Sys Rev Pharm 2020;11(10):1171-1180
A multifaceted review journal in the field of pharmacy

Predict Some Soil Characteristics And Prepare Their Digital Maps From Remote Sensing Data

Mohammed A. Kadhim

Department of Soil Science and Water Resources
College of Agriculture / University of Basrah
Corresponding authormuhamed.ahmed15@yahoo.com:Mohammed A. Kadhim E-mail:

ABSTRACT

Remote sensing techniques and geographic information systems have been used for the purpose of predicting some of the physical and chemical properties of the soil and preparing its digital maps from the remote sensing data of the satellite image sensor The Operational Land Imager(OLI) of the Landsat 8 satellite for the year 2019. Non-linear equations were prepared to predict maps of physical soil characteristics represented by soil content of clay, silt and sand and maps of chemical soil characteristics represented by soil salinity, sodium adsorption ratio, gypsum and organic matter by performing multiple regression analysis with the following spectral indices (NDVI, SI, GSI) , And with highly significant identification factors which amounted to (0.85, 0.81, 0.85, 0.92, 0.81, 0.89 and 0.82) for each of these characteristics, respectively. And through the high accuracy of the correlations between the predicted and laboratory-measured values of the characteristics, the spectral evidence used in the study proved its efficiency to predict these characteristics. In general, the best predictive mathematical equations were found for soil characteristics and with high significant correlation relationships (0.94, 0.89, 0.94, 0.97, 0.85, 0.93 and 0.90) for each of the studied soil characteristics.

Keywords: **Soil characteristics , Remote Sensing , Digital soil mapping , NDVI , SI ,**

Correspondence:
Mohammed A. Kadhim
Department of Soil Science and Water Resources
College of Agriculture / University of Basrah

*Corresponding author: Mohammed A. Kadhim email-address: muhamed.ahmed15@yahoo.com

INTRODUCTION

Remote sensing technology is one of the modern means of studying natural resources, including soil, as it analyzes the electromagnetic energy falling from the sun on the targets and interacts with them either to absorb, transfer, reflect or emit . This energy in all its forms is used to explore objects in many fields, including forest study, agricultural crop control, desertification, land use, and soil classification (Lillesand and Kiefer , 1999) .

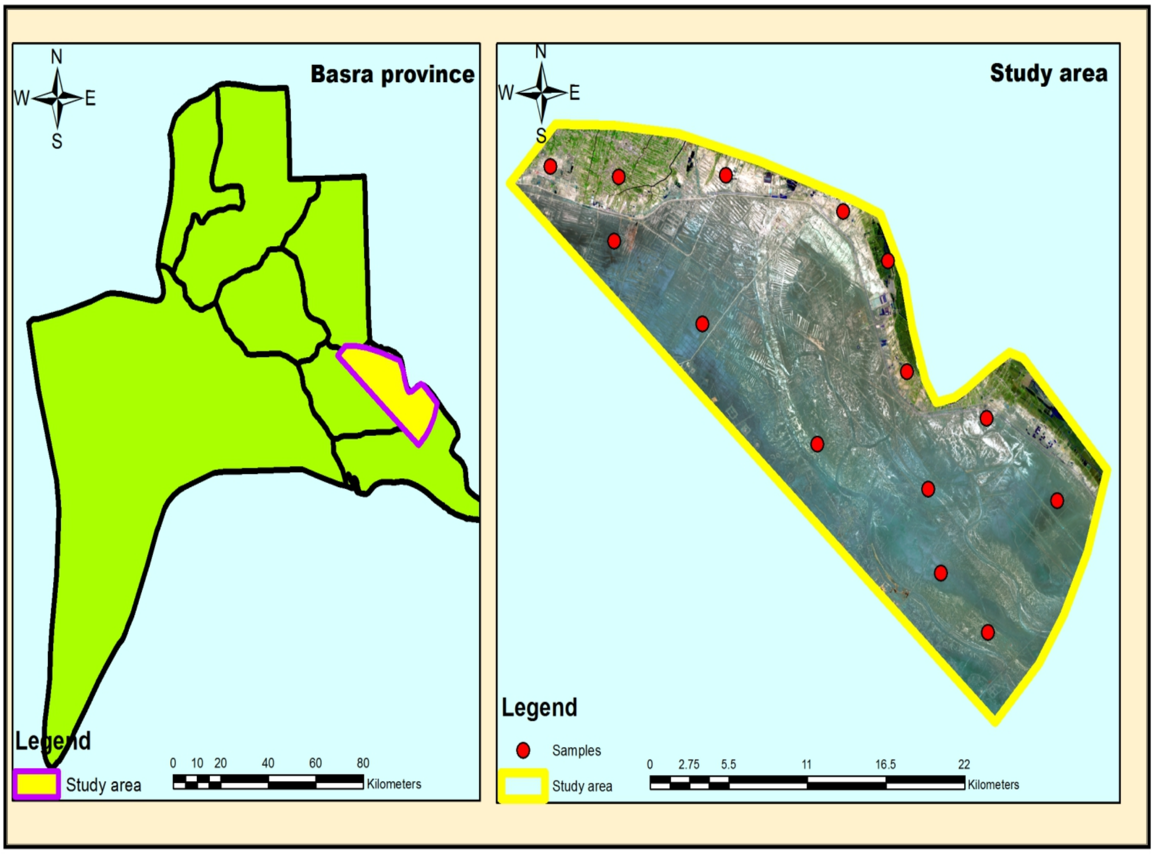
Al-Kubaisi (1997), when studying some soils of the desert of western Iraq, was able to find different statistically significant statistical relationships linking spectral data with some soil properties (soil content of clay, silt, sand, salinity, organic matter, gypsum and lime) , He explained to conducting many studies to devise mathematical models to study the relationships between soil particals and spectral data . The use of the spectral reflectivity of the soil enabled the prediction of the soil properties over a large agricultural area, which helps to take better management of the land resources in the dry areas. And the ability to map soil traits (Nawar *et . al* 2015). Abbas (2010) found in his study on the characterization and classification of soil units in the North Kut project that the use of spectral bands was beneficial, as they were statistically associated with some of their physical and chemical characteristics and this indicates the possibility of employing remote sensing data to predict some of their characteristics, especially (soil particles, The bulck density, particles, content and quality of salts) in the soil of the study area , as it was noted that most of them have to do with the presence of salts and gypsum, and thus between the salinity and gypsum traits outperformed the other soil characteristics by their effect on the values of spectral reflectivity. Xiao *et al* (2006) has used the Topsoil Grain Size Index (GSI) as the best evidence for predicting surface soil particles volumes through spectral data, as there is a positive correlation of 0.73 with the content of fine sand while there is an inverse correlation relationship Its amount is 0.61 with the soil content of the clay particles volumes of the surface layer in dry areas with low vegetation. Taha *et al.* (2014), in their study, were able to diagnose salty degraded soil varieties from predicted chemical soil properties from spectral indications derived from Landsat7 ETM + sensor data. Soil salinity map, percentage of sodium exchange and sodium adsorption ratio in the soil were prepared by conducting multiple regression analysis with The Salinity Index (SI) and Generalized Difference Vegetation (GDVI2) spectral indexes with highly significant determinationcoefficients of 0.88, 0.93 and 0.86 for each of these characteristics, respectively . Therefore, this study aimed to take advantage of the spectral criteria derived from the Landsat8 OLI sensor in producing digital maps of soil characteristics by building statistical relationships between some of the studied soil characteristics and their spectral characteristics and testing the predictability of some of their properties using remote sensing methods.

MATERIALS AND METHODS

Study Area

The study area was chosen as part of the sedimentary plain that contains sediments belonging to the Tigris, Euphrates and Karon rivers. The soil of this region is characterized by being of sedimentary sedimentary origin due to the recent formed soil order of Entisols. As the study area is located east of Basra Governorate, in southern Iraq, within the administrative borders of the Abu Al-Khasib District, which extends south to the Al-Siba district and is bordered to the east by the Shatt Al-Arab River and lies between latitudes 30 ° 28'1.173 "- 30 ° 8'49.676" north and longitude 47 ° 56'17.09 "- 48 ° 14'49.96" east, with an area of 598.77 km2, as shown in Figure 1. Fourteen locations were identified using the

GPS and UTM system, as samples were taken from the surface layer of all locations with a depth of 0-25 cm.



Figure(1) Study area

Laboratory analysis of soil samples

Soil samples were taken from the surface layer of all sites to perform some required laboratory analyzes, as the methods described in Black (1965) were used to estimate the soil texture and the degree of electrical conductivity in the soil extract and sodium ion was measured using the described methods In Page (1982). Organic matter were estimated according to what was reported in Jackson (1958). Calcium and magnesium ions were measured by calibration with EDTA 0.01 standard as well as gypsum by acetone sedimentation method, Calculated percentage of sodium was calculated through the following equation and as described in Richards (1954).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

spectral data

The satellite image captured by Landsat 8, the OLI (The Operational Land Imager) for the year 2019, was completely corrected after all steps were taken to eliminate distortions due to multiple causes. The digital image manipulation was done using the Arc map 10.4.1 software. Selection of spectral bands 7, 5 and 3 that have the highest Optimum Index Factor (OIF) to create the best color composition to distinguish the soils of the study area (Faleh and Shawan, 2012) . Satellite imagery was used to extract spectral data for the purpose of finding correlations and calculating spectral indices .

Indices

Digital Indices was used to construct predictive models to produce soil characteristic maps, as a set of digital Indices was used, including the Normalized Difference Vegetation Index (NDVI) proposed by Rouse *et al* (1974) equation (2) and the Salinity Index (SI) reported by (Khan *et al.*, 2005) equation (3) and the topsoil Grain Size Index (GSI) proposed by (Xiao *et al*, 2006) Equation (4) .

$$NDVI = \frac{B5 - B4}{B5 + B4} \quad \ldots\ldots(2)$$

$$\text{Salinity Index} = (B3 * B4)/B2 \quad \ldots\ldots(3)$$

$$GSI = (B4 - B2) / (B4 + B2 + B3) \quad \ldots\ldots(4)$$

Whereas B2, B3, B4, B5, B6 represent the spectral bands of the OLI sensor.

Predictive maps of soil characteristics

The above numerical Indices values were extracted using ArcMap10.4.1 program, then SPSS 22 was used in order to perform multiple correlation and regression to determine the best predictive relationships, and the resulting mathematical models were applied in ArcMap10.4.1 to produce maps of soil characteristics, then the accuracy of the results was tested with soil characteristics Measured in the laboratory in order to determine the significance of the accuracy of these maps.

The values of the studied soil characteristics were also extracted from the maps in order to identify their intersection points.

RESULTS AND DISCUSSION

General characteristics of the study area

The results showed in Table 1 the volumetric distribution of soil particles for the surface layer in the study area, as it is generally noticed that there is a difference in the pattern of distribution of soil particles (sand, silt and clay) within the studied soil sites and this is due to the variation in the sedimentary environment of these sites, if it is observed that the content Clay and silt were high in all locations compared to the small amount of sand, and the dominance of silt minutes was in most locations, ranging from 373.2 - 792.7 g kg $^{-1}$, then clay ranged between 158.8 - 475.3 g kg $^{-1}$, while the sand ranged between 50 - 332.5 g kg $^{-1}$. The sites studied were characterized by medium to soft textures. The results showed the values of the degree of soil interaction, as all values were within moderate to medium soil soils ranged between 7.38 – 8.10, while the electrical conductivity values showed that the soil sites showed a change in the salinity content, as it is noticed that the values of electrical conductivity are between low salinity soils to The soil is highly saline and ranged between 7.28 – 56.52 dsm $^{-1}$.

Table (1) some physical and chemical properties and Digital Indices of the bands sensor OLI for Satellite images 2019 in the study area

Samples	clay	silt	Sand	Texture class	pH	EC	CaSO4	O.M	SAR	spectral indices		
	gkg $^{-1}$					dsm $^{-1}$	gkg $^{-1}$		Meq/L	NDVI	SI	GSI
1	253.9	413.6	332.5	Loam	7.49	44.04	5.36	9.6	15.83	0.09135	0.33226	0.12072
2	464.2	402.1	133.7	SiC	7.56	38.16	1.99	10	14.5	0.11981	0.23415	0.08885
3	223.8	373.2	403	Loam	7.53	56.52	6.17	6	20.04	0.07649	0.41528	0.13133
4	158.8	538.1	303.1	SiL	8.10	39.32	2.82	9	14.02	0.0898	0.29629	0.10752
5	173.3	770.6	54	SiL	7.84	7.38	0.17	1.9	10.71	0.0423	0.17357	0.03619
6	457.2	792.7	50	SiC	8.05	7.28	0.1	9	7.85	0.08719	0.11397	0.026469
7	440.4	459.5	100.1	SiC	7.45	16.04	0.16	4	11.71	0.06504	0.21952	0.07116
8	186.1	739.5	73.4	SiL	7.51	7.58	0.15	12.6	8.22	0.18289	0.16189	0.04162
9	378.4	438.5	183.1	SiCL	7.51	42.12	4.33	7	15.5	0.08062	0.3086	0.10591
10	464.6	405.1	130.3	SiC	7.47	29.25	0.38	3.9	12.44	0.06486	0.22051	0.07451
11	185.5	721.4	92.8	SiL	7.94	30.72	0.29	3.8	12.34	0.06062	0.22383	0.06661
12	409.7	500.2	90	SiC	7.79	7.78	0.16	2.6	10.69	0.06192	0.19382	0.0624
13	300.4	621.1	78	SiCL	7.76	34.04	1.49	2	13.83	0.05521	0.22625	0.06181
14	475.3	397.2	127.5	SiC	7.38	16.53	0.23	5.1	12.19	0.07141	0.2172	0.07497

Preparing maps of soil characteristics from digital indices a - Clay content map

The soil content of the clay was predicted by applying equation (5) and shown in figure (2) as follows :

% Clay = 1572.782 NDVI + 757.396 SI – 117.269 GSI $R^2 = 0.85^{**}$ …………(5)

It had a high significance determination coefficient with a value of 0.85, with a highly significant correlation accuracy with the values of the soil content of clay measured laboratory, reaching 0.94, as in Figure (3). Through high accuracy, the efficiency of the spectral indices used in the study is shown in extracting the values of the soil content of clay and its spatial distribution, and these results are in agreement with what Zain (2008) found, as he indicated that there is a negative correlation between the spectral reflectivity of the soil and the percentage of soil content of clay. Al-Hayali (2017) also found, when studying some sedimentary soils, that the GSI and NDVI index is an accurate indicator for separating the variation in the content of soil particles in the conditions of the study area with a dry climate, which is an important indicator for predicting the content of clay in the surface soil through spectral data.

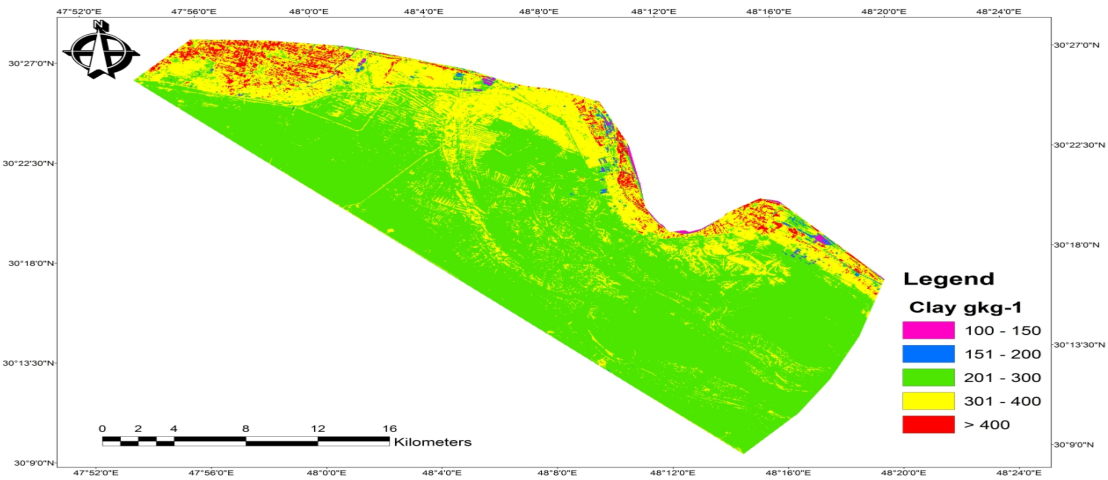


Figure (2) Spatial distribution of clay content in soil

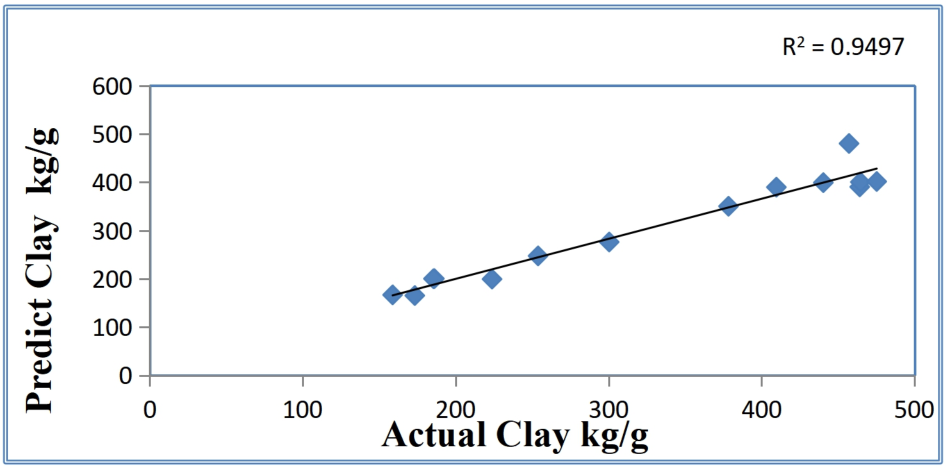


Figure (3) the accuracy of the relationship between clay values resulting from the application of Equation 5 and the laboratory measured clay values

B - Silt content map

The soil content of the silt was predicted by applying equation (6) and shown in figure (4) as follows :

% Silt = 3196.650 NDVI + 6777.228 SI – 17803.796 GSI $R^2 = 0.81^{**}$ ……(6)

It had a high significance determination coefficient with a value of 0.81, with a highly significant correlation accuracy with the values of the soil content of silt measured laboratory, reaching 0.89, as in Figure (5). Through high accuracy, the efficiency of the spectral indices used in the study is shown in extracting the values of the soil content of silt and its spatial distribution, These results are consistent with the findings of Xiao et al (2006). It was found that the reflectivity values of the GSI index decreased with an increase in the total content of silty particles in the surface layer and with an inverse correlation relationship with a correlation coefficient of 0.73, and that the value of the negative correlation coefficient of this index with clay and silts increased in soils Dry areas with low vegetation

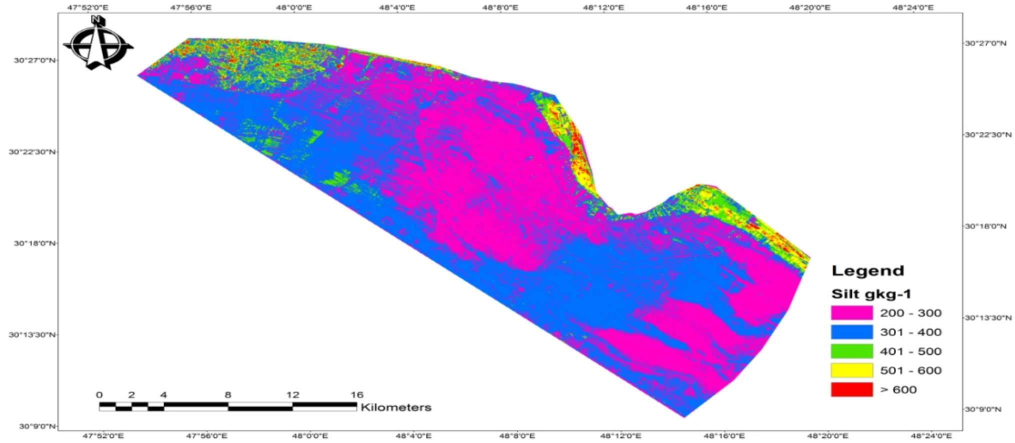


Figure (4) Spatial distribution of silt content in soil

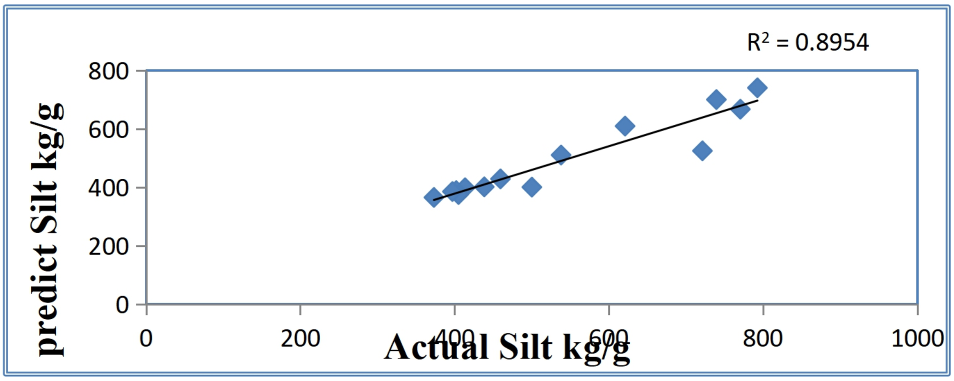


Figure (5) the accuracy of the relationship between silt values resulting from the application of Equation 6 and the laboratory measured silt values

C - Sand content map

The soil content of the sand was predicted by applying equation (7) and shown in figure (6) as follows :

% Sand = – 351.032 NDVI – 241.287 SI + 3232.112 GSI $R^2 = 0.85^{**}$ **......(7)**

It had a high significance determination coefficient with a value of 0.85, with a highly significant correlation accuracy with the values of the soil content of sand measured laboratory, reaching 0.94, as in Figure (7). Through high accuracy, the efficiency of the spectral indices used in the study is shown in extracting the values of the soil content of sand and its spatial distribution , These results are consistent with the findings of both El Hayali (2017) and Abbas (2010), as we were able to obtain significant differences between the spectral reflectivity values of fine, medium and coarse soil particles, and showed that sand particles absorb light "more than the clay and silt particles and that There is a possibility to predict particle sizes using spectral indices, since their results were of a statistical error of zero and the correlation was positive between the spectral reflectivity of the soil and the content of the particles and sand

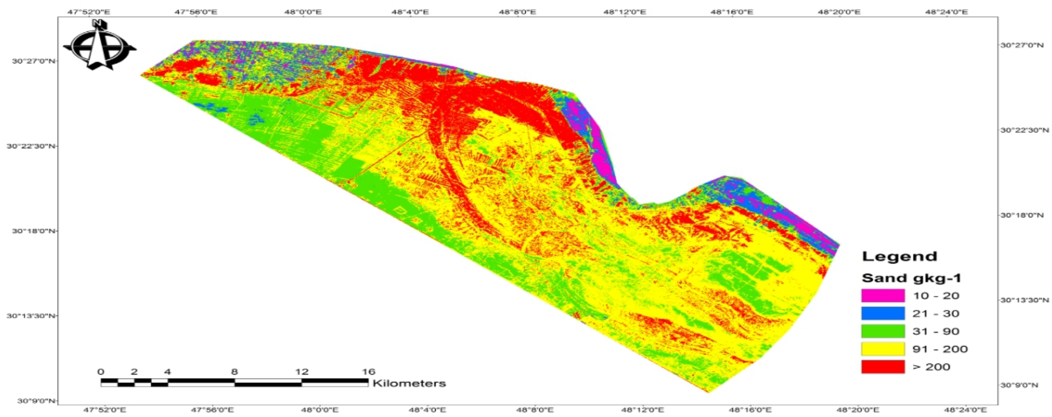


Figure (6) Spatial distribution of sand content in soil

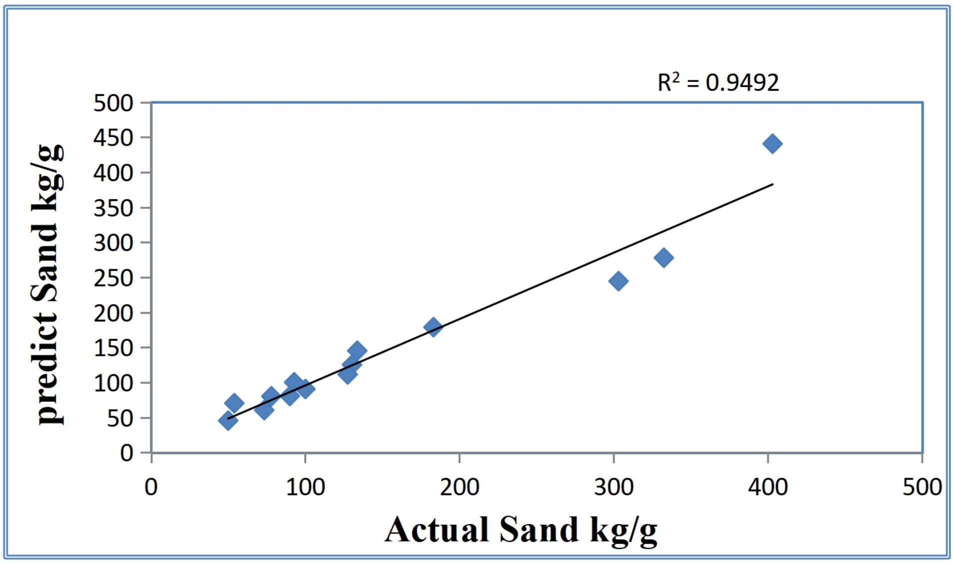


Figure (7) the accuracy of the relationship between sand values resulting from the application of Equation 7 and the laboratory measured sand values

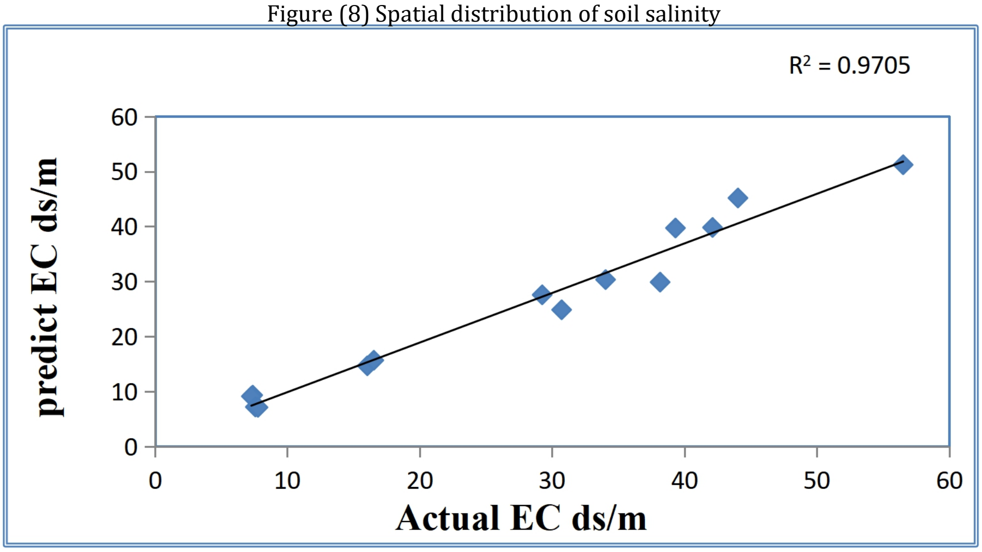
D - Soil salinity map

Soil salinity was predicted by applying equation (8) and shown in figure (8) as follows :

EC= – 59.596 NDVI + 13.451 SI + 382.203 GSI R^2 = 0.92 ……… (8)**

It had a high significance determination coefficient with a value of 0.92, with a highly significant correlation accuracy with the laboratory measured electrical conductivity values, reaching 0.97, as in Figure (9). The high resolution shows the efficiency of the spectral indices used in the study in extracting the values of soil salinity and their spatial distribution , As the study area was characterized by the high salt content in it, especially the sodium chloride salt, which has radiation-reflective properties. The results of the study indicated that the effect of the soil content of salts on the spectral reflectivity depends on the quality of the salts prevailing in the soil, and among the salts that have a positive effect in increasing the values of reflectivity are the salts of sodium chloride and calcium sulfate This is in agreement with what Khan et al. (2005) found in his study, in which the highest reflectance in the numerical number values of the spectral bands occurred in the regions affected by the salts with their decrease in the waterlogged regions, and he obtained a high significant positive correlation between the salt index and the spectrum bands B3, B2 and B4 and a highly significant negative correlation with NDVI index . From the above, it is possible to refer to the accuracy of the SI index in determining and separating the spatial distribution of the soil salinity characteristic of the study area due to the presence of the influential relationship of this characteristic on the spectral reflectivity values, directly or indirectly through its effect on the growth and density of vegetation cover, which increases the reflectivity of the soil surface and thus can predict With salinity of the soil.

Figure (8) Spatial distribution of soil salinity



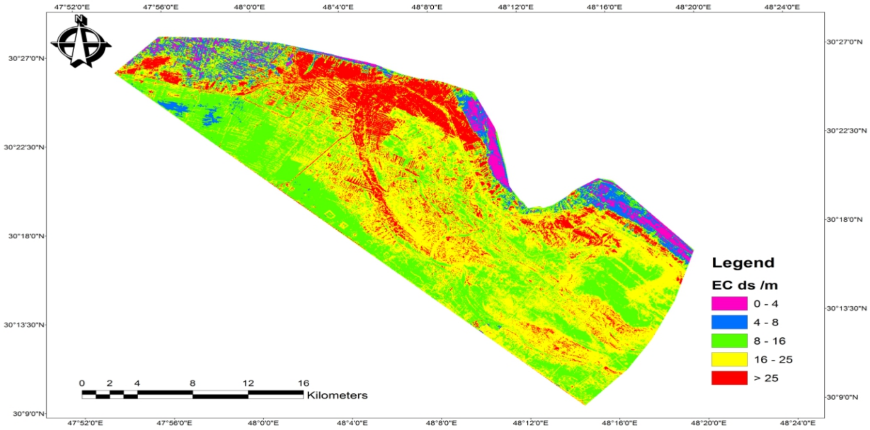


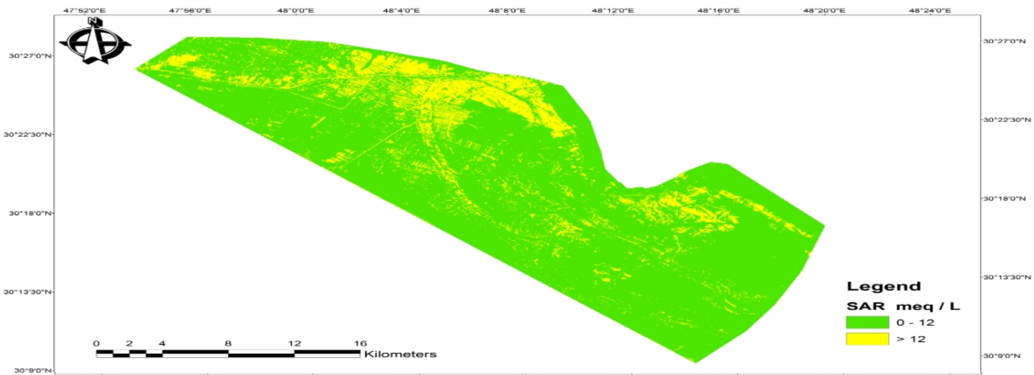
Figure (9) the accuracy of the relationship between soil salinity values resulting from the application of Equation 8 and the laboratory measured soil salinity values

E - Sodium adsorption ratio map

Sodium adsorption ratio was predicted by applying equation (9) and shown in figure (10) as follows :

SAR= 7.042 NDVI + 67.601 SI – 52.530 GSI $R^2 = 0.81^{**}$ **………. (9)**

It had a high significance determination coefficient with a value of 0.81, with a highly significant correlation accuracy with the laboratory measured the Sodium adsorption ratio values, reaching 0.85, as in Figure (11). The high resolution shows the efficiency of the spectral indices used in the study in extracting the values of the Sodium adsorption ratio and their spatial distribution , Therefore, the results showed the importance of the SI index and the NDVI index in representing the spatial distribution of the Sodium adsorption ratio with high accuracy for the types of soil in which the value increased or decreased by the Sodium adsorption ratio more than 12. Where the results indicated that there is a positively significant positivecorrelation between the Sodium adsorption ratio and the SI index, and this depends on soil salinity



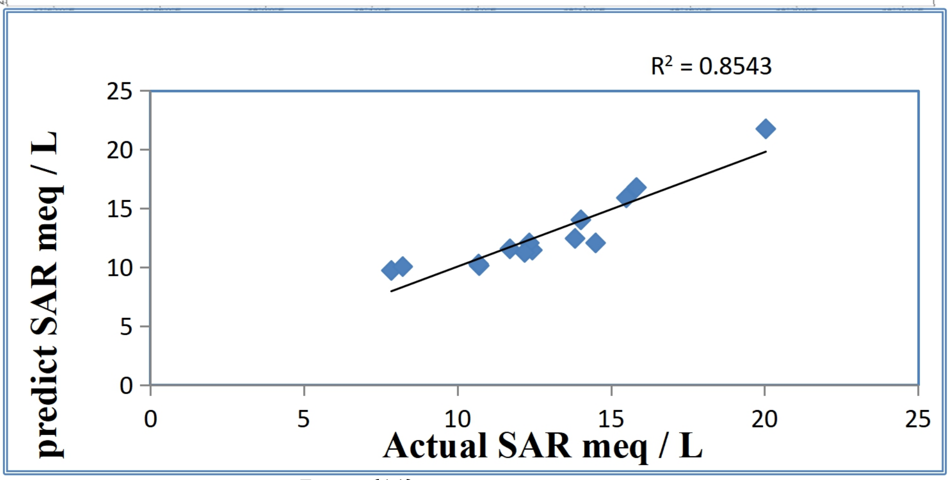


Figure (11)

the accuracy of the relationship between Sodium adsorption ratio values resulting from the application of Equation 9 and the laboratory measured Sodium adsorption ratio values

F - Gypsum map

The soil content of the gypsum was predicted by applying equation (10) and shown in figure (12) as follows :

CaSO4 = – 11.758 NDVI – 6.508 SI + 57.864 GSI
R2 = 0.89………. (10)**

It had a high significance determination coefficient with a value of 0.89, with a highly significant correlation accuracy with the values of the soil content of gypsum measured laboratory, reaching 0.93, as in Figure (13). Through high accuracy, the efficiency of the spectral indices used in the study is shown in extracting the values of the soil content of gypsum and its spatial distribution , As it was observed that there is a positively significant positive correlation between the soil content of gypsum and the SI index, and this is consistent with Muhamid and Hamid (2002), who showed in their study that the gypsum soil showed the highest values of spectral reflectivity compared to the rest of the soils of desert areas in Iraq. From the above, it is possible to refer to the accuracy of the SI index in determining and separating the spatial distribution of the gypsum characteristic in the study area due to the presence of the influential relationship of this characteristic on the spectral reflectivity values, directly or indirectly through its effect on the growth and density of vegetation cover, which increases the reflectivity of the soil surface in addition to the emptiness of most of it. Of vegetation.

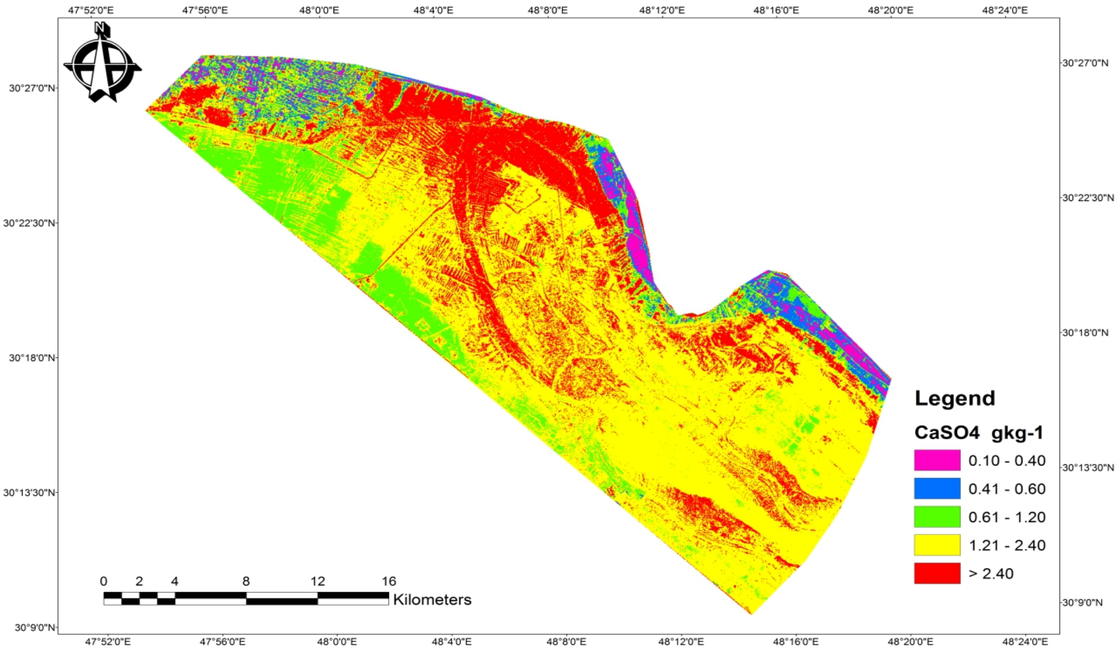


Figure (12) Spatial distribution of gypsum content in soil

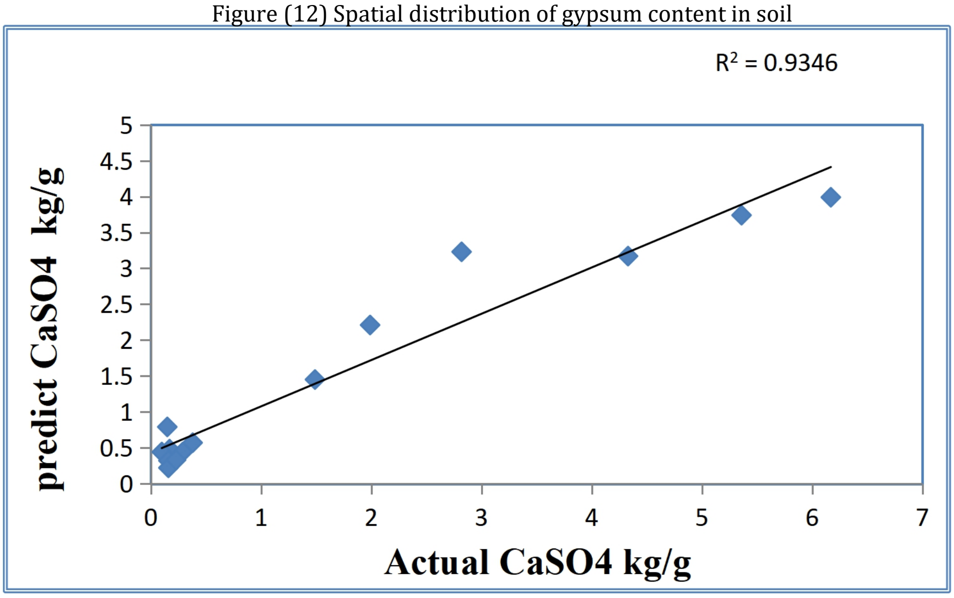


Figure (13) the accuracy of the relationship between gypsum values resulting from the application of Equation 10 and the laboratory measured gypsum values

g - Organic matter map

Soil content of organic matter was predicted by applying equation (11) and shown in figure (14) as follows

O.M = 79.092 NDVI – 29.918 SI + 89.721 GSI R2 = 0.82………. (11)**

It had a high significance determination coefficient with a value of 0.82, with a highly significant correlation accuracy with the values of the soil content of organic matter measured laboratory, reaching 0.90, as in Figure

(15). Through high accuracy, the efficiency of the spectral indices used in the study is shown in extracting the values of the soil content of organic matter and its spatial distribution , Whereas, a highly significant positive correlation was observed between soil organic matter content and NDVI index, and a highly significant negative correlation with SI and GSI index. Therefore, this index can be used in diagnosing the vegetation cover, which relied on the ratio between the spectral reflectivity values of the infrared band and the red band that are suitable for this purpose, and then these values appeared very low and this is an indication of poor agricultural investment and low content of organic matter in the study area.

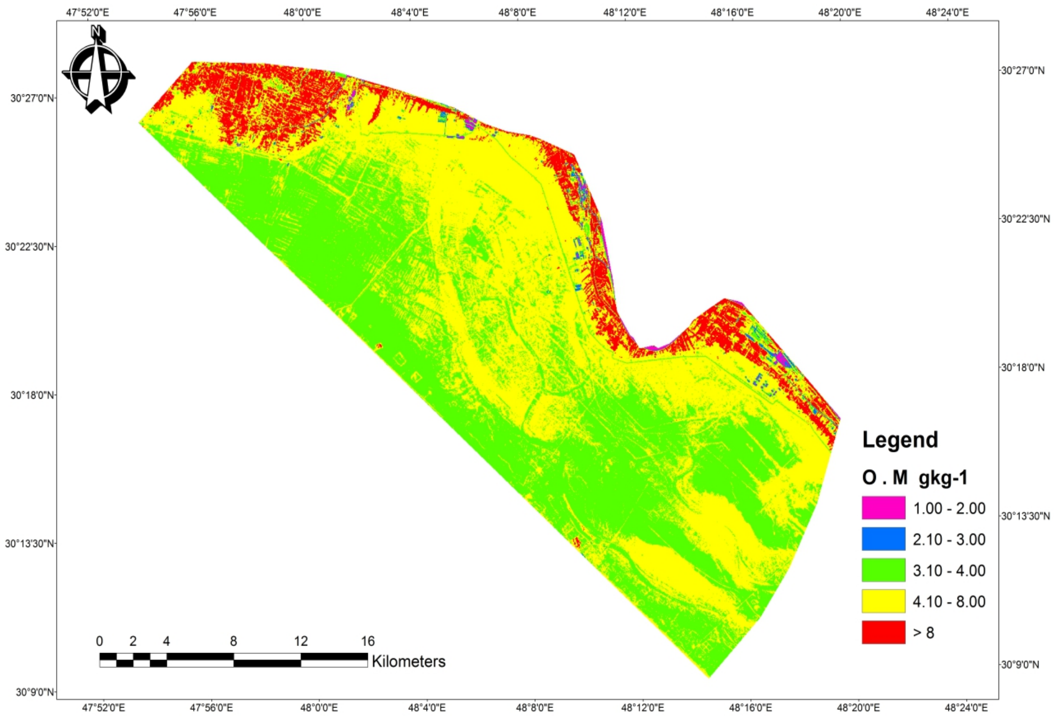


Figure (14) Spatial distribution of organic matter content in soil

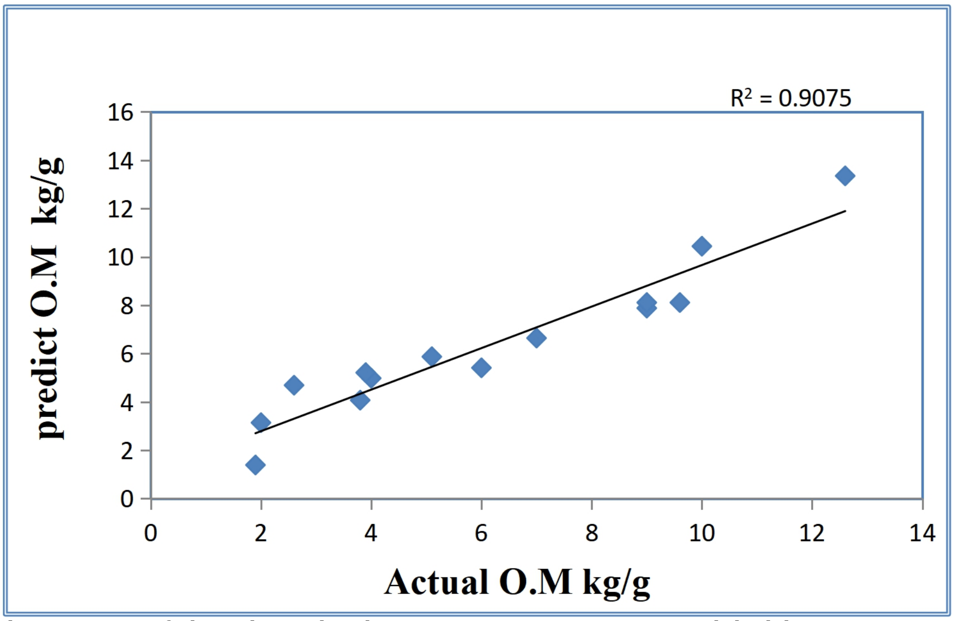


Figure (15) the accuracy of the relationship between organic matter values resulting from the application of Equation 11 and the laboratory measured organic matter values

REFERENCES

1. Abbas, A, H.(2010) . Characterization and Classification of Soil Units of North Kut Project and Prediction of Some Soil Physical Properties by Using GIS and Remote Sensing . PhD thesis , College of Agriculture at University of Baghdad .

2. Al-Hayali, M ,A . (2017). Classification of some soils of eastern Shatt Al– Arab region in Basrah province and evaluation of land suitability for agricultural purposes by using remote sensing technologies. PhD thesis - College of Agriculture - University of Basra.

3. Al-Kubaisi, A, M .(1997) . Modeling spatial variations of some soil characteristics in the eastern Hasaba region, using digital data for the Landsat 5 satellite.. PhD thesis, College of Agriculture at University of Baghdad .
4. Black , C . A . (1965) . Method of soil analysis , Am . Soc . of Agronomy No . 9 part I and II .
5. Faleh, Ali and Jamal Shawan. (2012). Geographical Information Systems and Remote Sensing: Principles and Applications. Infoprant Press. Axe . The Kingdom of Morocco .
6. Jackson , M . L . (1958) .``Soil chemical Analysis `` . printice – Hall . Inc . , Engle wood cliffs . , N . Y .
7. Khan , N . M ., V . V . Rastoskuev , Y . Sato and S . Shiozawa . (2005) . Assessment of hydrosaline land degradation by using a simple approach of remote sensing indicators . Agricultural Water Management . 77 : 96 – 109 .
8. Lillesand , T . M . and R . W . Kieffer . 1999 . Remote sensing And Image interpretation . 2nd .Ed . John Wiley and sons . Inc .
9. Muhaimid, A, S. and H, Hamid. (2002). The relationship between the geomorphological units and the distribution of soil units in the western region of Lake Razzazah. Iraqi Journal of Soil Sciences. 1 (2) 129-140 .
10. Nawar , Henning Buddenbaum and Joachim Hill . (2015). Digital Mapping of Soil Properties Using Multivariate Statistical Analysis and ASTER Data in an Arid Region . Remote Sens. 2015, 7, 1181-1205.
11. Page , A . L . , R . H . Miller and D . R . Keeney . (1982) . Methods of soil analysis , part (2) 2nd ed . Agronomy g – Wisconsin , Madison . Amer . Soc . Agron . Inc . Publisher .
12. Richards , L . A . ed . (1954) . Diagnosis and improvement of salin e and alkali Soils . USDA Handbook 60 . U . S . Govt ., printing office , Washington .
13. Rouse, J.W. et al., (1974). Monitoring the vernal advancement and retrogradation (greenwave effect) of natural vegetation. NASA/GSFCT Type III Final report. Greenbelt, MD, USA.
14. Taha, A, M., Mahmoud , S. S., Obaid , E.(2014) . The Diagnosis of Saline Degradation of chemical Properties of Sodic and Non sodic Soil and Remote Sensing Data. Al-Qadisiyah Journal of Agricultural Sciences. Vol. 2, No. 4 , 2014, 67–81 .
15. xiao, J, Y., Shen, Y.J., Tateishi R.(2006) . Development of topsoil grain size index for monitoring desertification in arid land using remote sensing. International Journal of remote sensing. Vol. 27, No. 12, 20 June 2006, 2411–2422 .
16. Zain, A, A. (2008) . The use of remote sensing to study the reflectivity of the land cover and its relationship to some soil characteristics in the Abu Ghraib area . M.A thesis . College of Agriculture - University of Baghdad .