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Field Electrical Conductivity (EC) Mapping of a Selective Irrigated Units at Northern Al-Jazirah Irrigation Project, Iraq Using GIS and GPS Techniques

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ABSTRACT

The application of apparent electrical conductivity (ECa) to agriculture is due to the soil salinity measurement, which represents a problem in arid areas associated with irrigated agricultural land and shallow aquifers.

The purpose of this paper is to apply the modern geo-referenced technology by using LandMapper ERM-02 device and GPS receiver to measure manually the soil ECa of (50) sites in the irrigated units N15 and N16 at Northern Al-Jazirah Irrigation Project. The remote sensing data, the map of Northern Al-Jazirah Irrigation Project and GIS are utilized to support the analysis and the spatial information of the measured ECa data. A kriging interpolation method is adopted to predict the ECa values at non-surveyed location and to create the final soil ECa map. The results of the field measurements show that the ECa in the study area varies between 2.66 to 51.74 dS/m. The results of the geostatistical analysis and the regression function of the ECa data indicate a decrease in the errors associated with the soil ECa interpolated map with increasing the values of soil ECa in the study area.

However, the studied method is less accurate than the laboratory based soil sample analysis method, but for a quick estimate of soil salinity, this method is highly satisfied.

Keywords: Apparent electrical conductivity (ECa), GIS, LandMapper ERM-02, GPS, Kriging Interpolation

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رسم خارطة الايصالية الكهربائية لوحدات اروائية منتخبة في مشروع ري الجزيرة الشمالي باستخدام تقنيات نظم المعلومات الجغرافية والنظام العالمي لتحديد المواقع

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الملخص

تعد الايصالية الكهربائية من أهم المقاييس التي يعتمد عليها في تحديد ملوحة التربة التي تعتبر من أهم المشاكل في تحديد الإنتاج الزراعي وتدهور التربة للمشاريع الاروائية في المناطق الجافة وشبه الجافة.

تهدف الدراسة الحالية الى تطبيق التقنيات الحقلية الحديثة في دراسة ملوحة التربة من خلال قياس الايصالية الكهربائية الظاهرية (ECa) للتربة باستخدام جهاز (Land Mapper ERM-02) وجهاز النظام العالمي لتحديد المواقع (GPS) لخمسين موقع تربة ضمن الوحدات الاروائية (15N و 16N) في مشروع ري الجزيرة الشمالي في ربيعة، محافظة نينوى، العراق.

اعتمدت معطيات التحسس النائي وخارطة المشروع الاروائي وبرمجيات نظم المعلومات الجغرافية في دعم التحليل الإحصائي والمعلومات المكانية لبيانات (ECa) المقاسة حقليا. حيث طبقت طريقة (Kriging) في التحليلات الإحصائية لبرنامج (ArcGIS 9.3.1) للتنبؤ عن قيم (ECa) في منطقة الدراسة كلها باستخدام القيم المقاسة فعليا لإنشاء خارطة التوصيل الكهربائي النهائية لمنطقة الدراسة.

أظهرت نتائج البحث أن قيم (ECa) تتغير من 2.66 dS/m الى 51.74 dS/m. كما أظهرت نتائج التحليلات الإحصائية ودالة الانحدار لقيم التوصيلية (ECa) إن مقدار الخطأ في نتائج التنبؤ لخارطة الايصالية الكهربائية النهائية يقل بازدياد قيمة (ECa) للتربة.

ان الطريقة المستخدمة في البحث هي طريقة حديثة للقياس الحقلي للايصالية، ويمكن ان تكون هذه الطريقة اقل دقة من القياسات المختبرية، ولكن لغرض تخمين مقدار تأثر التربة بالملوحة حقليا فان هذه الطريقة تعتبر مقنعة بحسب نتائج البحث والبحوث العالمية الأخرى.

الكلمات الدالة: الايصالية الكهربائية الظاهرية، برمجيات نظم المعلومات الجغرافية، النظام العالمي لتحديد المواقع، طريقة (Kriging)، جهاز قياس الايصالية الكهربائية.

INTRODUCTION

Soil salinity is one of the greatest problems which affects both soil properties and plants growth and their production.

Salinization is found in the soil constituents of the soil, as a case in the aggregated saline strata, which is formed at different geological times and which may cause saline accumulations on the surface of the soil due to faulty agricultural processes and incorrect irrigation methods (Daood, 2007). The increase of the salinity in the soil affects in two directions: the first is the inverse proportion between increasing the concentration of salts in the soil and the ability of the plant to extract water from the soil, which leads to the plant wilt and death, while the second one is the imbalance in nutrition of the plant, which leads to increase concentration of toxic ions in the plant (Na, Br and Cl ions) (Mulders, 1987).

Soil salinity can be identified by measuring the electrical conductivity of the solution extracted from the saturated soil paste and is usually given by the abbreviation (EC) which expresses the existing negative ions (Anions) and positive ions (Cation) in the soil. Electrical conductivity of soils also varies according to the amount of moisture held by soil particles. Sands have a low conductivity, silts have a medium conductivity, and clays have a high conductivity (Robert et al., 2008).

One of the practical application of the EC is the measure of the apparent electrical conductivity ECa. ECa of the soil is a function of physico-chemical properties. Consequently, the field measurements of ECa can be used for mapping representation of the spatial variation of several soil properties as well as to improve the resolution and to reduce the cost of producing soil maps (Jurgen et al., 2009). The resulting soil ECa maps can be used to facilitate the operation of the management areas that reflect clear trends in soil characteristics and crop service. Areas can be sampled and processed independently (Mankin et al., 1997). Nowadays, the use of modern Veris ECa field measurement technologies (figure (1) is particularly well suitable for establishing a map of spatial variability of saline soil properties. These technologies indicate the influence of several soil properties that contribute to the electrical conductance of the bulk soil (Corwin and Lesch, 2005).

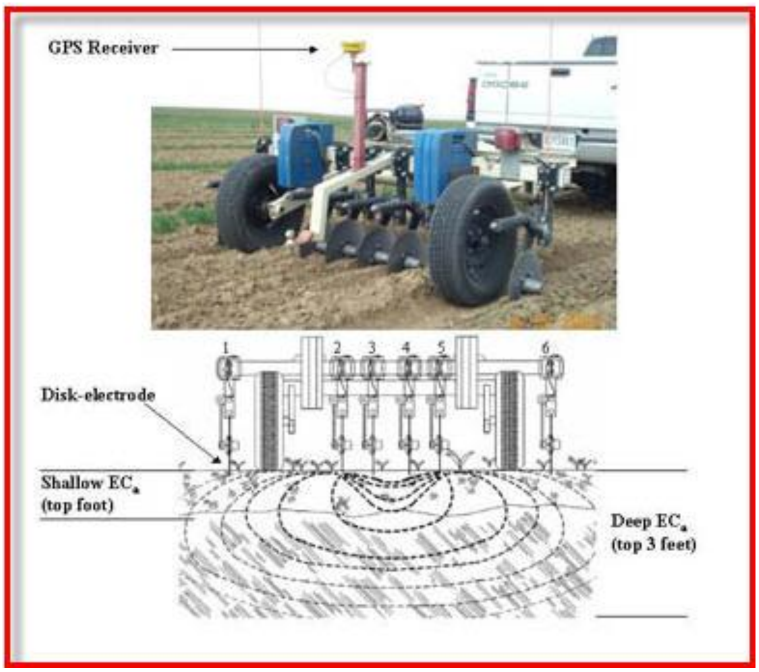

Fig. 1: Veris ECa field technology (Farahani , 2013).

In the present study, the soil ECa of (50) samples for the units N15 and N16 at the Northern Al-Jazirah Irrigation Project have been measured manually using the four-electrode probe methodology with a direct Global Positioning System (GPS) coupling.

The GPS coordinates are projected to WGS84_UTM_Zone38N. The integration of remote sensing data and the Geographical Information System (GIS) are used to create the ECa soil maps of the study area. The resultant maps provide vital information to the growers by identifying the salt-affected areas. The accuracy of the resultant maps depends on the GPS and LandMapper ERM-02 readout in addition to the interpolation method applied in the study.

STUDY AREA AND DATA COLLECTION

The study area is about (1.968 km^2) located in the northwestern of Mosul city between Latitude 36^0:41':18.41" to 36^0:42':16.73" N (N: 4063958.1 to 4065707.7m) and Longitude 42^0:11':29.05" to 42^0:12':19.86" E (E: 249096.5 to 250328.7m) in the Northern Jazirah Irrigation Project (Rabe'ea) as shown in figure (2).

The selected irrigation units N15 and N16 in the present study are thought be a good example for the salinity-affected area. The units are located approximately in the center of the Northern Al-Jazirah Irrigation Project.

The ECa of soil samples were measured on 16^{th} April 2013 in-situ in 50 locations with an average intervals of 150m in both irrigated units using the LandMapper ERM-02 probe [http://www.landviser.com/prod03.html, 2013] (figure (3). The spatial coordinates of each sample were recorded using a GPS receiver (GARMIN-GPSMAP76CSx) with accuracy of (±3m).

METHODOLOGY AND PROCEDURES

The field measurements started by setting the LandMapper ERM-02 to readout ECa parameter in Siemens per meter (S/m), then the reading values are converted to the unit deciSiemens per meter (dS/m) by multiplying by 10. After that, four-electrode probe is placed inside the soil surface and the conductivity value is read from the digital display as shown in figure (4). The figure illustrates the schema of current distribution in soil from four-electrode probe, AB electrodes induces current into soil, while the change in the voltage is measured across the MN electrodes resulting in simultaneous ECa readout. The distance between AB electrodes is 25 cm. ECa measurements are performed in a surface soil layer of the depth of 10 cm, which is set by varying the size of a four-electrode probe. The electrodes were made from corrosion-resistant and conductive metal that must be small enough to support itself when inserted to a depth of 10 cm or less.

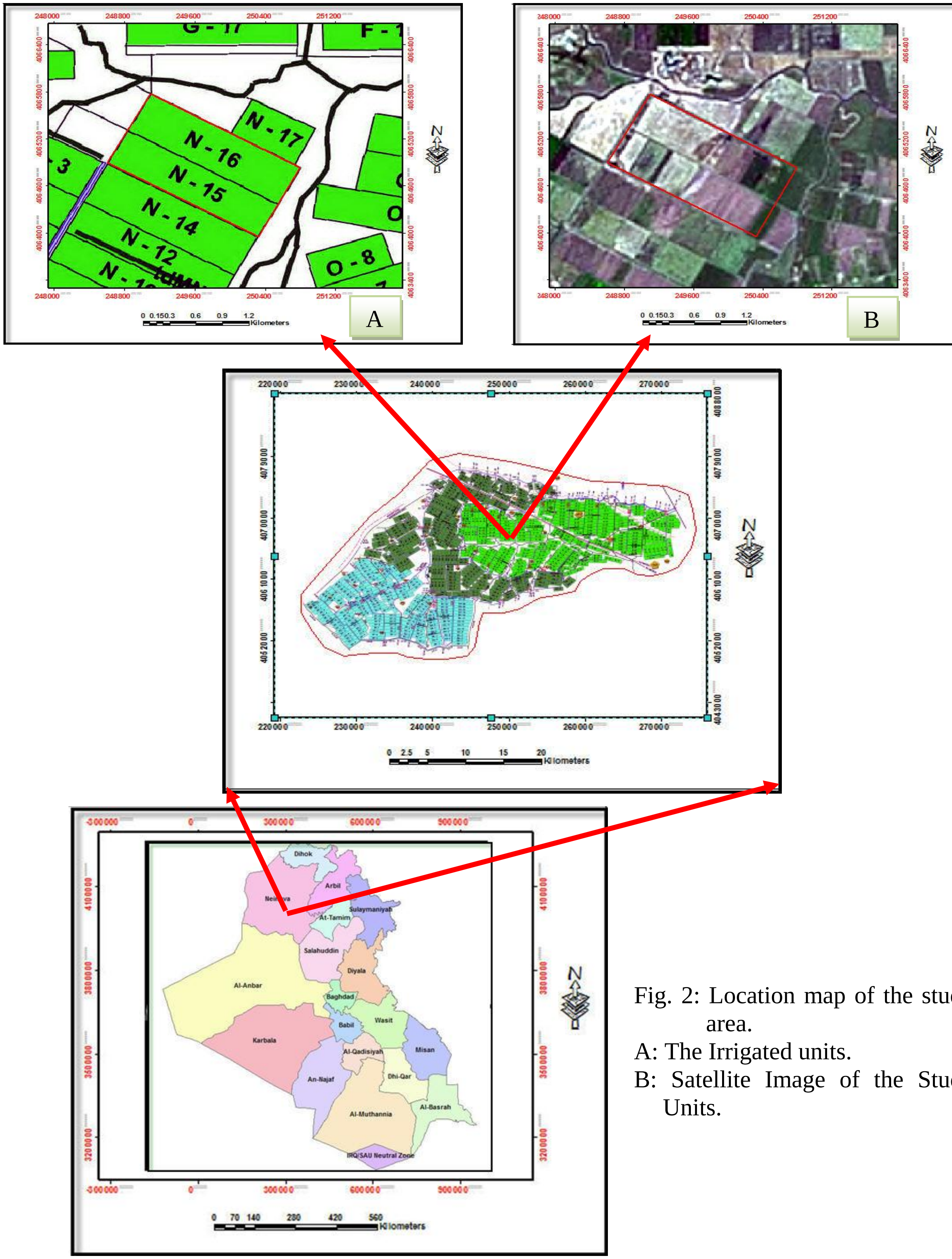

Fig. 2: Location map of the study area.
A: The Irrigated units.
B: Satellite Image of the Study Units.

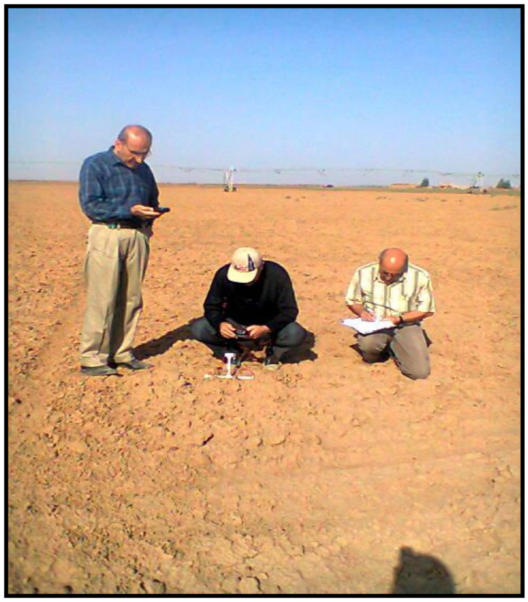

Fig. 3: Soil ECa in-situ measurements

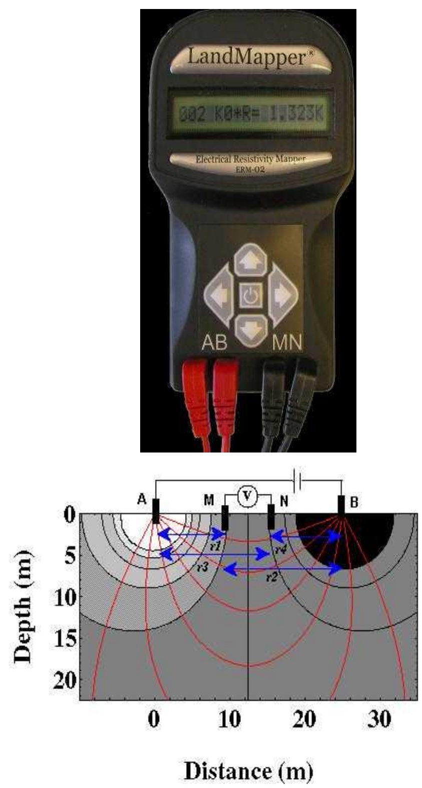

Fig. 4: Schema of current distribution in the soil by the LandMapper ERM-02 four-electrode probe(from http:// Landviser.net/web_send/10, 2013).

This field ECa measurements method is less accurate than the laboratory based soil sample, but for the purpose of estimating salinity in soil, this method can be adopted (Farahani et al., 2013). Therefore, the available sufficient reference samples, give the EC-probe the ability to perform many comparative measurements in a certain area in a short time.

A QuickBird satellite image acquired in 2008 (resolution of 60cm) and the map of the Northern Al-Jazirah Irrigation Project covering the study area and the surrounding areas have been used in the present study to locate the spatial location of the study units and to illustrate the locations of the measured soil samples by the LandMapper ERM-02 as shown in figure (5).

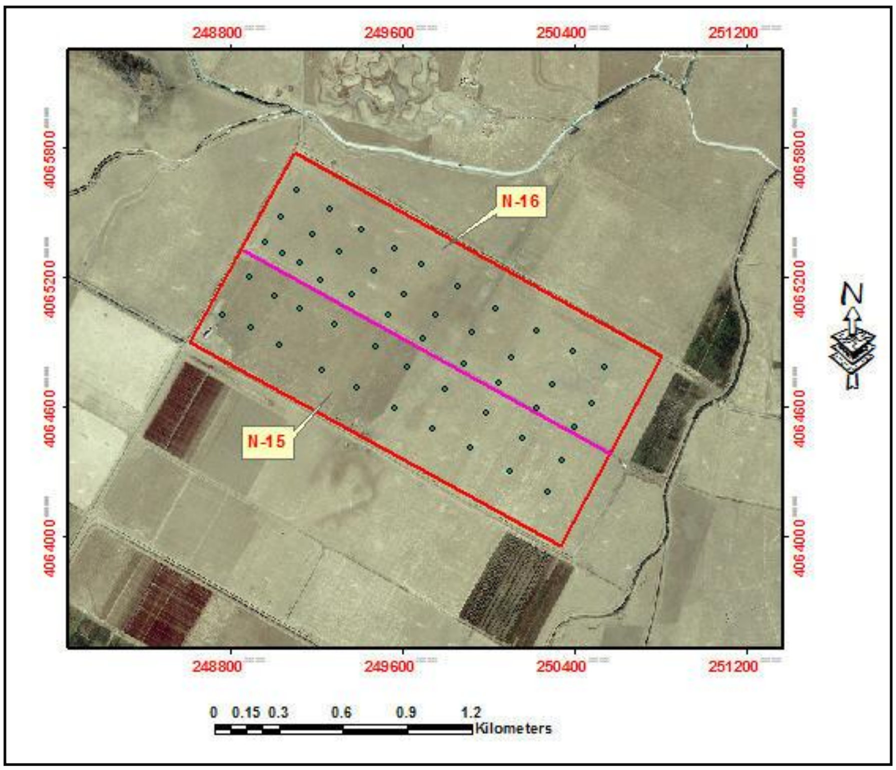

Fig. 5: ECa soil sample locations at the unites N15 and N16 using Quick bird image.

ArcGIS9.3.1(Spatial Analyst Extension) is used to create the surface map of the ECa according the GPS readout locations for each sample. Spatial analyst uses statistical methods to predict the ECa values at non-surveyed location. This procedure is called interpolation, and the ArcGIS Package provides several options to create surface raster map (Shahab, 2008). Ordinary kriging interpolation method is applied in the present study. This interpolation is a linear unbiased estimation method that provides estimates at unsampled locations based on the surrounding data collected at the measured locations of the ECa (David, 2007). Therefore, this method will provide information at any point in the irrigation unit of N15 and N16. The methodology presented here in the study focuses on mapping soil ECa in selected irrigated agricultural units but can be extended to any soil or plant parameters obtained experimentally in any grid pattern.

RESULTS AND DISCUSSION

The entire study area is mapped manually on parallel paths with approximately 150m apart. Table (1) lists the locations and the field measured ECa values for the irrigated units N15 and N16. Figure (6) shows the histogram distribution and the summery statistics of the ECa measured values.

Table 1: The locally measured values of ECa for the units N15 and N16.

Sample no.	Easting m	Northing m	ECa (dS/m)	Sample no.	Easting m	Northing m	ECa (dS/m)
1	249107.8	4065609.5	10.64	26	249532.3	4065029.1	10.64
2	249262.9	4065515.6	12.52	27	249699.7	4064899.2	3.55
3	249409.9	4065425.8	8.51	28	249883.4	4064801.2	2.66
4	249573.2	4065323.7	21.28	29	250054.8	4064707.3	21.28
5	249683.4	4065254.3	10.64	30	250230.3	4064609.3	14.18
6	249846.7	4065144.2	11.82	31	250409.9	4064491	8.51
7	250022.2	4065062.5	7.09	32	250344.6	4064352.2	6.08
8	250214	4064948.2	5.32	33	250160.8	4064450.2	28.37
9	250401.8	4064853.4	3.55	34	249993.6	4064580.8	25.03
10	250536.5	4064772.7	30.40	35	249793.6	4064682.8	32.73
11	250499.8	4064613.5	23.64	36	249618.1	4064793.1	14.18
12	250307.9	4064707.4	51.19	37	249471.1	4064891	8.51
13	250099.7	4064825.7	35.46	38	249283.3	4065005.3	6.08
14	249920.1	4064940	7.09	39	249124.2	4065050.2	5.32
15	249760.9	4065033.9	5.32	40	249001.7	4065111.5	4.26
16	249613.9	4065107.3	4.26	41	248887.4	4065209.4	8.51
17	249454.8	4065250.2	10.64	42	248744.1	4065021.7	38.68
18	249283.3	4065323.7	35.46	43	248895.6	4064956.4	25.03
19	249164.9	4065397.2	30.40	44	249018	4064882.9	21.28
20	249022.1	4065487	23.64	45	249230.3	4064772.7	51.74
21	248960.8	4065364.5	51.74	46	249381.3	4064682.9	42.55
22	249046.6	4065315.5	21.28	47	249548.7	4064597.1	14.18
23	249120.1	4065262.5	7.09	48	249756.9	4064491	8.51
24	249218.1	4065189	4.26	49	249911.2	4064409.4	7.09
25	249369.1	4065131.1	3.04	50	250099.8	4064315.5	10.64

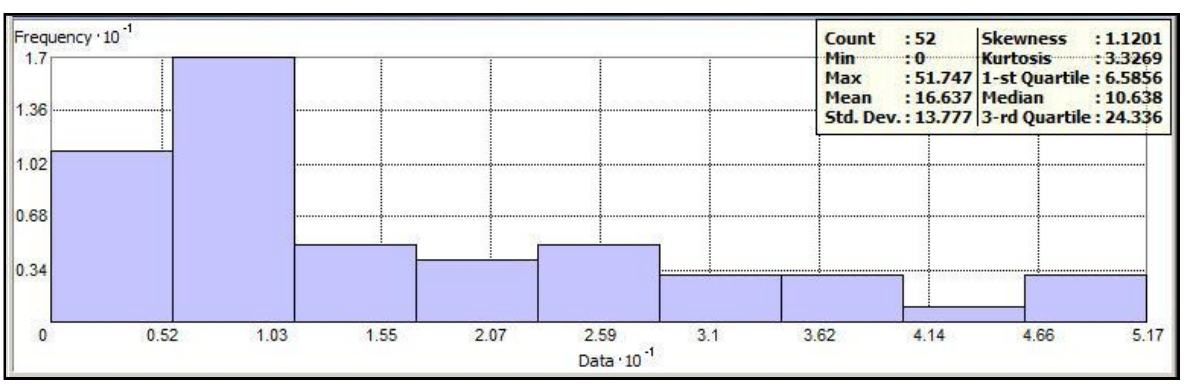

Fig. 6: Histogram and the statistics summery of the ECa.

The surface graphical representation of soil ECa data points listed in table (1) is created by using the Kriging interpolation through the ArcGIS 9.3.1 software package. The applied interpolation method has been classified the ECa map of the study area into (9) graduated color classes as shown in figure (7) below.

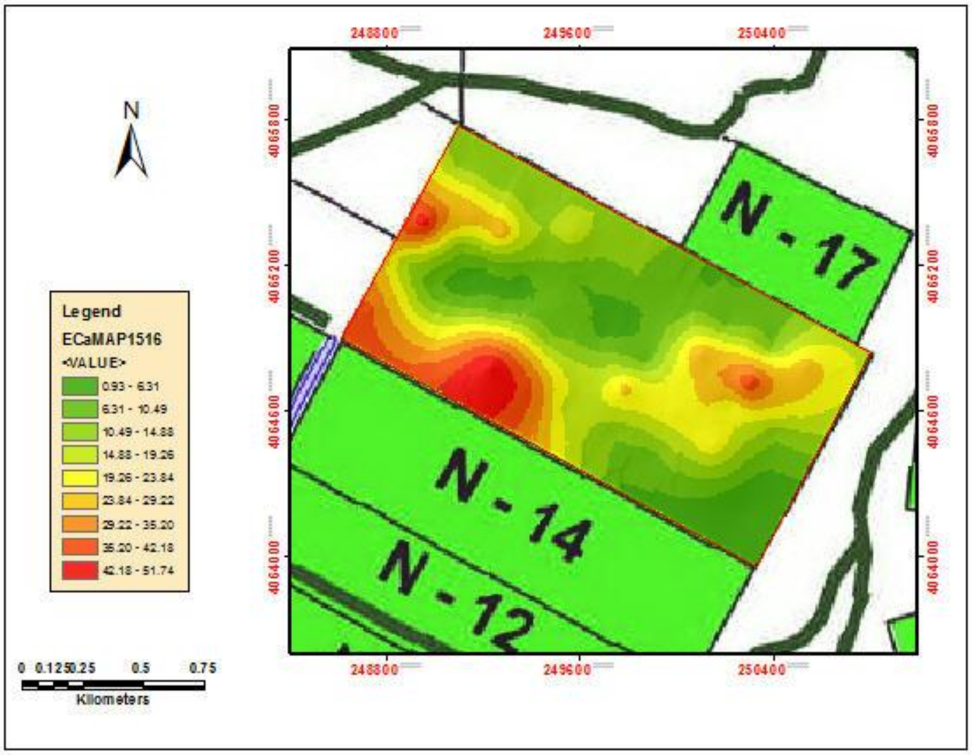

Fig. 7: A colored classes map of soil ECa overlay on the Northern Al-Jazirah Irrigation Project map.

The differences in the soil ECa values are caused by differences in the soil salinity related to the non-regulated irrigation operations, that in turn led to a high level of ground water. The difference in the ECa could also be caused by another physical and chemical properties of the soil, as well as to land use and the type of crop grown in the study area. The output soil ECa map shown in figure (7) can simply show how soil salinity changes across the irrigated units N15 and N16.

The variation in the ECa of soils also varies depending on the amount of moisture held by soil particles, then it can classify the soil in the study area according to its particles size and texture (Robert et al., 2008). And so, the soil can be classified according to the in-situ measured ECa, i.e. sands have a low conductivity, silts have a medium conductivity, and clays have a high conductivity.

The ArcGIS9.3.1/ geostatistical analyst extension is used to analyze and calculate the predicted error of the measured soil ECa data. Figure (8) shows the relation between the measured ECa data and the predicted error which was obtained by the following regression function:

$y=-0.995*x+16.267$ where; y=Error, and x= measured

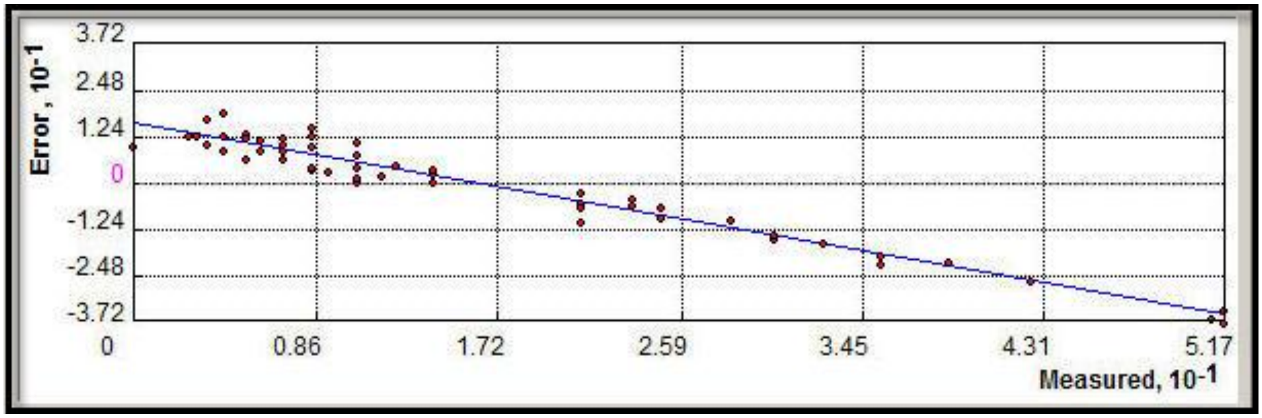

Fig. 8: Errors versus measure soil ECa

The regression function is obtained simultaneously by the Geostatistical analyst extension. Figure (8) shows that the errors associated with the soil ECa interpolated map explained in figure (7) decreased with increasing values of soil ECa in the study area. Statistically, the figure (8) shows that, the error values fluctuated around the regression line and distributed at the same time about the mean, this behavior is an indication of the stability in the data and thus give the best results in the statistical meaning of the measured values [William and We, 2006]. Table (2) listed the detail statistical propertied of the figure (8).

Table 2: Statistical Properties of the Measured ECa

Statistical Properties	value
Mean	-0.1207
Root Mean Square	13.96
Average Standard Error	14.1
Mean Standardized	-0.01156
Root Mean Square Standardized	0.9956

However, it is necessary to study the other soil properties that most significantly influence the ECa measurements in the study area in order to establish the soil properties that are influencing crops. The physical and chemical analysis of the soil samples by the modern measuring devices provide the spatial data for determining the soil properties that affect crops products causing within-field yield variation.

CONCLUSION

The results presented in this paper show the feasibility of using geo-referenced soil ECa measurements in the field using LandMapper ERM-02 and GPS receiver. It is clear from the results the importance of the Kriging interpolation method and regression function to determine the quality of the resulting soil ECa map of the study area, and to show the errors of the predicted ECa data. It is concluded that, the EC correlates strongly to soil particles size and texture. Also, presence of spatial relationship between satellite imagery features, GIS and ECa data measured by the modern techniques is very important to identify the graduated color classes of the ECa map.

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