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MONITORING AND EVALUATION OF SOIL SALINITY IN TERM OF SPECTRAL RESPONSE USING LANDSAT IMAGES AND GIS IN MESOPOTAMIAN PLAIN/ IRAQ

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Key words:Soil Salinity, Landsat Images, Mesopotamian Plain.
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Abstract

Soil Salinity is one of the most important considerations for monitoring soil degradation and continued desertification that threat some regions in Iraq. Remote sensing techniques and GIS operations have been used for multidate image processing to detect and monitor the history changes of soil in the western part of Mesopotamian plain. The aim of this research is to assign the appropriate and effective image processing techniques to be implemented for monitoring, and then to evaluate soil salinity in the term of the corresponding spectral response in the best spectral band. Landsat MSS, TM, and ETM images for the periods 1972, 1990, and 2000 respectively have been selected, as well as ancillary data of the available salinity field measurements have been used. ERDAS (8.5), ENVI (3.6), and ArcGIS (9.2) softwares have been used for the purpose of digital processing, creation of information layers, integration, and statistical correlation. It is concluded that created image brightness and salinity indices indicate the increasing of salt affected soil during the mentioned period of images. And these image indices have the highest correlation coefficient with Mid-IR band. A predictive equation is established to estimate soil salinity in the term of spectral response of Landsat images; the effective relationship is specified at the value above 28 ds/m of Electrical Conductivity (EC), and the obtained correlation coefficient 87 % reaches to 95% when EC values of soil increase to more than 70 dS/m.

مراقبة وتقييم ملوحة التربه بدلالة الأستجابه الطيفيه باستخدام مرئيات لاندسات ونظم المعلومات الجغرافيه في منطقة السهل الرسوبي في العراق

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المستخلص:

تعد ملوحة التربه احدى الأعتبارات المهمه لمراقبة مشاكل تدهور التربه واستمرارية التصحر التي تهدد بعض المناطق في العراق. أستخدمت تقانة التحسس النائي وعمليات نظم المعلومات الجغرافيه لمعالجة المرئيات الفضائيه متعددة الأزمان لغرض تعيين ومراقبة احداث تغير التربه في الجزء الغربي من السهل الرسوبي في العراق. يهدف البحث الى تعيين افضل طرائق المعالجات الرقميه المناسبه والفعاله للمراقبة ثم تقييم ملوحة التربه بدلالة الأستجابه الطيفيه ذات العلاقه في افضل الحزم الطفيه. تم اختيار مرئيات لاندسات MSS, TM, ETM للفترات 1972, 1990, 2000 على التوالي مع استخدام قياسات العمل الحقلي المتوفره عن ملوحة التربه واستخدمت البرامج ERDAS (8.5) و ENVI (3.6) و ArcGIS (9.2) لغرض المعالجات الرقميه وانشاء الطبقات المعلوماتيه ومكاملة البيانات وايجاد العلاقات الأحصائيه. تبين ان انشاء مرئيات دليل السطوع ودليل الملوحة تظهر ازديادا في تأثير الملوحه في التربه خلال الفترات الزمنيه المشار اليها للمرئيات الفضائيه وان مرئيات الأدله تمتلك أعلى معاملات الترابط مع الحزمه الطيفيه تحت الحمراء المتوسط. استنبطت معادله تنبؤيه لتقدير ملوحة التربه بدلالة الأستجابه الطيفيه على مرئيات لاندسات حيث تكون العلاقه فعاله عند قيمة التوصيل الكهربائي الأعلى من 28 dS/m وان معامل الترابط المستحصل 87% يصل الى 95% عندما يرتفع التوصيل الكهربائي للتربه الى أكثر من 70 dS/m.

INTRODUCTION

Soil salinity is one of the main problems of soil degradation; it is an environmental hazard that causes losing the agricultural productivity**.** Surface salinity processes are highly dynamic, so using multi-date images is a suitable way to detect the changing state of soil, as well as the technology development and extent of environmental change over the last 20th century have gave a new urgency for monitoring this change. Wide ranges of processing techniques are available to discriminate the spectral response in regard to the different soil quality. Salinity elements of MgCl2 and NaCl ions may form highly hygroscopic salts in the soil (Orlov et al., 1992), and the Electrical Conductivity (EC) and concentrations of Cl- and Na+ are important criteria in soil salinity (Panah and Zehtabina, 2002). Subsequently, and according to laboratory spectral investigations (Karavanova et. al., 1995); the increasing of salt contents leads to increase the spectral reflectance of the soil. Generally, it leads always to be associated with high reflectance in the visible and near- infrared (NIR) spectra (Everitt et al., 1988 and Karavanova et. al, 1995). And significantly, Middle Infrared (MIR) and near-infrared bands have the most correlation with the observed EC values of the soil (Shrestha, 2006), but nature does not always fulfill this phenomenon since many other factors play a role; soil reflectance is contributed by the heterogeneous combination of mineral, organic matter, particle size, and parent material. As well as, the presence of soil moisture tends to darken the soil and reduces the surface reflectance (Epema 1990). So, Multi-band image processing has to be proven to identify salts in soils and salt-stressed crops than individual bands (Hick and Russell, 1990). Significantly, Brightness Index (BI), Salinity Index (SI), and Normalized Difference Salinity Index (NDSI) give good results in detecting salt-affected lands; the spectral reflectance of NIR which radioed with red band gives very high spectral values for vegetation than other features. Here if the inverse is considered thus suppressing of vegetation and high lighting of soil is occurred (Tripathi et al., 1997; Odeh and Onus, 2008). Accordingly; soil salinity and salinity status is a complex phenomenon which may vary with the time, especially in areas which are affected by wind and sand movement and drainage status. So, proving the best band combination in adequate image processing has to be considered in such studies.

The aim of this research is using digital remote sensing technique and GIS operation to detect the temporal and spatial variability of soil salinity indicators and to estimate the salinity in terms of spectral response of satellite images.

The Study Area

The study area is located in the western part of Mesopotamian plan/south of Iraq, bounded (Figure-1) by the geographic coordinates corners of A: (31˚ 10'N, 45˚ 05' E), B: (31˚ 28' N, 45˚ 20' E), C: (30˚ 50'N, 46˚ 20' E), and D: 30˚ 20' N, 46˚ 05' E), and covers approximately 6500 square kilometers. The majority of the study area is flat with regional gradient decreasing towards southeast, and it is parallel to a fault boundary especially between Samawa and Nasiriya. The stratigraphic units (Figur-2) lie within Salman and Mesopotamian zones; ranging between Prequaternary (Middle Eocene to Pliocene-Pleistocene) and Quaternary deposits (Buday, 1980; Jassim and Goff, 2006). The hyrogeological setting is described (Al–Basrawi, 2005**)** as shallow aquifer, high level ground water table, and characterized by different high salinity levels in high risk zones. Furthermore, Salt-affected regions, which contain sandy, silty and clayey bare soils, probably originated from rising saline ground water, (Krasny and Salim 1982, Araim, 1984). However, Mohammad and Hussien (1993) established different category degrees of soil salinity (Table-1) which has been depended to describe soil salinity degree in the study area. The climate is systematized within arid zone during the period 1970-2000 (Al- Khateeb and Capaigian, 2007); most of rainfall precipitation falls during spring and winter, and the highest temperatures reach mostly to more than 40C° degree (Figure-3) during dry season (June-August). Vegetation is dense in the northern part and dominated by trees and shrubs which are disturbed alternatively with open grassland, but in the southern part, vegetation is sparse and dominated by desert plants.

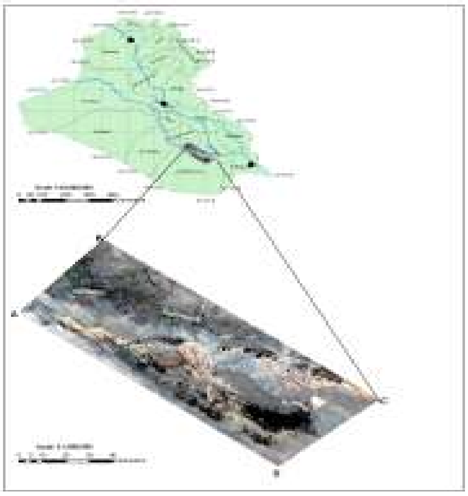


Figure-1: Location of the study area

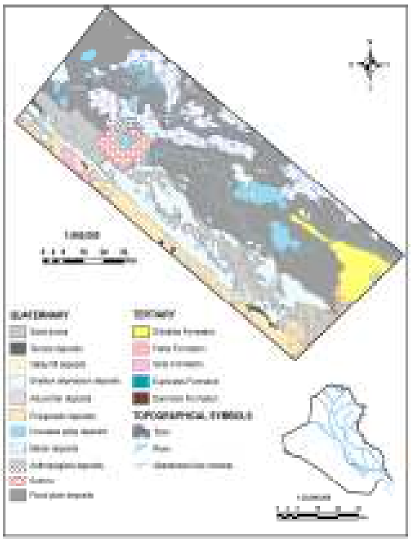


Figure-2: Digital-geological map of the study area (computerized scanning and digitizing, modified after GEOSURV, 1996).

Table-1: Deferent degrees of soil salinity, (Mohammad and Hussien, 1993)

Salinity class	Description	EC (ds/m)
So	V.Slightly saline	0-4
S1	Slightly saline	4-8
S2	Moderately saline	8-16
S3	Strongly saline	16-25
S4	v. Strongly saline	25-50
S5	Extremely saline	>50

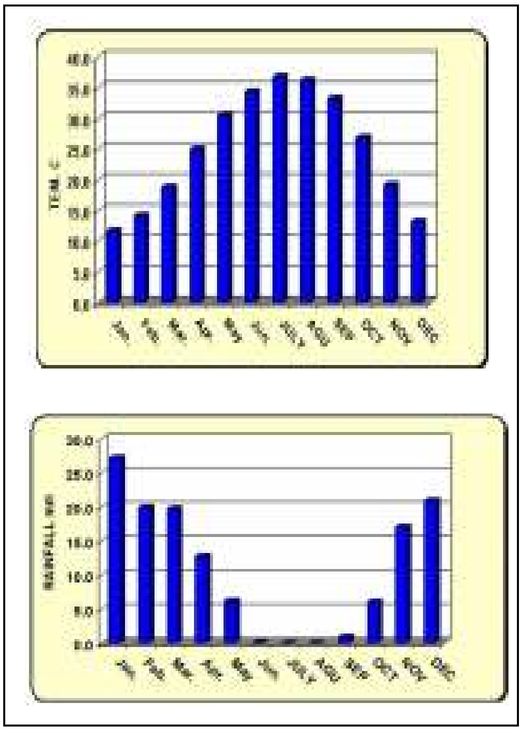


Figure-3: Some meteorological variables (monthly average) in the study area during the period (1970-2000), (Al- Khateeb and Capaigian, 2007)

MTHODOLOGY

The study has been based on three scenes of each of Landsat MSS, TM and ETM+ for the period (September) 1972, (September) 1990 and (March) 2000, respectively. Generally, these images are of good qualities, clouds–free, corrected geometrically, registered according to the orbit parameters, and identified by Lat / Long corner coordinates. UTM projection and datum WGS 84 have been used as the unified projection parameters. Creation of image indices have been derived and tested by using the professional ERDAS (8.5) and ENVI (3.6) softwares. All the created image indices have been registered and loaded as input data to ArcGIS 9.1 software as information layer.

The available previous data measurements of salinity elements for the samples that were examined during 1993-1994 have been prepared (11samples of spring water, 32 soil profile of drill rig, and 20 borehole) of the top soil depth 0-20 cm. And then they have been managed, integrated, and evaluated with the image output geo-statistically.

All the integrated data have been typed in a database file, loaded to ArcGIS, and then linked in order to maintain the association between the information layers, images, and tabular files. Regression-kriging method has been used to map the topsoil EC (ranging (from 3 to over 170 dS/m); it is a hybrid geostatistical method that combines a form of regression model with simple-kriging of the regression residuals.

Overlaying of all integrated images and information layers have been conducted to indicate the band that contain the most information in regard to the degree of salinity, as well as it has been conducted in order to estimate the spectral response of the different degrees of saline soil. These overlays are TM band-7, TM band-4, ETM band-7, ETM band-4, MSS-Green band, MSS-NIR, NDSI, SI, BI, SAR, and EC information layer.

A reconnaissance field trip to the study area has been carried out on 2008; photographs of the evidences have been acquired and documented for certainty and to support the results of the present research.

Creation of Image Indices

Brightness Index (BI) has been generated to separate the vegetation cover and to show the background of completely bare soil and (sparse and dense) canopy. Additionally, in order to enhance the saline zones and suppressing the vegetation, two indices of Salinity Index (SI) and Normalized Difference Salinity Index (NDSI) have been created depending on the spectral response of salt-affected soils (Odeh et. al., 1995):

$$BI = \sqrt{(Green^2 + Red^2)} \quad ...(1)$$

$$SI = \sqrt{Green \times Red} \quad ....(2)$$

$$NDSI = \frac{Red - NIR}{Red + NIR} \quad ....(3)$$

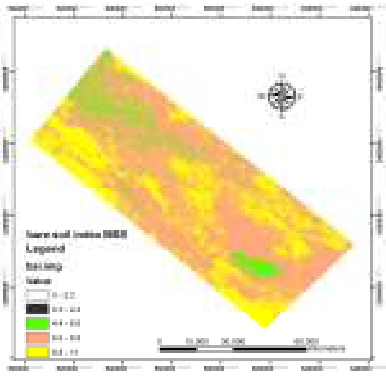
It is shown (Plate-1) that the most high index values are obtained to the north and northeast central section of the study area, while the lower values occurred in the vegetation location. The BI intervals indicate to the increasing of bare soil gradually. In addition, increasing of salt-affected areas has been distinguished in the both derived soil-salinity images (Plates-2 and 3); they depict the variation across the territorial extent of the image and reveal an increasing during the mentioned period.

Ancillary Data

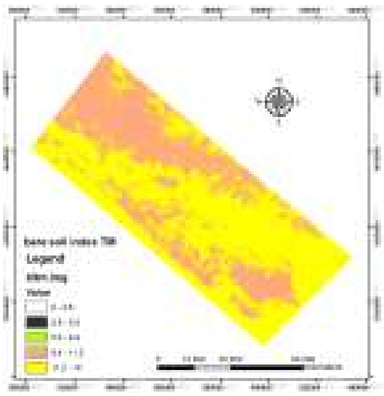
In order to study the contribution of soil salinity degree with the spectral response in Landsat images, Samples of the available previous studies (al-waaely et. al., 2002, al-basrawi, 2005, and Mohammad and Hussien, 1993) have been selected. From these data measurements, Sodium Adsorption Ratio (SAR) has been calculated by the following equation:

$$SAR = \frac{Na+}{\sqrt{\frac{Ca+Mg}{2}}} \quad ...... (4)$$

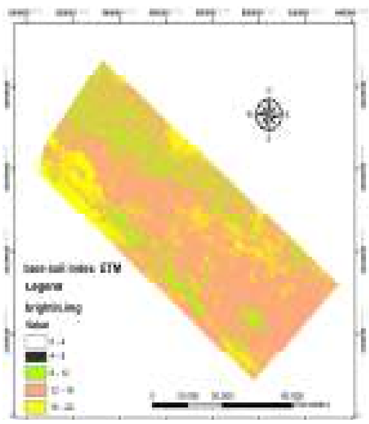
Then, the summary statistics that is shown in Table (2) indicates that Na+, Mg+2, and Cl− are the dominant ions, and the mean EC values is 41.14. Thus, according to the soil salinity classes (see Table-1); the soil in the study area is described as very strongly saline. In addition, a significant positive correlation between SAR and EC values (Figure-4) is evident (r = 0.797) and indicates that there is greater soil salinity with increasing Na+ content. Accordingly, many information layers of the salinity elements have been created as shown in Figure (5).



1972

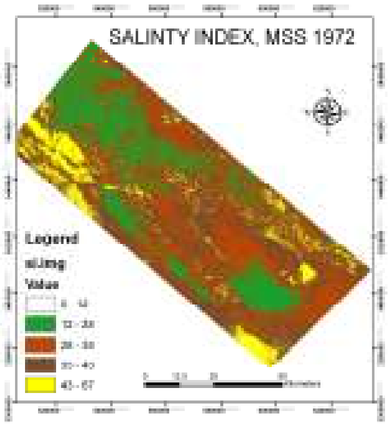


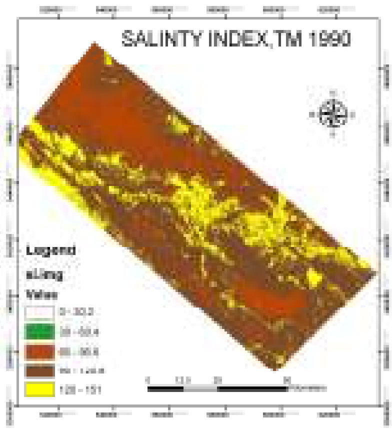
1990



2000

Plate-1: created Brightness index (BI) for the periods 1972, 1990, and 2000





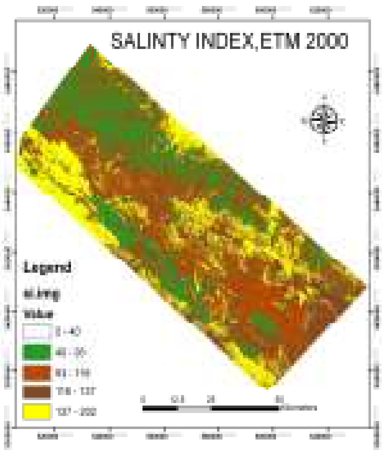
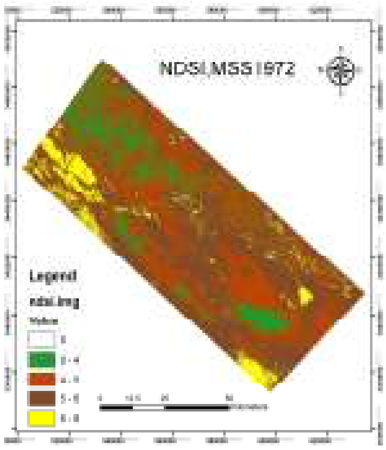
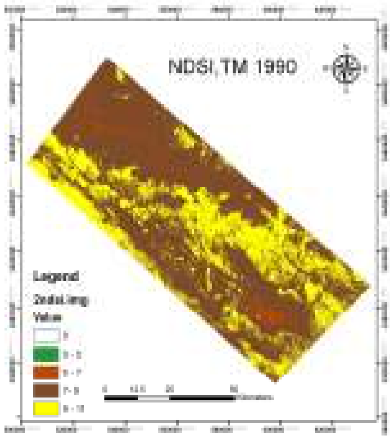


Plate-2: created salinity index (SI) for the periods 1972, 1990, and 2000





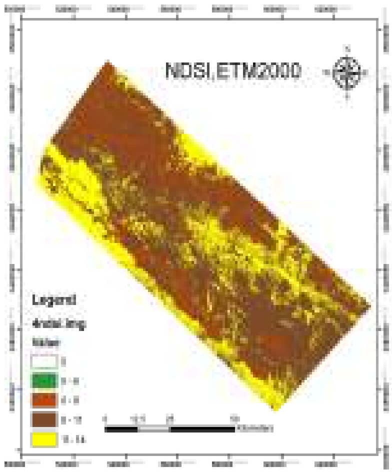


Plate -3: NDSI images for the period 1972, 1990, and 2000

Table-2: Statistic values of the salinity elements in the study area

Variable	Min.	Max.	Mean	Stand. Devi.
Ca	26.00	3720.00	445.41	508.40
Mg	21.96	1264.00	219.54	180.33
Na	7.57	20010.00	1040.69	2556.65
HCO3	0.00	156.00	42.59	47.33
Cl	14.39	39582.00	1793.53	5039.70
SO4	1.44	2740.00	1077.37	1026.83
PH	6.20	8.05	7.51	0.47
EC	2.86	170.00	41.14	48.14
SAR	2.44	77.35	18.67	18.90

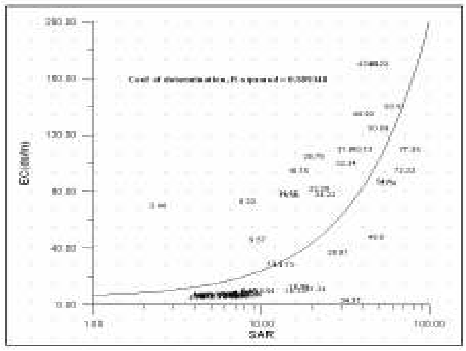


Figure-4: The relationship of EC with SAR

Integration and the Best Band Combination

The spectral reflectance of saline soils and other categories that cover the study area have been obtained from six image bands of 1990 (Figure-6). Generally, it can be observed that the spectral response increases with increasing salts content at the terrain surface. In addition, there is a spectral response contrast between Visible and NIR bands and between NIR and MIR band in salt existing soil. So, these effective band intervals have to be considered to differentiate the background of completely bare and salt-affected soil. Accordingly, the correlation coefficients have been computed between the soil variables, the spectral values, and the derived indices as illustrated in Table (3). It is shown that the highest correlation coefficient 0.501 of the observed EC values is obtained in MID-IR bands but in a close magnitude with NIR. As well as, the created NDSI, SI, and BI have the highest correlations of 0.812, 0.843, and 0.875 respectively with MID-IR. Subsequently; for each salinity level, the mean spectral brightness value and the spectral confidence limits have been computed from the mentioned overlaid image bands as shown in the Table (4). It is shown that within each separated date there is a harmonious response of the spectral value in each of the two bands those have been depended to detect each salinity degree.

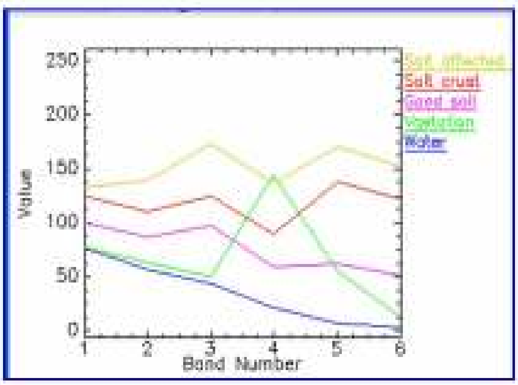


Fig-6: Reflectance curves of the salt content soils and other categories in the study area.
Note: The series number of band 6 indicates to the band-7 (2.1-2.35µm)

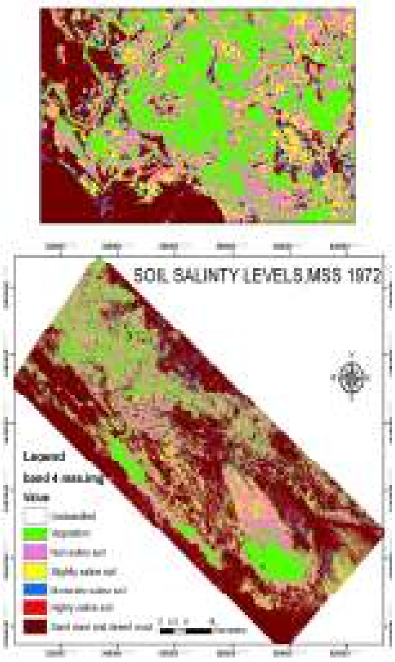
Spatial and Spectral Salinity Levels:

As a result of above analysis, the spectral values in regard to the salinity degree have been extracted and classified into four salinity levels (Plates-4) in addition to the desert crust and sand dune category which mainly occur in non-saline soil and show very high spectral response reach in some location to more than 250 . It is illustrated that most of the moderately and highly saline soils are restricted to the north and northeast central section of the study area. And in the low-lying plain, it is characterized by flood plan deposits of Mesopotamian plan. In addition, patch to the west and southwest of the study area is largely occupied by sand dunes and other high –lying desert crusts deposits. Moreover, increasing of the spatially predicted saline-affected areas is illustrated during the addressed period; it is shown that slightly and moderately saline soil are increased rapidly during 1972-1990, and the highly saline soil is increased during 1990-2000. This spectral-classified salinity level agrees with the Kriging presentation of EC values (3 to over 170 dS/m) that is shown in Figure (7). Both the predicted image data and the geostatistical EC values show some large coherent patterns of soil salinity.

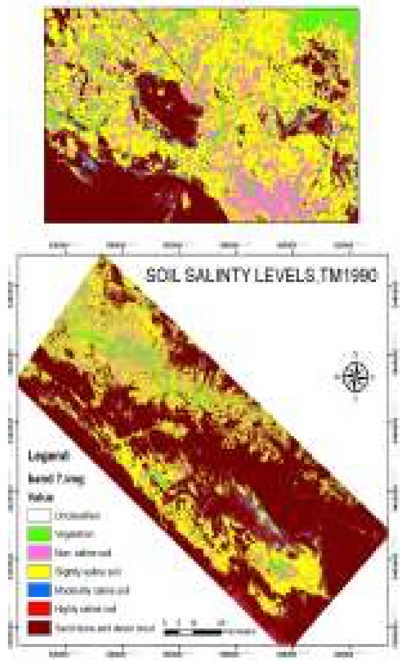
Table-3: Correlations among the derived indices, soil variables, and spectral response.

	NDSI	SI	BI	Band 7	Band 4	SAR	EC dS/m
NDSI	1.000						
NDVI	-0.190						
SI	0.829	1.000					
BI	0.794	0.859	1.000				
BAND 7	0.812	0.843	0.875	1.000			
BAND 4	0.642	0.699	0.631	0.783	1.000		
SAR	0.198	0.421	0.387	0.382	0.388	1.000	
EC dS/m	0.239	0.419	0.42	0.501	0.416	0.797	1.000

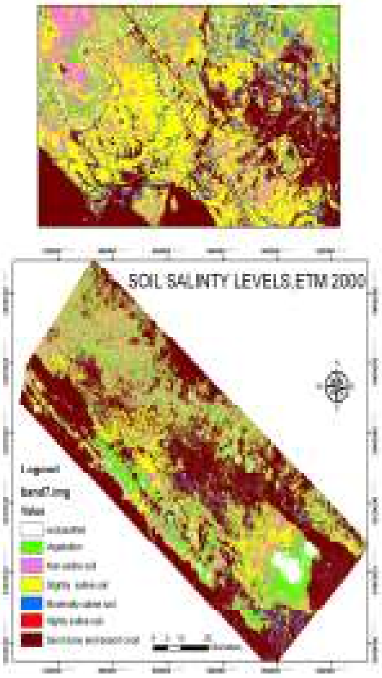
Soil salinity level	1972				1990				2000			
	Brightness in Green Band		Brightness in NIR		Brightness in NIR.		Brightness in MIR		Brightness in NIR.		Brightness in MIR	
	average	Confidence limits	average	Confidence limits	average	Confidence limits	average	Confidence limits	average	Confidence limits	average	Confidence limits
Non-saline	27.5	26-29	27.5	26-29	61.5	59-64	58.5	55-62	76	74-78	48	41-55
Slightly saline	31.5	30-33	32	30-34	66.5	65-68	72	63-81	82	79-85	68.5	56-81
Moderately saline	35.5	34-35	36.5	35-38	71	69-73	83.5	82-85	89	86-92	90	82-98
Highly saline	36.5	36-37	40	39-41	75	74-76	87	86-88	96	93-99	103	99-107
Sandy soil and desert crust	54.5	38-71	53	42-64	90.5	77-104	107	89-125	145	100-190	134	108-160



(a): Based on Green-Band, 1972



(b): Based on Band-7, 1990.



(c): Based on Band-7, 2000

Plate-4: Multi-date spectral soil salinity levels for all the study area and zooming to the NW central section (a), (b), and (c)

EVALUATION AND PREDICTION

Two dimensional spaces scatter plot that is shown in Figure (8) indicates that the correlation pattern of EC values versus the related spectral response is contributed to the values above 28 dS/m within two trends. This contribution represents the points of strongly and extremely saline soil. So, two regression curves for these effective sites show correlation coefficient of 87% (Figure-9) which is remarkably increased to 95% (Figure-10) in the sample sites above 70 dS/m. It is indicated that the high EC values are related to the response within the intervals of (72-113) and (201- 235) values respectively; in case r=87% the developed mathematical approach is:

$$Y = 0.56681 * X + 22.252 \ldots \ldots (5)$$

Where Y: is the estimated EC salinity value, and X: is the detected spectral response in the image. In order to identify the estimated relationship in a manner that satisfies the fundamental concepts in GIS operations, a quantitative Boolean expression has been developed and applied in the following construction:

((([\"REFLCTANCE\"] > 72) AND
([\"REFLCTANCE\"] <= 113))) OR
([\"REFLCTANCE\"] >201) AND
([\"REFLCTANCE\"] <=235)) OR
(([EC-DS/M] >=28)

Where (REFLCTANCE: is the spectral response in the images, and (EC-DS/M): is the electrical conductivity value. The results of the proposed expression have been illustrated in the integrated image (plate-5); the specified sites within the effective zones are highlighted, it meets the criteria in the derived equation (5) that have been developed. Moreover; the more accurate equation which is developed and promoted by more effective correlation (r= 95%) is:

$$Y = 4.66295 * X + 357.15 \ldots \ldots (6)$$

It suggests a good correlation when Y > 70 dS/m, where the best estimation is obtained.

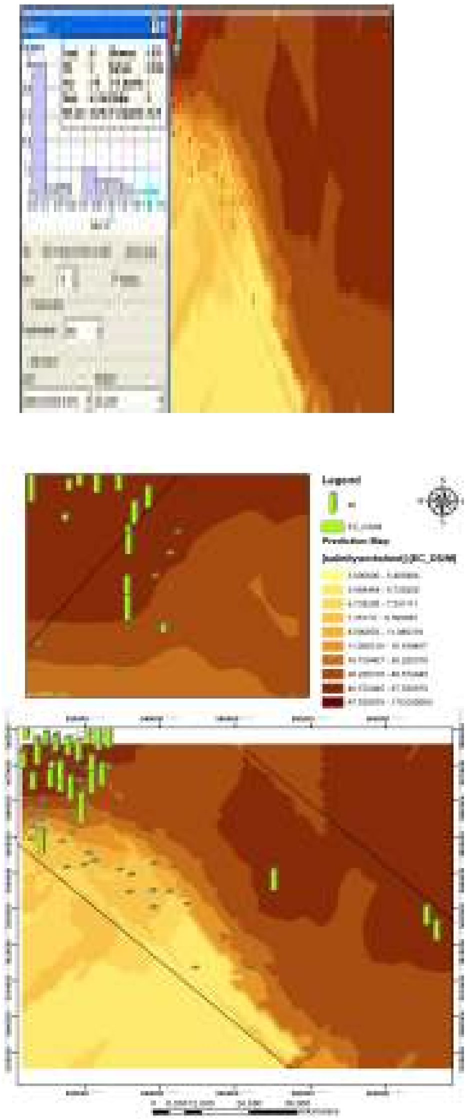


Figure-7: Geostatistical distribution of EC values in the study area, with two zooming

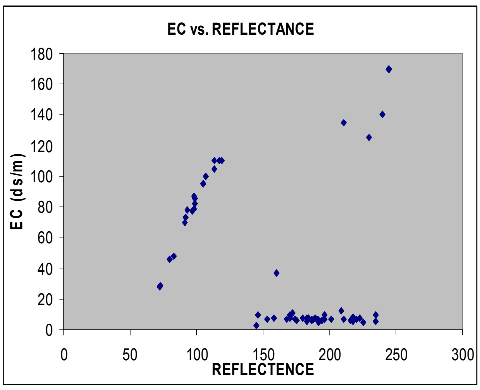


Figure-8: scatter diagram of image- spectral response (MID-IR) and EC values

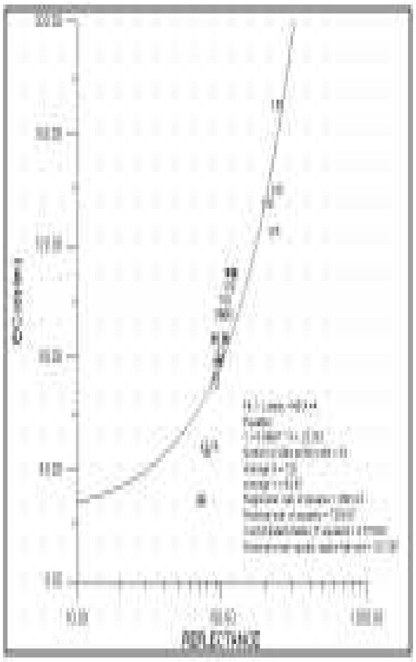


Figure-9: EC values of saline soil related to the spectral response values within effective relationship zone

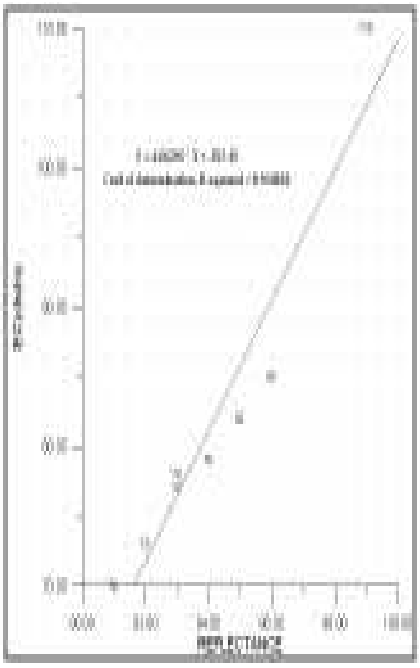


Figure-10: EC values above 70 ds/m related with the spectral response values within more effective relationship zone

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DISCUSSION OF THE RESULTS

Three scenes for each of Landsat MSS, TM and ETM+ for the period 1972, 1990 and 2000 respectively have been used to create image indices of BI, SI and NDSI depending on the spectral response of the soil. These indices reveal an increasing of bare soil and grassland extent and salt-affected area during the mentioned period. Some relatively ambiguity response occurred in NDSI of 2000; that is because the acquired image of this period was recorded during the wet season (March/2000), while the others were recorded during (September) the end dry season (see Figure-3). It means, moisture content leads to decrease the spectral response in the highest extent of red and near infrared bands that have been used to create NDSI image, but still this image has the most index values comparing with the image indices of the earlier dates. Thus, in case of avoiding the potentiality of moisture content the visible band is more accurate than NIR to detect the brightness values of saline soil.

Four salinity levels have been separated into non-saline soil, slightly saline soil, moderately saline soil, highly saline soil and desert crust and sand dune, where multi-date processing for these classes detects gradually increasing of soil salinity during the addressed period. Integration of image output and the available ancillary data measurements indicates that highly spectral response in Landsat images is contributed to the strongly and extremely saline soil. Furthermore, regression curves for the effective salinity sites shows correlation coefficient of 87% when EC values are above 28 dS/m and it reaches to 95% when soil salinity increases to more than 70 dS/m EC values. But generally, low or some-times non-significant correlation between saline soil and spectral response, may be due to the vertical variation in soil salinity within the top layer; the ground truth salinity data have been based on the average of 0-20 cm, while the soluble salt are usually accumulated in the uppermost horizon.

In the other hand some surface soil conditions such as gravely surface and crusted surface may hinder the reflectance of soils, or it may be contributed to the fact that spectral response is contributed to other salinity elements.

During the reconnaissance field trip to the study area on February 2008; sand encroachment from the west to the east and southeast was evidently observed cover the railway as shown in Figure (9), as well as increasing of grasses and herbs that usually grow and live in sabkha and saline soils was relatively distinct (Figure-10); they have been assigned and appeared as vegetation cover in created BI and SI images / 2000.

According to the personal meeting with the living people in the study area it is well evident that they depends heavily on producing and marketing salt in the study area as a vital source of income; they produce salt that accumulated in some playas and sabkha land (Figure-11).

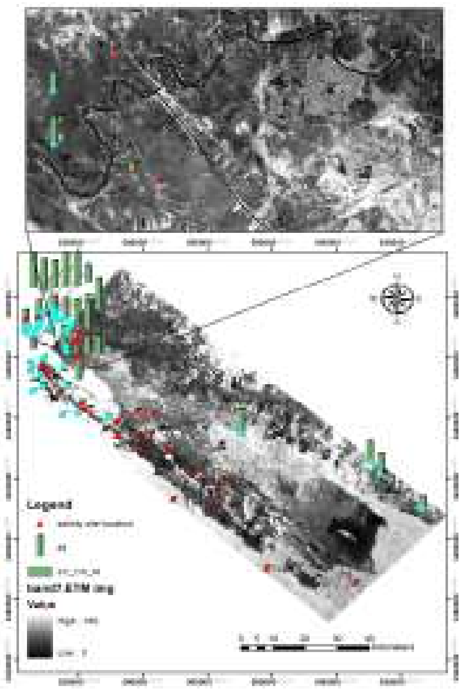

Plate-5: highlighted-selections (lighted bluish green dots) of Boolean expression in the effective zone of the study area and surrounding

CONCLUSIONS AND RECOMMANDATIONS

Created image indices of NDSI, SI, and BI are suitable processing to identify the spatial distribution of saline soil in the study area, and the integration of these indices with the ancillary data is accurate strategy that classifies different salinity levels in the term of spectral response. These detected classes are non-saline soil, slightly saline soil, moderately saline soil, highly saline soil and desert crust and sand dune**.** It is indicated that soil salinity in the study area has been increased gradually during the addressed period 1972, 1990 and 2000 respectively. The results highlight the incorporation of the EC relationship with Na+ content which provides a better and more objective indicator of soil salinity. As well as there is good contribution between EC and spectral response in Landsat images specifically in MID-IR which is considered the most accurate band to detect and evaluate soil salinity Mathematical approaches are established to estimate soil salinity level in terms of spectral response in Landsat ETM-7 images; they provide valuable information for soil management to conserve the natural resources. The reconnaissance field trip to the study area show good agreement of the observations and the estimated results of the present research.

In order to build up theories for proper assessment of soil salinity using digital remote sensing techniques; it needs the contribution of adequate image processing in the best band combination in addition to the ground truth data measurement. It is accurate and low-cost techniques to assess and monitor soil degradation processes in semi-arid areas.

The results and all the operation strategy are presented as information layers with their associated attribute documents; it means they are ready to operate as Environmental Information System (EIS) in a manner that satisfies the fundamental concepts of Geographic Information System (GIS). This proposed system depends on satellite images as the most important input data to the GIS, and it is ready to be imposed by other promoted required data for updating or any other environmental study in order to reduce the expense that is needed to construct other related study. So, it provides a tool easier to manage the immediate attention with greater monitoring.

Figure-9: Sand encroachment in the study area (Photographs of field trip, 2008)

Figure-10: Natural grasses in the study area. (Photographs of field trip, 2008)

Figure-11: Saline soils in the study area (Photographs of field trip, 2008)

REFERENCES:

1-Al-Basrawi, N.H., 2005. Hydrogeologicl and hydro-chemical study of Al-Nasria quadrangles (NH-38-3), Scale 1:250000, GEOSURV inter. rep. No. 2911

2-Al-Khateeb, A. G. and Capigian, A. O., 2007. Climatic changes and it's affect on geodynamic processes in Iraq during 1940-2000. GEOSURV, internal report. 40P.

3-Al-wa'aely, M.A., Al-dabbaj, A.A. and Mahmood, Q.A., 2002. Hydrogeological and hydrochemical study of Suq Al-Shoyokh (NH-38-7), Rep. No. 2806.

4-Araim, H.I., 1984, Regional hydrogeology of Iraq, GEOSURV Lib.unpub. report no. 1450. Baghdad, Iraq.

5-Buday, T., 1980. The regional geology of Iraq, stratigraphy and palegeography .V.I, Dar al-kutid, Pub1.house, Mousel, Iraq, 445p.

6-Epema, G.F., 1990. Effect of moisture content on spectral reflectance in a playa area in southern Tunisia. In: Proceedings of International Symposium of Remote Sensing and Water Resources, August 20–24, 301–308, Enschede

7-Everitt, J.D., Escobar, D.E., Gerbermann A.H., and Alanis, M.A., 1988. Detecting saline soils with video imagery Photogram. Eng. Remote Sensing. 54:1283–1287.

8-GEOSURV, 1996, Geological Map of Iraq, scale 1:250000. Baghdad, Iraq.

9-Hick P.T. & Russell W.G.R., 1990. Some spectral considerations for remote sensing of soil salinity. Australian Journal of soil research, 28(3), 417-431.

10-Jassim, S. Z. and Goff, J. C., 2006. GEOLOGY OF IRAQ. Dolin, Prague and Moravian Museum, Brno, Czech Republic.314 p.

11-karavanova, E.I., Shrestha, D.P., and Orlov, D.S., 1995. Application of remote sensing techniques for the study of soil salinity in semi arid Uzbekistan. Soil science department. Lomonosov, Moscow state university, 119899, Russia

12-Krasny,J. and Salim,T., 1982; Hydrogeology and hydrochemistry of Diwaniya- Samawa Area ,GEOSURV, Lib.Report no. 1335.

13-Mohammad, I. j. and Hussien, S. S., 1993. The soils of the Um-Al-Akaf-AL-Samawa area. State commission for irrigation and reclamation project. ministry of Irrigation –Iraq .report no. 41

14-Odeh I.O., McBratney A.B, Chittleborough D.J., 1995. Further results on prediction of soil properties from terrain attributes: heterotropic kriging and regression-kriging. Geoderma pp. 215–226.

15-Odeh, I. O. and Onus, A., 2008. Spatial analysis of soil salinity and soil structural stability in a semiarid region of New South Wales, Australia, Springer science +business media, LLC.

16-Orlov, D.S., Karavanova, E.I. and Pankova E.I. 1992. Effect of readily soluble salts on the spectral reflectivity of soils of the serosem zone. Eurasian Soil Science, 24 (1),104–118.

17-Panah S.K. and Zehtabian G.R., 2002. A Database Approach for Soil Salinity and Generalization from Remotely Sensed

18-Mapping Data and Geographic Information System. International Congress Washington, D.C. USA, 2002.

19-Shrestha, R.P., 2006.Relating soil electrical conductivity to remote sensing and other soil properties for assessing soil salinity in northeast Thailand. Land degradation and development.V.17 Issue 6, P 677-689.

20-Tripathi, N.K., Rai, B.K., and Dwivedi, P., 1997. Spatial modeling of soil alkalinity in GIS environment using IRS data.18 the Asian conference on remote sensing, Kualalampur, pp.A.8.1-A.8.6.