support technology. Decision Support Systems, 33, pp. 111–126.

Stein, A. (1998). Integrating spatial statistics and remote sensing. INT. J., 19 (9): 1793-1814.

Suliman, M. K. (1991). Universities and development of the desert land in the ARE. In The second annual university conference (pp. 2-5).

Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). The COVID-19 pandemic. *International Journal of Health Sciences*, *5*(2), vi-ix. https://doi.org/10.53730/ijhs.v5n2.2937

Sys, C. and Verheye, W. (1978). An attempt to the evaluation of physical land characteristics for irrigation according to the FAO Framework for land evaluation. Ghent, Belgium., The Netherlands, ITC. J., pp. 66-78.

Sys, C., E. Van Ranst and J. Debavey. (1991). Land Evaluation. Part I and S2, Ghent Univ., Ghent Belgium.

Sys, C., E. Van Ranst, J. Debavey and F. Beeranert. (1993). Land_ Evaluation. Part III Crops Requirements, Ghent Univ., Ghent Belgium., The Netherlands, 190 p.

USDA. (2004). Soil Survey Laboratory Methods Manual, Soil Survey Investigation Report No.42: vesion 4.0 November, 2004.

Zinck, J. A. (1988). Geomorphology and Soils. Internal Publ., ITC., Enschede, The Netherlands.