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Application of Geo-information Techniques in the study of Soil Properties as Indicators of Soil Quality Evaluation in Fragile-ecosystem

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Abstract:- Recently, the need for assessing soil properties has expanded. This is because of the growing public interest in determining consequences of management practices on the quality of soil relative to sustainability of fragile-ecosystem functions in addition to plant productivity. In this study, 12 physical, chemical, and biological attributes of various soils at a different land use/cover plots in Basra Province, Iraq were determined by remote sensed (RS) imagery. Also, soil samples were positioned by GPS to quantitatively evaluate soil quality with the method of integrated soil quality index (SQI). The analytical hierarchy processes (AHP) and experts' knowledge were used to determine soil quality indicators and their weights.The assessment units were created by overlaying soil map with land use/cover map in GIS spatial analysis module and using Multiple Variable Indicator Transform (MVIT). The distribution map of soil quality showed that the area of first-grade quality (I), second-grade quality (II), and the third-grade quality (III) was 19.8, 23.9, and 56.3 %, respectively. The result could help to promote the production of non-harmful produces, provide scientific information for adjusting agricultural structure, and maintaining sustainable development in agriculture.

Keywords:- Remote sensed; soil quality index; land use/cover; Geo-information technology, Semi-Arid region; Iraq.

I. INTRODUCTION

The soil is a critically important component of the earth biosphere as it functions not only in the production of food but also in the maintenance of environmental quality as related to fragile-ecosystem management and in formulating and evaluating sustainable agricultural and land use/cover policies [1-3]. In Iraq, soil quality was not discussed in the literature for nearly two decades because the primary emphasis of soil management was on controlling soil erosion and minimizing the effects of soil loss on productivity (e.g. [4]).

Influential soil properties i.e. soil quality may have significant influence on the health and productivity of an ecosystem and the related environment [5, 6]. Soil variability is not a problem, although it can be helpful in minimizing crop risk failure through design and implementation of site-specific management [7]. A significant decline in soil productive capacity has occurred worldwide through adverse changes in its physical, chemical and biological properties and contamination by inorganic and organic chemicals [8]. The rate of growth of global grain production dropped from 3% in the 1970s to 1.3% in the 2003 periods, and one of the key reasons of this decline is inadequate soil and water management [9]. The properties of soils may be determined by many attributes, whereas there is no fixed method to objectively select the parameters that affect soil quality. It is often a dilemma to decide how many and which of the measured parameters should be included in the assessment [10, 11]. A number of mathematical procedures such as AHP (Analytical Hierarchy Process), PCA (Principle Component Analysis) and LR (Linear Regression) were developed to help the screening of the parameters and determining of the weights [12-14].

The present study was carried out to assess the map quality of the soils under different land use/cover and proposed a quantitative formula for assessing soil quality and suggested that such assessments could help determine how soils responded to various management practices. Soil quality map began to be interpreted as a sensitive and dynamic way to document soil condition, response to management, or resistance to stress imposed by natural forces or human uses.The hypothesis is that soil properties build up at different land use/cover in very fragile soil is the driving force to resist a high degradation process.

The objectives of this research were to assess soil qualitymapby using the method of integration soil quality index (SQI) with aid of geo-information techniques in Basra Province, Iraq and explore the influence factors of land use/cover types and soil management practices on spatio-temporal variation of soil quality.

II. DESCRIPTION AND DATA OF THE STUDY AREA

The study region selected was Basra Province, Iraq (Fig. 1), representing a total area of 19,070 km2 between longitude 46o 60′ to 48o 60′ E and latitude 29o 13′ to 31o 29′ N. The predominant soil of Iraq is considered sedimentary, especially in central and southern parts of the country. Basra Province is situated in a desert-type environmental zone with a monsoon climate; summers are very hot, especially July and August, with a mean temperature of 37.4°C and a maximum temperature of 45°C. The average potential evapotranspiration exceeds 2450 mm/year, while average annual rainfall is less than 100 mm/year [15].

A multi-temporal Landsat (WRS2: 165/39, 166/38, 166/39 and 166/40, dated March 2003) image dataset covering the study area was assembled and analyzed for land use/cover change as part of the soil degradation indicator analysis. The spatial resolution of one pixel of the ETM image was 28.5 m by 28.5 m. A county-level topographic map, geological map, soil map, meteorological data and all thematic layers were generated in a GIS environment at a scale of 1:250 000. The software packages employed in the present study were ERDAS (image processing), Arc/GIS (analysis and presentation of results) and SPSS (statistical analysis).

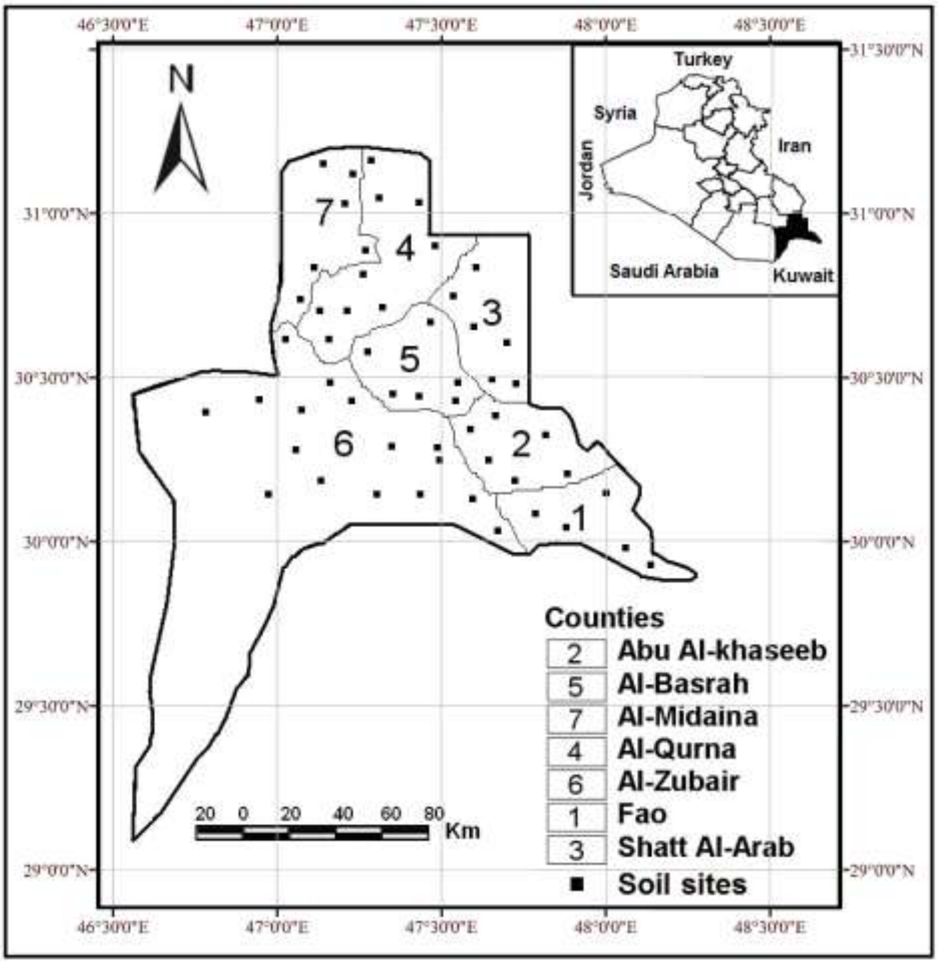

Fig.1: General location of study area showing counties boundary and soil sites.

III. METHODS OF THE STUDY

Image processing included geometric correction in which ground control points were chosen, referencing a topographic map of scale 1:250 000. The land use/cover characteristics of the study area were classified into 5 categories: vegetable plots, sand, urban/residential land, water bodies and unused land (bare land). Samples were collected within each assessment unit and evenly distributed to account for the overall property of the soil in the sampling unit using Global Positioning System (GPS) receiver set into WGS84 at zone NUTM38 and later transferred to GIS and projected to the datum used for the satellite images [16]. Field sampling and survey were taken from[17], when most of the crops were harvested, thus to avoid the period of fertilization, ploughing, and manuring to minimize the human's disturbances. In all, 516 samples (Fig. 1) were taken and analyzedsoil properties in laboratory(Table 1) according to the procedures of Black [18].

Table 1: Soil quality indicators and their average value in the BasraProvince dataset

Soil indicators	Mapping unite: County name (ID) / Area (km^2)						
	Khaseeb (2)/1,152	Midaina (7) /989	Qurna (4)/2,612	Zubair (6)/11,618	Basra (5)/1,085	Fao (1)/98	Shatt Al-A. (3)/1,516
Sand (g Kg^{-1})	245.0	133.1	240.0	930.9	255.4	123.0	161.1
Silt (g Kg^{-1})	483.6	394.4	489.6	10.2	463.5	486.6	541.2
Clay (g Kg^{-1})	271.4	472.5	270.4	40.8	281.1	390.4	297.7
ST [b)]	Silty L [a)]	Silty clay	Silty L	Sandy	Silty L	Silty clay	Silty L
AS >0.50 %	60.60	61.5	60.60	0.20	62.40	69.5	64.75
AS 0.5-0.25 %	10.30	9.45	10.30	8.02	8.40	5.45	6.44
AS0.25-0.10 %	8.25	7.28	8.25	61.23	7.35	4.28	7.11
AS < 0.10 %	2.29	3.16	2.29	21.58	3.29	2.16	3.15
GMD (mm)	0.18	0.17	0.20	0.28	0.22	0.21	0.19
BD (gcm^{-3})	1.21	1.23	1.22	1.68	1.41	1.23	1.25
AWC (cm^3cm^{-3})	0.19	0.21	0.18	0.03	0.12	0.14	0.16
SP (g g^{-1})	0.35	0.39	0.38	0.15	0.25	0.31	0.37
TP (cm^3cm^{-3})	0.45	0.41	0.35	0.19	0.37	0.30	0.40
OMC (g Kg^{-1})	3.70	3.10	3.75	0.19	2.60	3.20	3.73
pH	7.87	7.95	7.82	7.84	7.85	8.90	7.80
EC (dsm^{-1})	4.50	6.30	8.90	3.80	5.80	15.60	7.40
CEC ($Cmol_cKg^{-1}$)	13.25	10.92	11.36	5.75	12.45	9.80	12.96
TN (%)	0.05	0.04	0.04	0.02	0.03	0.03	0.05
$CaCO_3$ (g Kg^{-1})	120.2	130.5	118.9	169.5	118.9	125.5	124.1
DPW g/plant	120	98	103	56	75	70	109
CO_2 mg/g/d	0.02	0.04	0.05	0.001	0.08	0.07	0.03
ESP (%)	76.9	87.4	82.8	89.7	93.7	88.6	74.7
SAR (%)	26.5	28.2	29.7	37.6	34.3	41.9	27.1
GW (cm)	5-20	2-15	2-15	20 --50	10-30	2-15	3-20

a) Loam**,**
b) (ST) = Soil texture, (AS) = Aggregate size (mm), (GMD) = Grain mean diameter, (BD) = Bulk density, (AWC) = Available water capacity, (SP) = Saturation percentage, (TP) = Total porosity, (OMC) = Organic matter content, (pH) = Soil pH, (EC) = Electrical conductivity, (CEC) = Cation exchange capacity, (TN) = Total nitrogen, ($CaCO_3$) = calcium carbonate, (CO_2) = Respiration rate, (DPW) = Dry plant weight,(ESP) = exchangeable sodium percentage,(SAR) = sodium adsorption ratio (SAR), and (GW) = Ground water.

IV. METHODS OF THE STUDY

Soil quality indicators were selected using the approach suggested by Cameron [19]. The approach is based on the equation:

$$M = \sum(S, U, M, I, R) \qquad (1)$$

where A = acceptance score for indicator, S = sensitivity of indicator to degradation or remediation processes, U = ease of understanding of indicator value, M = ease and/or cost effectiveness of measurement, I = predictable influence of property on soil, plant/animal health and productivity, R = relationship to ecosystem processes (especially those reflecting wider aspects of environmental quality and sustainability). Each parameter in the equation is given a score (1 to 5) based on expert's knowledge and experience of it. The sum of the individual scores give the level of acceptance (A) score which can then be ranked in comparison to other potential indicators, thus aiding the selection of indicators for a site. For example, organic matter content (OMC) received the following scores (S = 5, U = 4, M = 4, I = 3, and R = 2) giving an A value of 72% i.e. (A=18/25×100 = 72%). The 'A' is high for OMC and is selected to be one of the indicators for soil quality assessment for crop production function. The following indicators were then selected based on the above approach: bulk density (BD), soil texture (ST), available water capacity (AWC), saturation percentage (SP), total porosity (TP), organic matter content (OMC), soil pH (pH), electrical conductivity (EC), cation exchange capacity (CEC), total nitrogen (TN), calcium carbonate ($CaCO_3$), and dry plant weight (DPW). The contribution of each indicator for soil quality is usually different, which can be indicated by a weight value. The Principle Component Analysis (PCA) was used to determine the weights of each factor in this study [12].

V. SOIL QUALITY MODEL

Assessment of soil quality was often used to solve particular problems, such as soil erosion, soil pollution and soil nutrient depletion. The soil quality evaluation data was collated into the five major land use/covers: (1) vegetation land, (2) sand land, and (3) unused land. The other classes viz (4) urban area and (5) water bodies have not been included in this analysis. The twelve soil quality indicators were examined for each land use/cover class.Table 2 shows a comparison of the sites sampled in the Basra province, grouped by land use/cover according to the south parts of Iraq land use/cover database derived from landsat ETM 2003 and the frequency of occurrence of that land use/cover in the soil quality evaluation set. There is a large bias in the soil quality data, with unused land 1.3 being greatly underrepresented and arable crops and horticulture being greatly over-represented according to the actual area extent. A bias factor 0.43 and 0.80 means the number of samples in the soil quality data corresponds well to the area extent of that land use/cover. The quality of soil function was assessed using Multiple Variable Indicator Transform (MVIT) by Smith [20]. The indicators were transformed on the basis of their ability to attain a critical level or range. Any indicator that is equal to or above the critical level for crop production is scored 1 and anyone below the critical level is giving 0. These were later integrated into percentage quality ratings (Table 2):

$$\text{\% Quality Rating} = \frac{\text{No. indicators that attain critical level}}{\text{Total No. of indicators assessed}} \times 100 \qquad (2)$$

The soil quality model is to qualitatively describe the attributes of a high-quality soil, where soil quality is defined based on its capacity to perform a certain function [21]. Based on the results of modeling, we can compare effects of different practices on similar soil types or temporal trends on the same soil type, and to understand the complete value of dynamic soil quality assessment [9]. Karlen and Stott [22] suggested a simple additive model:

$$\mathrm{Q} = q_1(wt) + \ldots q_k(wt) \qquad (3)$$

Where Q is the soil quality index (SQI), qk variables represent values for different soil quality attributes, and wt is the weights applied to each attribute. In order to combine all the indicator measurements with totally different measurement units, each indicator has to be normalized, often using ranges established by the soil's inherent capability to set the boundaries and shape of the membership functions.

Table 2: The proportion of land use/cover class in 2003 and their representation

Land use/cover class	Area (Km^2)	Proportion (%)	Number of Soil sites	Proportion (%)	"bias" factor
Vegetation land	4595.9	24.1	292	56.5[a)]	0.43[b)]
Sand land	4557.7	23.9	153	29.8	0.80
Urban area	3794.9	19.9	1	0.19	No data
Unused land	3356.3	17.6	70	13.5	1.30
Water bodies	2955.9	15.5	0	0	No data
Total	19,070	100	516	100	

[a)] Proportion (%) =292 × 100 / 516
[b)] Bias factor =24.1 / 56.5

VI. RESULTS AND DISCUSSION

A. Soil indicators evaluation

Correlation analysis with SPSS packages was made for soil properties measurements 0-30 soil depths which indicted intra and inter-relationships among the soil properties while revealing significant and non-significant correlations between the variables assayed (Tables 3). The study results provide a significant negative correlation (r > -0.94) between the bulk density (gcm^{-3}) and the saturation percentage ($g\ g^{-1}$). Another significant positive correlation (r > 0.87) was found between the organic matter content ($g\ Kg^{-1}$) and total nitrogen (%), while the correlation between cation exchange capacity ($CmolcKg^{-1}$) and calcium carbonate ($g\ Kg^{-1}$) was significant negative (r >-0.91); however, most of the soil properties were negatively correlated with sand and positively correlated with silt and clay. Therefore, it is clear that the physical and chemical properties had the strongest effect on the soil quality index more than the biological properties. With respect to weight contributions (Table 4), soil organic matter accounted for almost 21.6% of all the contribution, which implied that soil organic matter is the most important parameters in soil's quality.Thiscould be because of the reason that organic matter could influence soil porosity, and thus gas exchange reactions and water relations. The soil texture and bulk density are made a contribution of 14.2 and 13.1%, respectively, which reflected the facts that there were obstacle layers in soils of study location and need improvement. CEC and EC both took a share of 10.7% each. It is well known that CEC represents the soil's ability of holding nutrients and soil texture could affect the availability of some nutrients and also influences some other properties. The biological attributes, dry plant weight (DPW) and soil respiration rate (CO2), did not appear to contribute significantly toward the total variance and were among the twelve attributes of the lowest communality values. The data presented in Table 5 show the soil quality ratings for crop production function. In mapping units viz Abu Al-Khaseeb and Shatt Al-Arab, Al Midaina, Al-Qurna, Basra, Fao, and Al Zubair counties have number indicators which met the threshold value requirement for crop production function, so they have 74.6, 66.4, 49.8, 58.1, 41.5, 34.5, and 33.2% quality ratings respectively. With these results, the soils have low to high inherent quality for crop production function. The statistical analysis showed that soil organic matter has a significant correlation with dry plant weights' positive change ($r > 0.80$). Organic matter content (OMC) is an important component of the soil because it is relevant to all biological, chemical and physical functions in the soil. Biologically, soil organic matter is the source of energy for soil microorganisms (or microbes). Microbes are the 'engine' that drives the cycling of nutrients within the soil[23]. Chemically, soil organic matter is a major reservoir of plant nutrients. It is the major source of plant nitrogen, sulphur and phosphorous, which are cycled through accumulation and decomposition of soil organic matter[22]. Other nutrients, such as calcium, magnesium, potassium and sodium, are loosely attached as positively charged cations to the negatively charged bonding sites on organic matter. Physically, soil organic matter stabilises soil structure and soil pores and therefore has a marked effect in enhancing structural stability, aeration, water storage capacity and rainfall infiltration[8].

B. Distribution map of soil quality

The spatial distribution map of soil quality was prepared by using ARC/GIS software after the completion of field verification of the classified images, soil sampling, laboratory analysis, % quality ratings, and SQI model (Fig. 2). Statistical analysis of soil properties indicates that the most effective soil properties were the soil texture, calcium carbonate, bulk density, Organic matter content (OMC), and CEC in addition to electric conductivity (EC) and soil pH. An integrated soil units by GIS of study area for each soil mapping units including representative profile, area size and some soil properties (Table 1). The soil quality in vegetation plot, irrigated land and orchard was significantly higher than other land use/cover types. Fig. 2 showed that the study area could generally be divided into three regions in term of soil quality, that is, the southeast part (Abu Al-Khaseeb, Shatt Al-Arab, and some parts from Basra counties) with highest quality, the north part (Al Midaina and Al-Qurna counties)with moderate quality and the rest (Zubair and Fao counties) with low quality. The southeast part soils developed from sedimentary deposit have good texture and high organic matter content and the high values of organic matter content may be due to residues of root, from natural vegetation. Data of pH values in the soil samples are ranged between 7.84 to 8.90, indicatingslightly to high alkaline soil reaction change and it may be due to relatively high concentration of alkaline cations. The EC values are classified into moderate to high saline soil range according to soil survey. The high EC values may be due to soil texture and high concentration of soluble salts in the soil solution. The results of the statistical analysis showed that saline area has a significant correlation with vegetation cover negative change (0.89, $p<0.05$).The higher content of Ca^{2+} may be an indictor to their derivation from calcareous parent rocks. The north part (Al Midaina and Al-Qurna counties) is largely occupied by clay soils derived from which have moderate content of organic matter and mineral nutrients. The slightly high values of ESP may due to relatively high concentration of sodium cations in soil solution and slightly high percentage of fine particle (silt and clay) and moderately high level of phosphorus may be due to their origin of deposits and fine texture. The rest are hilly sand dunes (west part) in Zubair county and easily flooded (south part) in Fao county areas, characterized by shallow soil layer, lack of organic matter and nutrients and result in poor soil quality. The low values of CEC may be due to fine texture (loam and sand loam) in Al-Zubair county soil samples. Generally, the organic content in the study area is low values may be due to virgin soils and climate effect (arid conditions), and the high content gypsum and lime may be due to derivations from natural formations of parent materials. According to the results of the physical and chemical properties of Basra Province, soil it was observed that these soils do not have any visible diagnostic horizons that could be recognized in any studied soil profiles in all location study area, that undeveloped and immature. The main factors influencing soil quality were land use/cover and soil management practices. The spatial distribution pattern of soil quality matched the distribution of land use/cover. Among various land use/cover types, irrigated lands and orchards had the best quality.

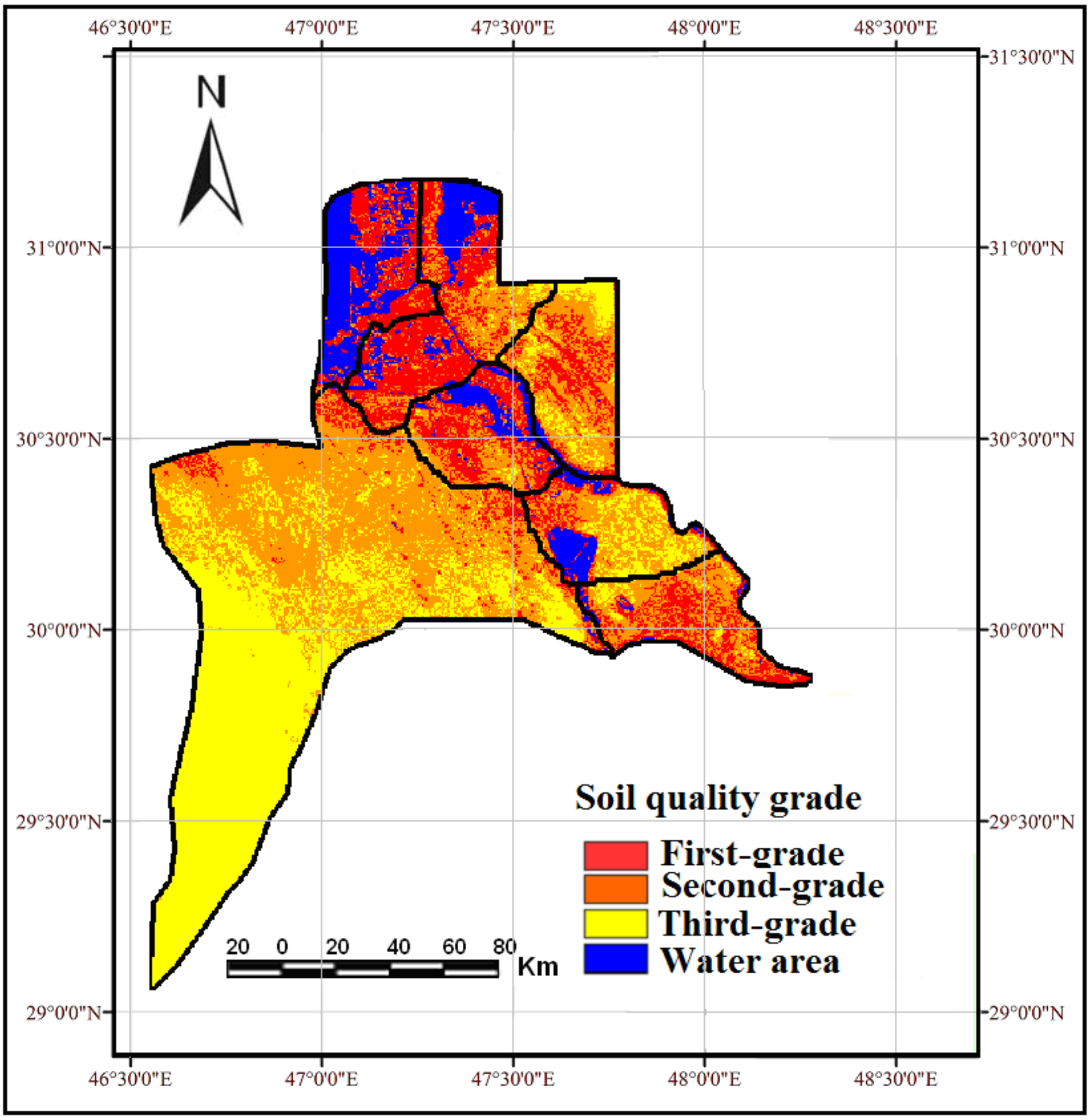

Fig.2: Distribution map of soil quality in the Basra Province

Table 3: Matrix of correlation coefficients for soil properties in the fragile-ecosystem

DPW														1.00
$CaCO_3$													1.00	ns -.645
TN												1.00	ns -.662	** .976
CEC											1.00	*	** -.913	* .799
EC										1.00	ns .14	Ns	ns -.384	ns -

Variables		Si	Cl	BD	AW	SP	TP	OMC	pH
(Sa) Sand (g Kg^{-1})	1.00								
(Si) Silt (g Kg^{-1})	**	1.00							
(Cl) Clay (g Kg^{-1})	*	ns .727	1.00						
(BD) Bulk density (gcm^{-3})	** .931	** -.898	* -	1.00					
(AWC) Available Water capacity (cm^3cm^{-3})	* -[illegible]	* .786	* .847	** -.958	1.00				
(SP) Saturation percentage (g g^{-1})	* -.849	* .799	* .854	** -.945	** .963	1.00			
(TP) Total porosity (cm^3cm^{-3})	* -.785	* .790	ns .565	* -.793	** .880	* .802	1.00		
(OMC) Organic Matter content (g Kg^{-1})	** -.923	** .959	* .787	** -.970	** .898	** .920	* .835	1.00	
(pH) Soil pH	ns -.294	ns .174	ns .252	ns -.244	ns .006	ns .003	ns -.236	ns .104	1.00
(EC) Electrical conductivity (dsm-	ns -.502	ns .440	ns .519	ns -.462	ns .184	ns .275	ns -.109	ns .379	** .88
(CEC) Cation exchange capacity ($Cmol_cKg^{-1}$)	* -.809	** .901	ns .524	* -.767	* .767	ns .726	** .934	* .873	ns -.195
(TN) = Total	ns	ns	ns	*	*	*	**	*	ns
($CaCO_3$) calcium carbonate (g Kg^{-1})	** .914	** -.972	ns -.737	* .860	* -.789	* -.755	* -.809	** -0.927	ns -.099
(DPW) = Dry plant weight (g/plant)	ns -.593	ns .663	ns .477	* -.758	* .833	* .837	** .875	* .806	ns -.372

*, ** Indicated relationships significance level at $p < 0.05$ and $p < 0.01$; ns- non-significant and '-' sign denoted negatively correlated (n=101).

Table 4: Soil quality indicators and weights

Indicator	Weight	Contributing to soil quality	Recommended by
BD (gcm^{-3})	0.1447	Bulk density is the weight of soil in a specified volume. Bulk density provides a measure of how loose or compacted the soil is. Loose soils may be subject to increased risk of erosion. Compaction reduces the porosity and stability of soil aggregates. The consequences may include reduced supply of air to plant roots, increased resistance to penetration that may limit root extension and germination, and reduced capacity of the soil to store water that is available to plants.	[29]
ST (gKg^{-1})	0.1519	Root growth, rate of water movement, soil volume expression, retention and transport of water and nutrients	[3]
AWC (cm^3cm^{-3})	0.0355	The preferred indicators for soil physical condition is available water, as give an indication of the number of larger pores in soil, which are crucially important for aeration and storage of plant-available water.	[30]
SP (g g^{-1})	0.0166	Water and air balance, hydrology regulation	[31]

TP (cm^3cm^{-3})	0.0562	Water/air balance, water retention, root growth	[32]
OM (gKg^{-1})	0.1795	Available water, nutrient, root growth, environmental concern	[28]
pH	0.0311	Measure of the acidity or alkalinity of soil, is an important indicator because acidity influences both the ability of plants to grow in soil, the availability of nutrients, and the functioning of beneficial organisms. Acidification is a natural soil process, but can be accelerated by cropping, excessive use of fertilizers, leaching, and application of acidic wastes.	[33]
EC (dsm^{-1})	0.1335	Soil chemical characteristic to be included as basic indicator	[34]
CEC ($Cmol_cKg^{-1}$)	0.1188	The CEC of a soil often indicates its natural fertility and its development and ability to supply Ca, Mg, and K for plant growth. It is also a measure of the ability of the soil to store added nutrients (fertilizers). Soils which have a low CEC cannot store large amounts of plant nutrients and must be replenished more regularly.	[31]
TN (%)	0.0934	Indicator of soil quality change due to Land use/cover change	[35]
$CaCO_3$ (gKg^{-1})	0.0327	Plant productivity and environmental quality functions of SQI.	[36]
DPW g/plant	0.0061	Index for microbial biomass (i.e. biological function).	[32]

(BD) = Bulk density, (ST) = Soil texture, (AWC) = Available water capacity, (SP) = Saturation percentage, (TP) = Total porosity, (OMC) = Organic matter content, (pH) = Soil pH, (EC) = Electrical conductivity, (CEC) = Cation exchange capacity, (TN) = Total nitrogen, ($CaCO_3$) = calcium carbonate, and (DPW) = Dry plant weight.

Table 5: Information used in calculating the value of parameter in Eqn 2 for percentage of soil quality ratings

Soil indicators	Mapping unite: County name (ID) / Area (km^2)						
	Khaseeb (2)/1,152	Midaina (7) /989	Qurna (4)/2,612	Zubair (6)/11,618	Basra (5)/1,085	Fao (1)/98	Shatt Al-A. (3)/1,516
BD (gcm^{-3})	1	1	0	1	0	0	1
ST (Soil Texture)	1	0	1	0	1	0	0
AWC (cm^3cm^{-3})	1	1	1	0	1	1	1
SP ($g\ g^{-1}$)	0	0	1	0	0	0	1
TP (cm^3cm^{-3})	1	1	0	0	0	0	1
OMC ($g\ Kg^{-1}$)	1	1	1	0	0	1	1
pH	1	0	1	1	1	0	0
EC (dsm^{-1})	0	0	0	1	0	0	0
CEC ($Cmol_cKg^{-1}$)	1	1	0	0	1	1	1
TN (%)	1	0	1	0	0	0	1
$CaCO_3$ ($g\ Kg^{-1}$)	0	0	0	0	0	0	0
DPW g/plant	1	1	1	1	1	1	1
% Quality ratings	74.6[a)]	49.8	58.1	33.2	41.5	34.5	66.4

[a)] High = > 65%, Medium = 35 – 65%, Low = <35% [25]

(BD) = Bulk density, (ST) = Soil texture, (AWC) = Available water capacity, (SP) = Saturation percentage, (TP) = Total porosity, (OMC) = Organic matter content, (pH) = Soil pH, (EC) = Electrical conductivity, (CEC) = Cation exchange capacity, (TN) = Total nitrogen, ($CaCO_3$) = calcium carbonate, and (DPW) = Dry plant weight.

C. Soil quality evaluation

The study area was divided into three grades according to SQI values (Table 6). According to Table 6, the third-grade quality (III) accounted for nearly half of total stud area (56.3%), subsequently was second-grade quality (II), with a percentage of 23.9%, and then was the first-grade quality (I), the highest quality soil was only 19.8%, which indicated that soils in Basra Province were not capable of sustaining agriculture.As the predominant texture classes were sandy soil, silty loam, and silty clay,the soils are usually dry in all parts of the year and do not have cracks or lithic and or paralithic contact within 60 cm of the soil surface. They have a torric moisture regime and thermic characteristics. Therefore, these soils are placed in the order Entisols, suborder Orthents, and great group TypicPetroargids (PetrogypsicPetroargids) according to the USA Soil Taxonomy. Soil representatives for the different land use/cover were not having any diagnostic horizons. They have sand to medium texture, a high content of $CaCo_3$, and the soil temperature regime being thermic. The different values of CaCo3 content revealing the original deposits formations in these soil, which may be due to derivation from calcareous parent rocks and it was distributed in coarse sand, fine, silt and clay fractions. These soils represent the flat soil association are mineral soils, devoid of any observable signs of soil development and do not have any diagnostic horizons, therefore, these soils can be classified into order Entisols, suborder Psamments, great group Quartzipsamments and subgroup TypicQuartipsamments. Generally, the soils of Iraq are considered as sedimentary soil according to the USA Soil Taxonomy these are TypiPetroargids (PetrogypsicPetroargids) especially in the central and southern parts.

VII. CONCLUSION

Numerous studies had been carried out in assessing soil quality aiding with various mathematical methods for sampling strategy, indicator selection, weight determination and model construction. With the advance of spatial information science, geo-information technologies provide powerful tools for data manipulation and information acquisition, which may, along with the previously stated methods, bring the research of soil quality assessment into a new era. This research, selecting south part of Iraq as study area, assessed the spatial variability of soil quality and explored the variation features of soil quality under different land use/covers and a total of 516 sites in the location have been examined to assess soil quality condition, using a set of 12 key indicators. About two-third of the sites (70%) met all soil quality targets, specific to those soils, and using these data and other ancillary spatial information in the GIS environment, it is possible to identify and map similar soil characteristics that can be used to predict potentials and constraints of land for specific crop production. Soil quality maps indicate areas with a high probability of having good soil quality according to predetermined criteria. This procedure and the resultant maps can be produced at various time intervals to monitor changes in soil quality due to management practices or treatments. Moreover, by evaluating individual indicators over time, it is possible to identify specific soil properties that are affected by management practices. The probability map produced from this study is more useful than rating soil quality on a scale of 1 to 10, and provide more flexibility to incorporate management decisions and environmental constraints into the soil quality profile. The spatial distribution pattern of soil quality matched the distribution of land use/cover. Among various land use/cover types, irrigated lands and orchards had the best quality. We concluded that the soil quality restoration in the non-vegetation sandy areas should emphasize increasing the base saturation and CEC reducing in the aluminum saturation, and increasing the soil organic matter. Greater soil physical change occur at the soil surface and are closely related to the soil organic matter content, which in turn, affects aggregate stability, pore size distribution and water flux. For the fact that soil quality was a complex process, there was need for it to be corrected by soil physical, chemical, and environmental factors to form the actual productivity of land. Further studies be carried out to determine the most important soil properties and their respective critical values for each land use/cover type that should be considered in developing minimum datasets for SQ index determination and there is need to determine the optimum sampling strategies and intensities that will give consistently good result of predicted parameters at un-sampled locations at coarser scales e.g. regional levels.

Table 6: Soil quality grades and their properties in Basra Province

Grades	Area (km^2)	%	Soil properties
quality (I)	3775.86	19.8	The first-grade quality (I) is good have few problems for sustainable production. In this grade care must be taken to reduce degradation. The lower resilience characteristics of first-grade quality (I) soils make them more risky, particularly for low crop production. Soil temperature and moisture conditions are ideal for annual crops. However, their productivity is generally high and consequently, response to management is high. Conservation tillage is essential, buffer strips are generally required and fertilizer use must be carefully managed. Due to

			the relatively good field conditions, the soil is suitable for crop production. Risk for sustainable crop production is generally < 25% but risk can be reduced with good conservation practices.
quality (II)	4557.73	23.9	The second-grade quality (II) is moderate productive, with few management-related constraints. This grade requires important inputs of conservation managements. In fact, no crop production must contemplate in the absence of a good conservation plain. Lack of plant nutrients is a major constraint and so a good fertilizer use plan must be adopted. Soil degradation must be continuously monitored. This class productivity is not high and so low-input farmers must receive considerable support to manage these soils or be discouraged from using them. Soil can be set aside for orchards regions. In the semi-arid areas, they can be managed for range. Risk for sustainable crop production is 25-50%.
quality (III)	10736.41	56.3	The third-grade quality (III) is belonging to very fragile-ecosystem or is very uneconomical to use for crop production. The soil should be retained under their natural state. Some area may be used for recreational purposes but under very controlled conditions. In the third-grade quality (III), which is largely confined desert area, re-vegetation must be done very carefully with considerable attention to ecosystem damage. The third-grade quality (III) is mainly deserts where biomass production is very low. Risk for sustainable crop production is >75%
Total	19,070	100	The study area, in general, is exposed to a high risk of soil degradation caused by salinization, wind erosion, and The continuous use of unsustainable practices, damage of the infrastructure during the War, and poor maintenance worsened by sanctions, has caused a further soil and plant deterioration.

REFERENCES

[1]. A. S. Yakovlev, V. M. Gendugov, G. P. Glazunov, M. V. Evdokimova, and E. A. Shulakova, “Methodology for the environmental assessment of the soil state and regulation of the soil quality” Eurasian Soil Science. 42 (8), pp 916-925 (2009).

[2]. V. I. Kiryushin,” Assessment of land quality and soil fertility for planning farming systems and agrotechnologies” Eurasian Soil Science. 40 (7), pp 785-791 (2007).

[3]. D. Granatstein, and D.F. Bezdicek, “The need for a soil quality index: Local and regional perspectives” American Journal of Alternative Agriculture, 17, 12-16 (1992).

[4]. M.T. Jabbar, “Soil loss by wind erosion for three different textured soil treated with polyacrylamide and crude oil, Iraq”Journal of China University Geosciences 2:113–116 (2001).

[5]. R.D.Connolly, D.M. Freebairn,and M.J. Bell, ”Change in soil infiltration associated with leys in south-eastern Queensland”Australian Journal of Soil Research 36, 1057-1072 (1998).

[6]. L.F.C.Leite, E.S. Mendonca,and PLOA. Machado, “Influence of organic and mineral fertilisation on organic matter fractions of a Brazilian Acrisol under maize/common bean intercrop” Australian Journal of Soil Research 45, 25–32 (2007).

[7]. Z.Wang, A.C. Chang, L. Wu, and D.Crowley, “Assessing the soil quality of long-term reclaimed wastewater-irrigated cropland”Geoderma,114, 261– 278 (2003).

[8]. M.A. Arshad, and S.Martin, “Identifying critical limits for soil quality indicators in agro-ecosystems”Agriculture, Ecosystems and Environment 88, 153–160 (2002).

[9]. L. Douglas, C. A.Karlen, Ditzler, and S. A. Susan. “Soil quality: why and how?”Geoderma, 114,145–156 (2003).

[10]. B.P. Warkentin, “The changing concept of soil quality” Journal of Soil Water Conservation. 50, 226–228 (1995).

[11]. N.R. Hulugalle, and F. Scott, “A review of the changes in soil quality and profitability accomplished by sowing rotation crops after cotton in Australian Vertosols from 1970 to 2006” Australian Journal of Soil Research 46, 569–576 (2008).

[12]. G.A. Fox, and R. Metla, “Soil property analysis using principal components analysis, soil line, and regression models” Soil Science Society of America Journal 69:1782–1788 (2005).

[13]. M.T. Jabbar, and C. Xiaoling, “Land degradation assessment with the aid of geo information techniques” Journal of Earth Surface Processes and Landform 31:777–784 (2006).

[14]. F. Yang, G.M. Zeng, C.Y. Du, L. Tang, J.F. Zhou, and Z.W. Li, “Spatial analyzing system for urban land-use management based on GIS and multi-criteria assessment modeling” Progress in*Natural Science.* 18(10): 1279-1284(2008)

[15]. M.T. Jabbar, and X. Zhou, “Eco-environmental change detection by using remote sensing and GIS techniques: a case study Basra province, south part of Iraq” Environment Earth Science 64:1397–1407 (2011).

[16]. M.T. Jabbar, Z. Shi, T. Wang, and C. Cai, “Vegetation change prediction with geo-information techniques in the three gorges area of China” Pedosphere16(4):457–467 (2006).

[17]. N.A. Al-Mossawi, “Spatial variance of properties of Basra soil a study of soil geography” Ph.D. Dissertation, Basra University, (2005). (in Arabic).

[18]. G. R. Black, “Bulk Density. In: Black C A, Evans D D, White J L, eds. Methods of Soil Analysis” Part 1. Agronomy. 9: 379-390 (1965).

[19]. K. Cameron, M.H. Beare, R.P. McLaren. and H. Di, “Selecting physical, chemical, and biological indicators of soil quality for degraded or polluted soils” Proceedings of 16th world congress of soil science registration No. 2516. Symposium No. 37. August 20-26, (1998). Montpelier, France.

[20]. J.L. Smith, J.J. Halvorson, and R.I. Papendick, “Multiple Variable Indicator Kriging: A procedure for integrating soil quality indicator. In: Defining and assessing soil quality for a sustainable environment” Soil Science Society of America, Special Publication No. 35:149-156 (1994).

[21]. S. H. Schoenholtz, H. V. Miegroet, and J, A. Burger, “A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities” Forest Ecology and Management, 138, 335-356 (2000).

[22]. D.L. Karlen, and D.E. Stott, “A framework for evaluating physical and chemical indicators of soil quality. In: Doran, J.W., Coleman, D.C., Bezdick, D.F., Stewart, B.A. (Eds.), Defining Soil Quality for a Sustainable Environment” Soil Science Society of America, Special Publication No. 35, pp. 53-72 (1994).

[23]. D.E Romig, M.J. Garlynd, and R.F. Harris, “Farmer-based assessment of soil quality: a soil health scorecard. In: Doran JW, Jones AJ (Eds.) Methods for Assessing Soil Quality” Soil Science Society of America, Special Publication No. 49, pp. 39-60 (1996).