ZANCO Journal of Pure and Applied Sciences

The official scientific journal of Salahaddin University-Erbil
ZJPAS (2018),30 (5); 44-55
http://dx.doi.org/10.21271/ZJPAS.30.5.4

Soil fertility status for wheat crop production based on its soil organic matter and nitrogen contents

Aurass Muhi Taha1, Halema abduljabar abdul rahem 2 , Alwand Tahir Rasheed Dizayee3[**] , Ahmad Salih Muhaimeed 4

1 Department of Soil, College of Agriculture, University of Green Al-Kassim, Babylon, Iraq
2 Department of Soil, College of Agriculture, University of Bagdad, Baghdad, Iraq

3 Departments of Soil and Water, College of Agriculture, University of Salahaddin, Erbil, Iraq

4 Department of Soil, College of Agriculture, University of Bagdad, Baghdad, Iraq

A R T I C L E I N F O

Article History:
Received: 02/01/2018
Accepted: 12/08/2018
Published: 28/10 /2018

Keywords: Land suitability, soil organic carbon, total available nitrogen, wheat production.

***Corresponding Author:**
alwhtr_dizayee@yahoo.com

A B S T R A C T

The study was conducted to show the role of organic carbon and total content of available nitrogen on soil suitability for wheat production. The study area located in central of Iraq, in Al-Kufa – Alnajaf province situated approximately between 32° 00' N to 32° 10' N and 44° 20' E to 44° 35' E with total area of 27664 ha. Thirty five sites were selected representing all variations within the study area and located on landsat 8 image using GPS. Soil samples were taken from each of the selected sites and analyzed in laboratory to determine some physical and chemical properties. The results revealed that most soils of the study soils are Haplosalids and to some extend the presence of Torrifluvents. Most of soils have high salt accumulation. Rating scores for soil properties were evaluated using FAO, 2007 system to determine the suitability class for each soil site .The results indicated four suitability classes for wheat production in the study area including , S3, N1 and N2 with, about 37% of the total area of the study site are not suitable for wheat production due, mainly to the effect of high salinity level and to some extent to low content of organic carbon and total available nitrogen. Also, the results demonstrated the effects of organic carbon and available nitrogen on the spatial distribution pattern of soil suitability classes for wheat production.

Introduction

The population of the planet is growing dramatically. In order to meet the increasing demand for the food the farming community has to produce more crops mainly cereal types. Under present situations, where the land is a limiting factor, it is impossible to bring more area under cultivation, so farming community should tackle this challenge of producing more food. One approach to this point can be followed through using some conservation practices represented by land suitability evaluation systems. Further, land suitability analysis is needed for various purposes in the context of the present day agriculture. Land suitability evaluation is the prerequisites for sustainable agricultural production. It involves evaluation of the criteria ranging from soil, terrain to socio-economic, market and infrastructure (Prakash, 2003). According to the FAO general framework for land suitability evaluation (1976), the land suitability classification consists of assessing and grouping the land types in orders and classes according to their capacity. The results are intended to be used for land resource related decision making, both strategic land use planning by policy/planning institutions such as extension agencies, and specific local land allocation by the direct land users, that is, the farmers . Suitability of land is assessed considering rational cropping system, for optimizing the use of a piece of land for a specific use (FAO, 1976; Sys *et al*., 1991). The suitability is a function of crop requirements and land characteristics and it is a measure of how well the qualities of land unit match the requirements of a particular form of land use (FAO 1976). Land evaluation is a process of predicting land performance over time according to the specific types of use (Lee and Yeh, 2009 ; Martin and Saha, 2009 ; and Sonneveld et al., 2010). Agriculture land suitability assessment is defined as the process of assessment of land performance when used for alternative kinds of agriculture (He et al., 2011; Prakash, 2003). The principle purpose of agriculture land suitability evaluation is to predict the potential and limitation of the land for crop production). Conceptually, land evaluation requires matching of the ecological and management requirements of relevant kinds of land use with land qualities, whilst taking local economic and social conditions into account. Land evaluation provides practical answers to such questions as "What other uses of land are physically possible and economically and socially relevant?", "What inputs are necessary to bring about a desired level of production?", and "What are the current land uses and what are the consequences if current management practices stay the same?. In order to reach such aims, this study was conducted to meet the following objectives: 1- To evaluate land characteristic for wheat according to FAO, 2007 system, 2- to develop regression model to predict wheat production suitability using some spectral indices and 3- To show the impact of soil organic carbon and available nitrogen on the spatial distribution pattern of wheat suitability classes in the study area.

Materials and Methods

Study Site

The study area located in central of Iraq, in Al-Kufa – Al Nagaf province lying between latitude 32° 00' N to 32° 10' N and longitude 44° 20' E to 44° 35' E with total area of 27664 ha (Figure 1).

Land of the study area are used for some crops production including wheat, barley and corn.

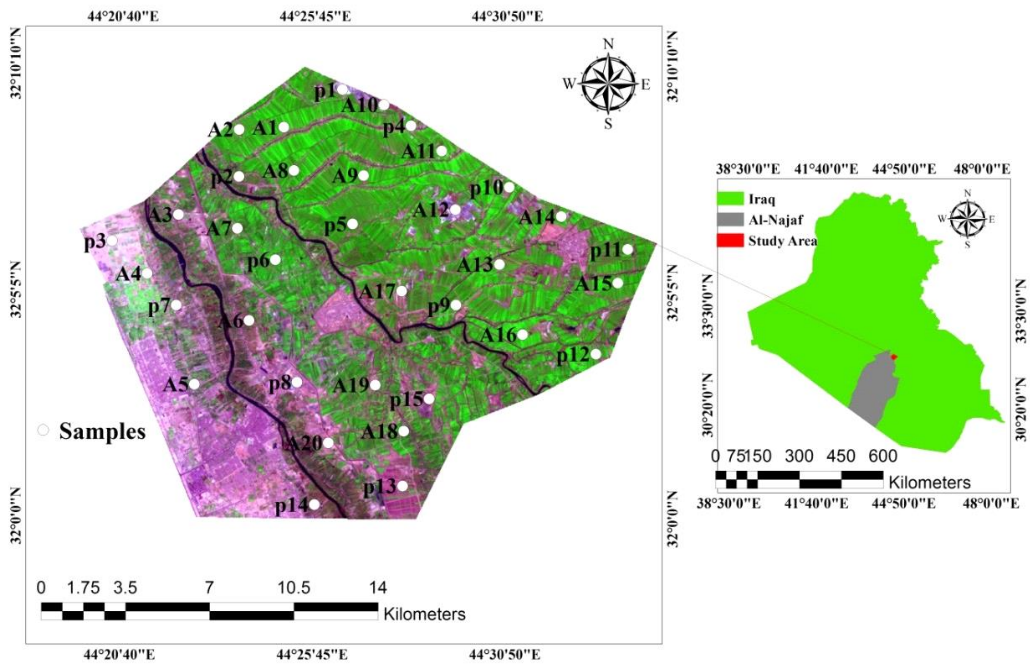

Fig.1. Location of the study area and sampling sites.

Field Work

Thirty five locations in the study area were selected to represent all variations in local conditions (Figure 1) . Soil samples were taken from fifteen pedons and twenty auger holes, and from all horizons or layers and described morphologically in the field according to Soil Survey Division Staff, 1993. Some physical , chemical and fertility properties for all soil samples were determined in laboratory using the common analysis methods mentioned by Bouyoucos (1962) ; Page et al.(1982) ; Hesse (1971); Papanicolaou, (1976) and Jackson (1958). Soils were classified according to Soil Survey Staff, (2012).

Satellite and ancillary data

The Landsat 8 OLI image (acquisition date: 1 Mar 2015) obtained from the USGS EROS centre was used in this study. The OLI image consists of eleven spectral bands with a spatial resolution of 30 meters for bands 1 to 7 and 9. The resolution for band 8 (panchromatic) is 15 meters. The time of acquisition corresponded closely to the field trips, and occurred while the main cereal crop (wheat) was in the growing stages. Atmospheric correction for Landsat image was done using the FLAASH model (Perkins et al. 2005) to correct both additive and multiplicative atmospheric effects. The corrected image was used to produce the following indices using ENVI 5 (Table 1) .

Table 1: Formulae of the vegetation indices.

Index	Full name	Formula	References
SAVI	Soil-Adjusted Vegetation Index	$\frac{(1+L)(\rho_{NIR}-\rho_R)}{(\rho_{NIR}+\rho_R+L)}$ Low vegetation, L = 1, intermediate, 0.5, and high 0.25	Huete (1988)
EVI	Enhanced Vegetation Index	$G=\frac{(\rho_{NIR}-\rho_R)}{(\rho_{NIR}+C1*\rho_R-C2*\rho_B+L)}$ ρ_B = reflectance of blue band, G = 2.5, C1 = 6, C2 =7.5 and L = 1	Huete et al. (1997)
GDVI	Generalized Difference Vegetation Index	$\frac{(\rho^n{}_{NIR}-\rho^n{}_R)}{(\rho^n{}_{NIR}+\rho^n{}_R)}$ n is power number, an integer of the values of 1, 2, 3, 4... n.	Wu (2012)

Note: ρ_{NIR} and ρ_R are reflectance of the near infrared (NIR) and red (R) bands; ρ_B and ρ_{MIR} are respectively that of blue band and of the middle infrared band (like TM band 5)

Land suitability Evaluation:

All soil properties were evaluated for wheat production and suitability classes were determined according FAO , 2007 (Equation 1) Table 2). Land suitability analysis and classes map for the study area were developed using ArcGIS .

$$\mathbf{I = A*\frac{B}{100}*\frac{C}{100}*\frac{D}{100}*\frac{E}{100}*\frac{F}{100}*\frac{G}{100}*\frac{H}{100}*\frac{J}{100}*\frac{K}{100}*\frac{L}{100}*\frac{M}{100}} \quad ....[1]$$

where :

I = suitability rating score
A = soil depth (cm)
B = soil texture
C = rock fragment
D = calcium Carbonate
E = CEC
F = PH
G = O.C.
H = EC
J = ESP
K = Slope %
L = Drainage
M= Gypsum

Table 2 . Land Suitability classes for wheat production (FAO, 2007).

Index	Definition	Symbol
80-100	Highly Suitable	S1
60-80	Moderately Suitable	S2
40-60	Marginally Suitable	S3
25-40	Currently not Suitable	N1
0-25	Permanently not Suitable	N2

Statistical Prediction Model

A Pearson correlation analysis was applied to compute the best statistical regression models for wheat suitability using some vegetation indices included EVI, SAVI, and GDVI (Table 1). The prediction accuracy was verified by comparing the predicted and the measured values of the studied soil properties using the 35 randomly selected field observations. The results of the best fitting correlation (Equation 1) was used to develop map for the pattern of spatial distribution for wheat suitability classes in the study area .

Map of the spatial distribution pattern of wheat suitability classes was developed using geostatistical analysis - ordinary Kriging model , according to Webster and Oliver , 2007 and using ArcGIS 10.1 .

Results and Discussion

Soils of the study area

The results of the physical and chemical properties of the studies soils indicated that the soils of the study area don't show some evidences for the formation of illuvial subsurface(Bt) and other horizons due to the effect of the dominant soil forming factors including dry climatic , high level of ground water and young calcareous parent materials. The results of physical and chemical soil properties revealed that the dominate soil types in the study area are Haplosalids and Torrifluvents. Most of the soils are affected by salt accumulation with low content of organic matter and available Nitrogen (Table3).

Table 3 . Some physical and chemical properties of the study area.

Site	pH	$dS.m^{-1}$	$g.kg^{-1}$			Textural name	$g.kg^{-1}$			$cmol_c.Kg^{-1}$	ESP%	$mg.kg^{-1}$
		ECe	Sand	Silt	clay		Lime	Gypsum	SOC	CEC		T.N
P1	7.23	28.04	160.28	505.81	333.91	SiCL	227.57	1.45	3.15	26.11	32.25	30.09
P2	7.57	6.14	366.79	425.21	208.00	L	201.51	0.47	5.79	23.17	12.00	44.90
P3	7.02	41.23	116.45	510.52	373.03	SiCL	241.21	1.93	1.73	26.67	35.41	25.08
P4	7.44	13.98	220.21	497.32	282.47	CL	208.90	0.78	4.78	24.68	24.38	34.87
P5	7.56	5.64	387.27	406.31	206.42	L	200.50	0.46	5.93	23.20	11.19	45.54
P6	7.60	4.18	348.64	493.30	158.06	SiL	201.37	0.42	6.13	22.90	6.90	48.65
P7	7.25	27.00	163.28	508.30	328.41	SiL	227.06	1.39	3.19	26.00	31.83	28.38
P8	7.04	40.13	65.01	558.97	376.02	SiCL	238.49	1.88	1.92	26.76	35.36	25.42
P9	7.57	6.08	487.02	333.81	179.17	L	201.78	0.44	5.74	22.93	10.51	45.95
P10	7.60	3.59	518.27	333.87	147.86	SL	199.35	0.40	6.05	22.43	5.05	49.90
P11	7.59	4.35	325.29	514.00	160.71	SiL	199.81	0.42	6.03	22.72	7.36	48.29
P12	7.59	3.30	494.32	363.20	142.48	L	199.10	0.39	6.09	22.30	3.89	50.66
P13	7.19	29.83	154.43	505.91	339.66	SiCL	229.53	1.54	2.97	26.16	32.74	27.58
P14	7.39	18.58	216.44	478.85	304.71	CL	216.10	1.01	4.33	25.36	27.75	32.15
P15	7.08	36.59	117.93	514.35	367.72	SiCL	234.58	1.78	2.37	26.63	34.66	26.14
A1	7.61	5.43	367.87	466.82	165.31	L	203.05	0.37	5.58	22.70	9.19	46.87
A2	7.61	5.61	404.28	427.97	167.75	L	203.14	0.37	5.56	22.74	9.54	46.60
A3	7.53	10.18	284.53	475.72	239.75	L	208.88	0.57	4.98	24.24	20.68	37.96
A4	7.57	8.15	317.07	455.27	227.67	L	207.15	0.51	5.15	23.94	18.53	39.73
A5	7.16	33.18	168.74	491.01	340.25	SiCL	235.39	1.48	2.27	26.16	33.22	26.77
A6	7.48	13.68	215.73	513.69	270.58	SiL	212.55	0.69	4.60	24.72	24.04	35.13
A7	7.59	7.12	364.80	414.90	220.30	L	204.43	0.42	5.44	23.25	13.47	43.69
A8	7.60	6.65	294.32	490.07	215.61	L	204.13	0.42	5.46	23.15	12.70	44.27
A9	7.62	5.15	384.07	453.56	162.37	L	202.89	0.37	5.59	22.63	8.61	47.29
A10	6.91	49.51	27.58	594.01	378.41	CL	252.7	2.07	0.53	26.72	36.49	23.57

A11	7.37	20.95	215.21	477.08	307.71	CL	220.48	0.97	3.8	25.4	28.55	31.18
A12	7.32	23.97	162.48	522.40	315.12	SiCL	225.62	1.15	3.28	25.71	30.5	29.37
A13	7.62	4.71	426.64	416.13	157.23	L	202.67	0.36	5.62	22.5	7.66	47.98
A14	7.64	3.59	541.75	317.33	140.93	SL	202.08	0.34	5.67	22.13	4.54	50.13
A15	7.62	4.20	363.68	486.56	149.76	L	202.39	0.36	5.64	22.35	6.36	48.87
A16	7.62	4.59	328.63	516.00	155.37	SiL	202.62	0.36	5.62	22.47	7.38	48.15
A17	7.52	11.36	242.69	511.42	245.89	SiL	209.90	0.60	4.88	24.38	21.75	37.08
A18	7.59	6.84	311.37	471.09	217.54	L	204.24	0.42	5.45	23.19	12.97	44.04
A19	7.43	17.31	204.15	501.19	294.66	SiCL	215.84	0.81	4.27	25.05	26.20	33.25
A20	7.16	34.60	84.44	574.02	341.54	SiCL	236.91	1.54	2.13	26.22	33.60	26.44

Data of the weighted soil properties (Table 3) were evaluated for wheat suitability using FAO,2007 and Sys et al.1993 (Fable 4). The results show that salinity and ESP are the

most limiting factors for wheat suitability, while lime, SOC and drainage show slight or moderately effects on the evaluation of wheat suitability in the study area.

Table 4. Rating scores of soil properties of the study area for wheat suitability

Site	Depth	Frag.	Tex.	Lime	CEC	pH	S.O.C.	ECe	ESP%	Slope	Drain.	Gyp.	Wheat Suit.	
													Value	Class
P1	100.0	1.00	1.00	0.90	1.00	1.0	0.75	0.25	0.7	1.00	0.70	1.00	8.27	N2
P2	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.40	0.95	1.00	1.00	1.00	29.32	N1
P3	100.0	1.00	1.00	0.90	1.00	1.0	0.60	0.25	0.76	1.00	0.70	1.00	7.18	N2
P4	100.0	1.00	1.00	0.90	1.00	1.0	0.85	0.25	0.8	1.00	1.00	1.00	15.30	N2
P5	100.0	1.00	0.95	0.90	0.95	1.0	0.99	0.60	0.95	1.00	1.00	1.00	45.84	S3
P6	100.0	1.00	0.95	0.90	0.95	1.0	1.00	0.65	0.95	1.00	1.00	1.00	50.16	S3
P7	100.0	1.00	0.95	0.90	1.00	1.0	0.75	0.25	0.7	1.00	0.70	1.00	7.86	N2
P8	100.0	1.00	1.00	0.90	1.00	1.0	0.60	0.25	0.6	1.00	0.70	1.00	5.67	N2
P9	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.40	0.95	1.00	1.00	1.00	29.32	N1
P10	100.0	1.00	0.60	0.90	0.95	1.0	1.00	0.85	0.95	1.00	1.00	1.00	41.42	S3
P11	100.0	1.00	0.95	0.90	0.95	1.0	1.00	0.80	0.95	1.00	1.00	1.00	61.73	S2
P12	100.0	1.00	0.95	0.90	0.95	1.0	1.00	0.85	0.99	1.00	1.00	1.00	68.35	S2
P13	100.0	1.00	1.00	0.90	1.00	1.0	0.75	0.25	0.7	1.00	0.70	1.00	8.27	N2
P14	100.0	1.00	1.00	0.90	1.00	1.0	0.85	0.25	0.8	1.00	1.00	1.00	15.30	N2
P15	100.0	1.00	1.00	0.90	1.00	1.0	0.60	0.25	0.6	1.00	0.70	1.00	5.67	N2
A1	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.60	0.95	1.00	1.00	1.00	43.98	S3
A2	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.60	0.95	1.00	1.00	1.00	43.98	S3
A3	100.0	1.00	0.95	0.90	1.00	1.0	0.90	0.25	0.85	1.00	1.00	1.00	16.35	N2
A4	100.0	1.00	0.95	0.90	0.95	1.0	0.92	0.35	0.85	1.00	1.00	1.00	22.23	N2
A5	100.0	1.00	1.00	0.90	1.00	1.0	0.70	0.25	0.7	1.00	0.70	1.00	7.72	N2
A6	100.0	1.00	0.95	0.90	1.00	1.0	0.85	0.25	0.75	1.00	1.00	1.00	13.63	N2
A7	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.40	0.95	1.00	1.00	1.00	29.32	N1

A8	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.40	0.95	1.00	1.00	1.00	29.32	N1
A9	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.60	0.98	1.00	1.00	1.00	45.37	S3
A10	100.0	1.00	1.00	0.90	1.00	1.0	0.95	0.25	0.4	1.00	0.70	1.00	5.99	N2
A11	100.0	1.00	1.00	0.90	1.00	1.0	0.78	0.25	0.65	1.00	0.70	1.00	7.99	N2
A12	100.0	1.00	1.00	0.90	1.00	1.0	0.75	0.25	0.6	1.00	0.70	1.00	7.09	N2
A13	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.80	0.95	1.00	1.00	1.00	58.64	S3
A14	100.0	1.00	0.60	0.90	0.95	1.0	0.95	0.85	0.95	1.00	1.00	1.00	39.35	N1
A15	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.80	0.95	1.00	1.00	1.00	58.64	S3
A16	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.80	0.95	1.00	1.00	1.00	58.64	S3
A17	100.0	1.00	0.95	0.90	1.00	1.0	0.90	0.25	0.85	1.00	1.00	1.00	16.35	N2
A18	100.0	1.00	0.95	0.90	0.95	1.0	0.95	0.40	0.95	1.00	1.00	1.00	29.32	N1
A19	100.0	1.00	1.00	0.90	1.00	1.0	0.85	0.25	0.8	1.00	1.00	1.00	15.30	N2
A20	100.0	1.00	1.00	0.90	1.00	1.0	0.60	0.25	0.6	1.00	0.70	1.00	5.67	N2

FAO, (2011) indicated that approximately 60% of the cultivated land in central Iraq has been seriously affected by salinity and 20-30% of the abandoned soils. Many researcher found that salinity and SOC are the most limiting factor for wheat production in central and southern Iraq (Alshafi and Muhaimeed, 2012; Muhaimeed et al., 2015 ; Muhaimeed et al., 2016). The results shown in Table 4 indicated that soils of the study area are moderately to not suitable for wheat production and the dominant suitability classes found are S2 , S3 , N1 and N2 .

Prediction of Wheat suitability

The results of Pearson correlation analysis for computing the best statistical prediction model for wheat suitability using some vegetation indices included EVI, SAVI, and GDVI, indicated very high significant positive correlation ($R^2 = 0.95$) between the actual suitability values (Figure 2) and the predicted suitability values calculated using equation 1. The prediction model was used to developed the map of spatial distribution of wheat suitability in the study area(Figure 3) .The results shown in Figure 3 revealed the presence of four suitability classes including S2 , S3 ,N1 and N2. The percentage area for classes S2 , S3 , N1 and N2 were 12.28 , 21.69, 20.36 and 36.26 respectively . Map of the spatial distribution pattern shows that the non- suitable classes(N1 and N2) are located with the area of salt affected soils, while the moderately suitable classes(S2 and S3) are located within the area of non- salt affected soils.

The non- suitable classes are dominant and cover more than 56 % from the total area of the study area (Figure 3). The domination of non – suitable classes are due to bad management practices as well as low content of SOC and total available nitrogen.

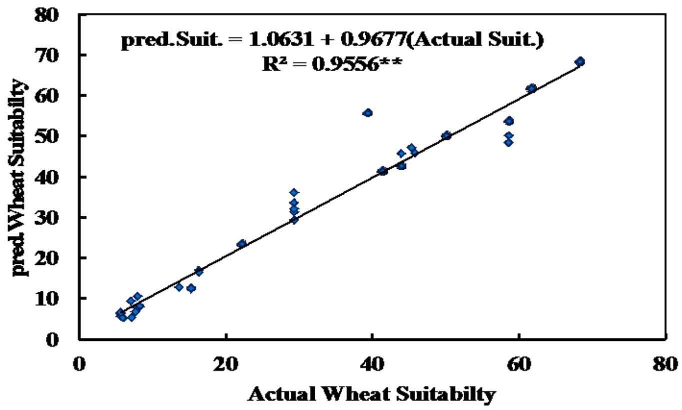

Figure 2 : The correlation between the actual and the predicted wheat suitability

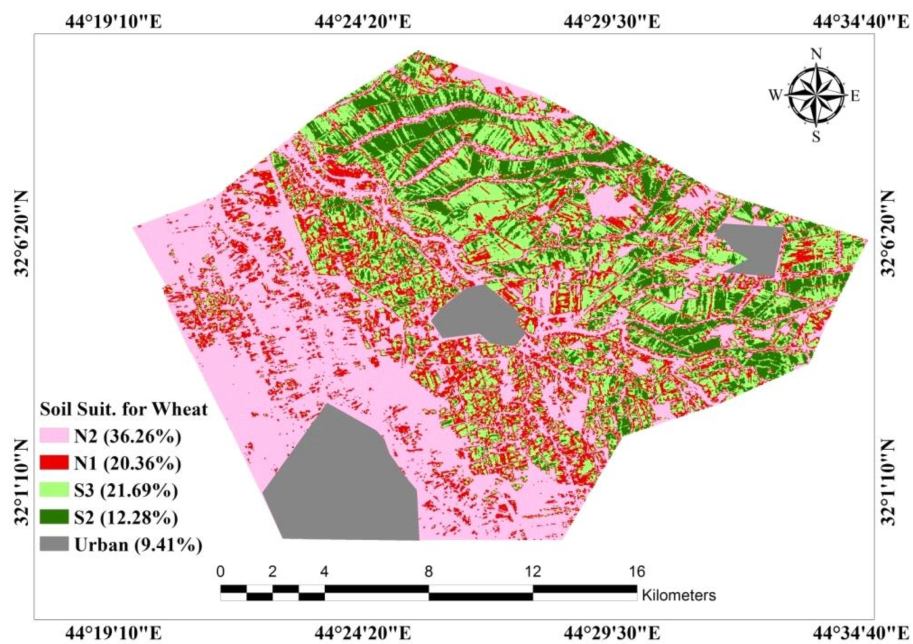

Fig.3. Spatial distribution of soil suitability classes for wheat production

The study area suffering from unsuitable irrigation and drainage systems as well as bad quality of irrigation water. These factors allow to increase the rate of salt accumulation in most of the soils in the study area.

Muhaimeed and Ali ,2016 indicated that land degradation which affects crop production in central Iraq is the result of complex interactions between physical, chemical, biological, socio-economical, and political issue of local and national conditions.

Effect of SOC and TAN on Wheat suitability

The results (Table 3 and 4) show that the content of SOC and total available Nitrogen in most soils in the study area are low and have moderate effect on the degree of soil suitability for wheat production. This is reflected by the pattern of spatial distribution for SOC and TAN in the study area. Figure 4 was developed by using geostatistical analysis and ordinary Kriging model to show the relationship between spatial distribution of SOC content and wheat suitability of study area . The results (Figure 5) revealed the presence of high positive correlation between soil suitability for wheat production and the content of SOC with R^2 =0.834. This results is due to the fact which indicated that soil organic matter is a major source of many nutrients including nitrogen used by crops and at any given time, a high portion of the potentially available nitrogen in the soil is in organic forms, either in plant and animal residues, in the relatively stable soil organic matter, or in living soil organisms, mainly microbes such as bacteria(Glass, 2003).

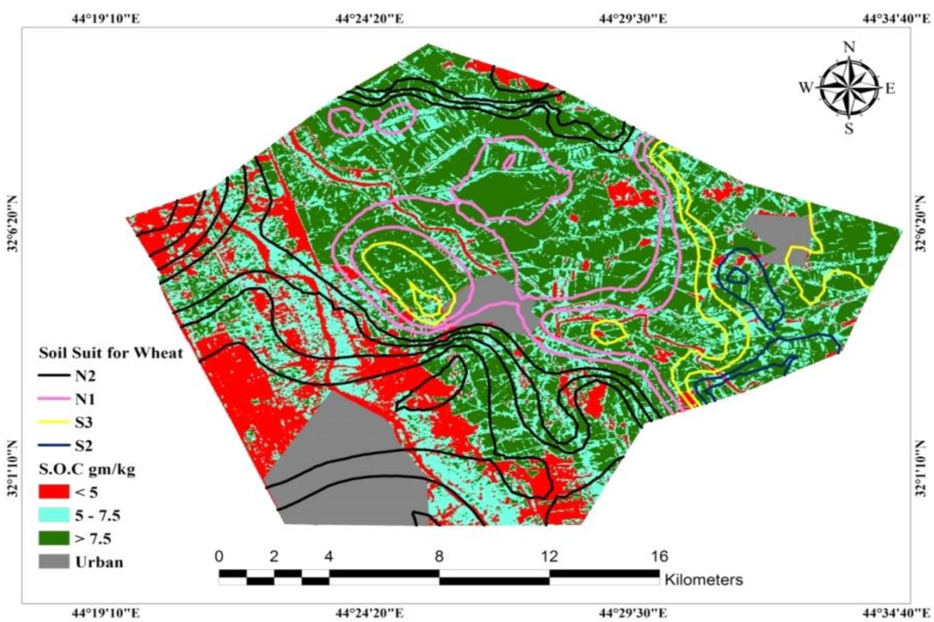

Fig.4. Spatial Distribution pattern for suitability classes and SOC in the study area.

Available total nitrogen in the studied soils show the same trend of correlation shown by SOC with soil suitability for wheat production. The results (Figure 5) revealed high positive correlation between wheat suitability and TAN with R^2 = 0.957. This correlation was used to develop the spatial distribution map for both wheat suitability and TAN in the study area (

Figure 6). The results indicated a good correlation between the location of wheat suitability classes and the soil content from TAN , moderately suitable classes(S2 ,S3) located within area of moderately content of TAN, while unsuitable classes going parallel with low TAN content in the soil of the study area. This shows the importance of available nitrogen on plant growth. Nitrogen is an important nutrient in soil, a basic resource for maintaining the Earth's ecosystems, and a primary restrictive factor for crop production(Glass,2003).

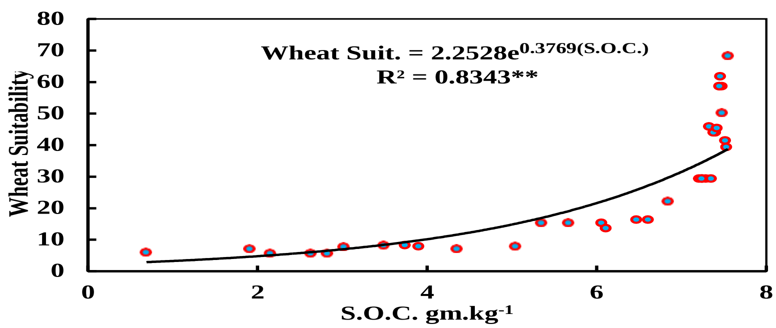

Fig.5. The correlation between wheat suitability score and SOC content

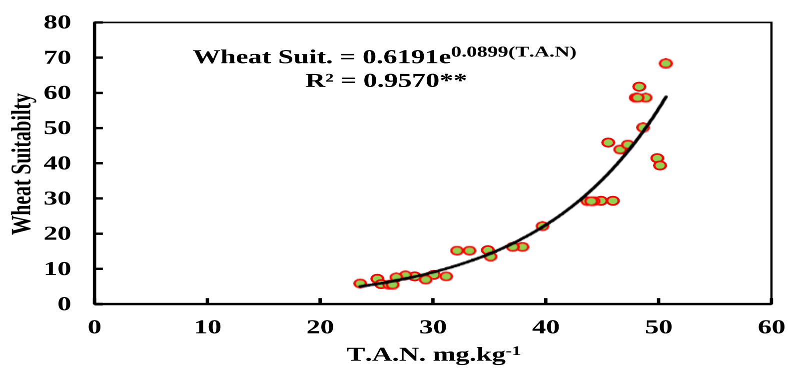

Fig. 6 . The correlation between wheat suitability score and TAN content

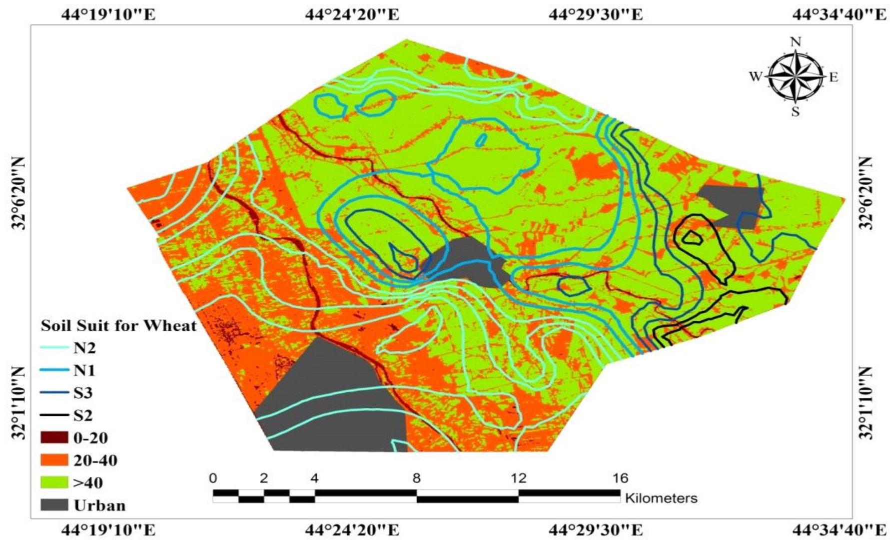

Fig.7. Spatial Distribution pattern for suitability classes and TAN in the study area

Conclusions

Statistical prediction models used in this study for both SOC , TAN and soil suitability for wheat production are corresponded well with actual measured values of these attributes. Soil organic carbon and available nitrogen content showed high correlation with spatial distribution pattern for wheat suitability classes in the study area. These results revealed the important of SOC and TAN for plant growth and consequently for soil suitability for wheat production.

Acknowledgement

The authors thank Dr. Tariq H. Karim for offering valuable comments before sending the article for reviewing.

References

Al-shafi W.M .and A.S. Muhaimeed. (2012) .Land Evaluation for wheat in Salamiyat project(Baghdad) using Geo-Information Techniques. Iraqi Journal of Agriculture.17:1: 65- 75.

Bouyoucos, G.L. 1962. Direction for making mechanical analysis of soil by the hydrometer method . Soil . Sci. 42 : 225-228.

FAO, 1976. A framework for land evaluation. Food and Agriculture Organization of theUnited Nations, Soils Bulletin 32. FAO, Rome.

FAO, 2007. Land Evaluation Towards a Revised Framework. Food and AgricultureOrganization of the United Nations, Rome, Italy.

FAO,2011. Country pasture/forage resource profiles: Iraq, FAO, Rome, Italy, p.34.

He, Y., Y. Yao, Y. Chen, and L. Ongaro . 2011. Regional Land Suitability Assessment for Tree Crops Using Remote Sensing and GIS Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM) IEEE, Changsha (2011) pp. 354–363

Hesse, P .R. (1971). A text Book of Soil Chemical Aanalysis. John Murray. LTD. London, British.

Huete, A. R. 1988. A soil adjusted vegetation index (SAVI). Remote Sensing ofEnvironment 25: 295–309.

Huete, A. R., Liu, H. Q., Batchily, K., and van Leeuwen, W. 1997. A comparison of vegetation indices global set of TM images for EOS-MODIS. Remote Sensing of Environment 59: 440-451.

ITT, corporation. 2009. ENVI 4.7 soft ware .1133 Westchester Avenue , White Plains,NY 10604 ,USA.

Jackson, M. L. S.L. Tyler , A.L. Willuims , G. A. Bourbear and R. P. Pennigton . 1958.Weathering Sequence of clay Size minerals in soil and Sediment J. phys . co 11 chems.52.

Lark, R.M .2009. Kriging a soil variable with a simple no stationary variance model. J.Agric. Biol. Environ. Stat. 14: 301–321.

Lee, T.M. and H.C. Yeh 2009 . Applying remote sensing techniques to monitor shifting wetland vegetation: a case study of Danshui River estuary mangrove communities, Taiwan Ecological Engineering, 35 (2009), pp. 487–496

Page , A.L., R.H. Miller, and D.R. Kenney. (1982). Methods of Soil Analysis Part (2).

2nd ed. Agronomy 9 Am. Soc. Agron. Madison, Wisconsin.

Papanicolaou, E.P.(1976).Determination of cation exchange capacity of calcareous soils and their percent base saturation. Soil Sci. 121:65-71.

Prakash, T. N.2003. Land Suitability Analysis for Agricultural Crops: A Fuzzy

Multicriteria Decision Making Approach, MSc thesis, ITC, Netherlands: 6- 13.

Richards, L.A. (1954) . Diagnosis and improvement of saline and alkalin soils. U.S.D.A Handbook No. 60. Rossiter , D.G. and ALES .1990: a framework for land evaluation using microcomputer Soil Use & Management, 6 . pp. 7–20

Soil Survey Division Staff . 1993. Soil Survey Manual. USDA – SCS. Agric. Hand book 18. Washington, DC: U.S. Government printing Office.

Lichtenstern , A . 2013 . Kriging methods in spatial statistics . Technics UniversityMunich . Department of Mathematics . Bachelor's Thesis .

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 .p. 1

Muhaimeed, A.S., Al-Falihi, A.A., Al-Aini, E., and Taha, A.M., (2014).Developing Land Suitability maps for Some Crops in Abu-Ghraib Using Remote Sensing and GIS. Journal of RS and GIS, Vol, 2, Issue (1): pp 2052-5583.

Muhaimeed ,A.S. and Z.R.Ali . 2015. Monitoring Degradation of Agricultural Land in Baghdad Province using Remote Sensing and GIS. International Journal of Geosciences and Geomatics, 3: 1 : 34 – 41.

Muhaimeed A.S .and Drakhshan R. Jaf D.R. 2016. Land Suitability for Wheat

Production under Dry Farming System in Erbil Plain Using Remote Sensing and GIS. International Journal of Research in Agriculture and Forestry .3: 8: 1-9.

Soil Survey Staff. 1999. Keys to soil taxonomy . 7th Edition USDA . NRCS . Washington, D.C.

Sonneveld , M.P.W, , M.J.D. Hack-ten Broeke, C.A. van Diepen, and H.L. Boogaard. 2010. Thirty years of systematic land evaluation in the Netherlands .Geoderma, 156 pp. 84–92.

Sys , C. , E. van Ranst and J. Debaveye . 1993. Land Evaluation part III , crop requirements . Agricltural Publication No.7 . General Administration for development Cooperation , Brussels , Belgium.

Webster, R. and M. A. Oliver (2007). Geostatistics for Environmental Scientists (2nd ed.). Statistics in Practice. Chichester: John Wiley & Sons, Ltd.

Wu , W . 2011 . Atmospheric Correction for Landsat Data – Material for remote sensing training . ICARDA .w.wu@cgiar.org .

Wu , W. (2014) . The Generalized Difference Vegetation Index (GDVI) for Dryland Characterization . Remote Sens. (6): 1211-1233.