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ASSESSMENT OF SOIL QUALITY INDEX ALONG HYDROSEQUENCE IN GRAIN CROPS GROWING AREAS OF NAJAF AND DIWANIYA GOVERNORATES OF IRAQ

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ABSTRACT

Kiffil Shinafiya project was selected as it's been conducted and covering the areas of grain crops agriculture in Najaf and Qadissiya provinces. Lands of this project are considered as a part of the Mesopotamian plain located in between N32º 15′, N31º 30′ and E44º 44', E44º 20′. Three hydrosequences were disclosed with three transects (T1, T2, T3) in the area of study. The first hydrosequence was perpendicular on the other two sequences. Fifteen pedons were outcropped, five pedons in each transect in addition to eighteen more surface samples to be a total samples of 33 locations. Pedons were morphologically described. Carbonate minerals showed simple variation as well in the area of study in a range of 114.15-494.37 $gm.kg^{-1}$ in the surface horizons and samples where the highest content was in the third pedon of the first transect. Spatial distribution maps showed that there is a similarity between both of organic matter an organic carbon, where the highest content of the organic matter and carbon was in the thirteenth pedon of the third transect at 21.85 $gm.kg^{-1}$ and 12.70 $gm.kg^{-1}$ respectively. Total nitrogen showed highest content of 0.16% in the sixth pedon in the second transect and the thirteenth pedon in the third transect of the hydrosequences. Available nitrogen, phosphorus, and potassium content in soil showed that the highest content of available nitrogen was 77.00 $mg.kg^{-1}$ in the tenth pedon of the second transect which is located at the end of the hydrosequence, while available phosphorus of the highest value was in the fifth pedon of the first transect that is located at the highest part of the hydrosequence of that transect, and the available potassium did not show a specific distribution spatially. But we can notice that it showed that the lowest parts of the hydrosequences showed highest contents of available potassium when compared to the northern parts of them. Also, available potassium showed a spatial dependency to clay content distribution where both showed closer patterns spatially, where it increased when clay content increased as compared to the rest sites of the samples. Results also confirmed that there is a significant relationship between organic matter or carbon, with the total nitrogen in soil and the available nutrients of nitrogen and phosphorus while potassium did not show that correlation with terrain attributes. Soil quality index classes' results showed the dominancy of the moderate class followed the good class. Covering an area of 65.41 and 34.59 of the total area of project respectively where the moderate class distributed at the northern part while the good one distributed at the middle and southern part of the project.

***Keywords*:** soil quality, hydrosequences, grain crops areas

Introduction

Soil quality is defined as the ability of the soil to perform its necessary functions for its various uses. This definition includes the study of physical, chemical, and biological properties of soil, and the evaluation of soil quality indicators must be flexible and broad-based to be relevant to a wide range of soil functions (Andrews *et al*., 2002).

De Paul Obade and Lal, 2016 studied methods for evaluating soil quality in selected soil chains from Ohio, North America, where they found that the properties of bulk density, soil salinity, capacity of available water, and organic carbon in the soil were the most influential properties of the soil quality index. They also found that the soil quality index was strongly associated with yields of 64% for yellow corn and 100% for soybeans. Gong *et al*. (2015) selected the lowest number of soil properties to reach an indication of the quality of river basins soils compared to the soils of desert oases in the Kiriya Valley in China, such as soil moisture, organic matter, degree of interaction, and a number of plant nutrients, as well as soil salinity and its construction of a hundred soil samples taken from the study area. They found that the oases area was suffering from a lack of soil moisture and high salinity, and that the building of the soil was non-existent and the content of organic matter was minimal despite its high content of nutrients, which led to a decrease in the soil quality index in it compared to the soils of river basins, which can be compensated for the deficiency in their content of nutrients, management applications and fertilization plan. In a critical review of soil quality and its assessment methods, Bünemann *et al*. (2018) presented an article stating that the common properties in assessing soil quality in a review were the content of soil organic matter, degree of reaction, available phosphorous, and the soil's ability to retain water. It also showed vital biological and chemical indicators that did not play their role effectively, but they are promising in assessing soil quality. They also emphasized that assessing soil quality must deal with the problem present in the soil under study. Therefore, the soil quality index must be developed from one place to another according to what each site of soil suffers.

Materials and Methods

Kiffil Shinafiya project was selected as it's been conducted and covering the areas of grain crops agriculture in Najaf and Qadissiya provinces. Lands of this project are considered as a part of the Mesopotamian plain located in between N32º 15′, N31° 30′ and E44º 44', E44º 20′. A map of soil units at the level of chains was adopted in order to determine the hydrosequences and direct transects to take the study samples. Three hydrosequences were disclosed with three transects (T1, T2, T3) in the area of study, Three hydrosequences and three transects (T1, T2, and T3) were detected in the project area, the first hydrosequence was perpendicular on the other two sequences. It is worth noting that the second and third transects were in a general direction north-south, where the general slope of the area was directed, while the first transects was towards east-west heading from the low-lying areas that represented Hor Ibn Najm previously (as the problem of water scarcity led to a decrease in water levels in this the marshes and the exploitation of its lands for grain cultivation), towards the high areas adjacent to the western plateau. These sequences were determined by a punch-check method and the first occurrence of the spotting condition was recorded to ensure that the variation in hydrological conditions was achieved in each pedon, while the spotting depths and drainage classification of the surface samples sites were recorded in the same way. Fifteen pedons, five pedons were drilled in each movement transects, in addition to eighteen surface samples, so that the total surface samples would be thirty-three samples. Table 1 and Fig. 1 show the hydrosequences and drainage status of a studied bedon. Soil pigeons were excavated and their morphology was originally described according to the Soil Survey Manual and its annexes (Soil Survey Staff, 2017). Samples were taken from every horizon for the purpose of transporting them to the laboratory and conducting laboratory analyzes on them.

Table 1 : Hydrosequences in Terms of Internal Drainage Class in the Study Pedons

No.	First Transect	Second Transect	Third Transect
1	Imperfectly drained	Moderately well drained	Excessively drained
2	Moderately well drained	well drained	well drained
3	Moderately well drained	Moderately well drained	Moderately well drained
4	well drained	Imperfectly drained	Moderately well drained
5	Excessively drained	Imperfectly drained	Imperfectly drained

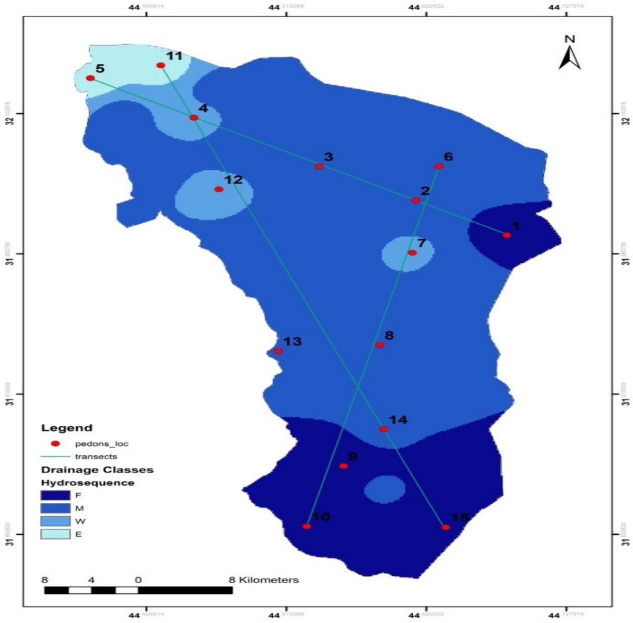

Fig. 1 : Hydrosequences Showing the Pedon Sites

Laboratory Procedures

Soil content of organic carbon (OC) and organic matter (OM): they were estimated by the wet digestion method according to the Walkly and Black method reported in Jackson, 1958. The value of organic carbon was first calculated, and the value of organic matter was calculated from it through the equation:

Organic matter (%) = Total **organic carbon** (%) x 1.72

Total N: the total nitrogen was estimated by digesting the soil sample using the catalyst, concentrated sulfuric acid, and distilling it with a microchloride device according to the Bremner method and as reported in Page *et al.* (1982)

Available nitrogen (N): It was evaluated in the soil by the method of extraction with a solution of potassium chloride (2M KCl) and by using magnesium oxide MgO, the nitrate ion was reduced to ammonium (NH4) by means of a Devarda alloy and then distilled after volatilization and by using a microclassic device and correcting with sulfuric acid (H04). 005) according to the Keeney and Nelson method described in Page *et al.* (1982).

Available phosphorous (P): It was extracted by using sodium bicarbonate (0.5 M) $NaHCO_3$ at pH = 8.5 according to the Olsen method mentioned in Page *et al.*, 1982 and the color was developed with ammonium molybdates and ascorbic acid and was estimated using a Spectrophotometer at length. The waveform is 882 nanometers.

Available potassium (K): It was extracted with ammonium acetate (NH_4OAC) 1 standard at pH = 7 and measured using a flame photometer according to the method mentioned in Page *et al.* (1982).

Soil Quality Assessment

Some characteristics and properties of soil quality assessment were selected by using the classification followed by Pham *et al.*, 2015, which relies on indicators of organic carbon content and measured nutrients as shown in Table 2. It is worth noting that these divisions are specific to crop growing soils, especially rice in terms of the world. Therefore, some modifications were made for the soils of arid and semi-arid areas and the crop growing in Iraq[1] (Ali, 2012 and Hassan *et al.*, 1990), especially with regard to the soil available content of nitrogen, phosphorus and potassium for plants.

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[1] Consultation with soil fertility specialists in the Department of Soil Sciences and Water Resources. Personal interview with Prof. Dr. Nour El-Din Shawki Ali, Assistant Professor Dr. Qahtan Jamal Abdel-Rasoul, and Assistant Professor Dr. Jawad Taha Mahmoud.

Table 2 : Soil Quality Index assessment (Pham *et al*., 2015) and modifications

Parameter	Content (%)	class	Hierarchy for SQI (%)	SQI class
SOM	>2.5	High	>2.5	Good
	1.25-2.5	Medium	1.25-2.5	Moderate
	<1.25	Low	<1.25	Poor
Total N	>0.**15**	Rich	>0.**15**	Good
	0.1-0.**15**	Moderate	0.1-0.**15**	Moderate
	<0.1	Poor	<0.1	Poor
Parameter	Content (mg.kg^{-1})	Hierarchy	Hierarchy for SQI (mg.kg^{-1})	SQI
N bioavailable	>**50**	Rich	>50	Good
	20-**50**	Moderate	20-50	Moderate
	<20	Poor	<20	Poor
P bioavailable	**>25**	Rich	>25	Good
	20-25	Moderate	20-25	Moderate
	<20	Poor	<20	Poor
K bioavailable	**>250**	Rich	>250	Good
	200-250	Moderate	200-250	Moderate
	<200	Poor	<200	Poor

Spatial Distribution Maps

ArcGIS 10.3 for desktop software package (ESRI, 2014) was used for mapping the spatial distribution of measured soil properties as well as for slope properties maps and soil maps.

Results and Discussion

Table (3) shows the results of the fertility elements, and when talking about the content of organic matter in the soil, it includes talking about organic carbon at the same time as it is mainly calculated from it, so the organic matter and organic carbon distribution map appears similar in terms of the formal units in the map and with the same separation lines. The highest content of organic matter and organic carbon was in the thirteenth pedon, which is located in the third transects, with a percentage of 21.85 g. Kg-1 and 12.70 g. 40.94 meters above sea level compared to the rest of the sites that were less elevated, and that this area is close to rural population activity, and it is very close to the Euphrates River, where the area was cultured with many crops such as wheat, barley, Medics, as is the custom in the crop growing of its soil always. While the first pedon from the first transects showed the lowest content of organic matter and organic carbon with values of 4.03 g. kg^{-1} and 2.35 g. kg^{-1} for organic matter, organic carbon in the soil respectively, as shown in Table (3). It can also be observed that the poor part in the content of organic matter or organic carbon was most likely in the southern areas of the study area, where the site is the lowest on the one hand and in areas of almost poor hydrological conditions, and this may be due to the low oxygen content in soil air and the weakness of the decomposition and accumulation processes the organic matter in poor drainage conditions and thus its low soil content (Sahrawat, 2004). Also, these areas were farthest from the Euphrates River and the fresh water sources used in irrigation of crops and thus their optimal growth, which increases the biomass growing above and below the soil surface and thus higher content These two vare found in soil (Delfine *et al*., 2001). As shown in Figure (2)

Table 3 : Some Fertility Properties of the Upper Horizons and Surface Samples of the Studied Soil

Id	Location		OM	Org C	Total N	Avail N	Avail P	Avail K
	E	N	g.kg^{-1}	g.kg^{-1}	%	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}
1	44.682361	32.002599	4.03	2.35	0.04	48.00	25.00	305.00
2	44.630379	32.083712	20.17	11.73	0.16	66.00	23.00	117.00
3	44.538398	32.083523	18.49	10.75	0.12	26.00	26.00	176.00
4	44.442238	32.140994	14.91	8.67	0.07	16.00	18.00	209.00
5	44.362680	32.187499	19.31	11.23	0.10	24.00	66.00	249.00
6	44.612666	32.043561	6.72	3.91	0.05	29.00	33.00	354.00
7	44.609903	31.982001	16.81	9.77	0.09	19.00	16.00	228.00
8	44.585093	31.873336	16.24	9.44	0.08	68.00	17.00	260.00
9	44.556971	31.731011	20.69	12.03	0.12	62.00	12.00	359.00
10	44.528757	31.660135	17.41	10.12	0.11	77.00	31.00	210.00
11	44.416769	32.202556	15.34	8.92	0.08	47.00	24.00	295.00
12	44.461384	32.056574	19.27	11.21	0.10	42.00	21.00	237.00
13	44.635412	31.658998	10.09	5.86	0.05	52.00	37.00	137.00
14	44.506783	31.866313	21.85	12.70	0.16	32.00	30.00	291.00
15	44.587982	31.774286	4.03	2.35	0.03	62.00	25.00	247.00
16	44.461505	32.173416	15.69	9.12	0.08	34.86	24.18	236.97
17	44.498375	32.150726	16.18	9.41	0.09	34.86	24.49	224.89
18	44.546589	32.123310	16.92	9.84	0.08	34.36	25.95	204.73

Id	Location		OM	Org C	Total N	Avail N	Avail P	Avail K
	E	N	$g.kg^{-1}$	$g.kg^{-1}$	%	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$
19	44.607094	32.117638	16.61	9.66	0.08	47.91	25.05	190.48
20	44.677052	32.070369	14.00	8.14	0.07	44.48	24.82	222.13
21	44.386820	32.144109	16.94	9.85	0.08	34.37	37.61	244.31
22	44.411400	32.088331	17.12	9.95	0.12	41.42	25.44	231.74
23	44.497430	31.972995	16.29	9.47	0.08	46.28	23.30	245.15
24	44.525791	31.903983	18.27	10.62	0.13	57.26	24.97	274.20
25	44.563186	31.836312	14.86	8.64	0.07	61.66	21.76	267.77
26	44.655308	31.718688	11.97	6.96	0.06	49.89	27.78	222.46
27	44.556043	31.638331	11.98	6.97	0.06	68.67	29.36	220.53
28	44.588186	31.704508	15.35	8.92	0.09	57.92	22.49	277.01
29	44.624110	31.810390	11.19	6.51	0.06	59.02	22.91	258.61
30	44.630728	31.903037	14.68	8.53	0.07	50.40	20.47	260.55
31	44.643963	31.963541	13.03	7.58	0.08	29.79	21.04	256.64
32	44.552262	32.009865	14.94	8.69	0.07	36.38	23.85	244.79
33	44.478522	32.102512	16.94	9.85	0.12	39.83	23.48	223.33

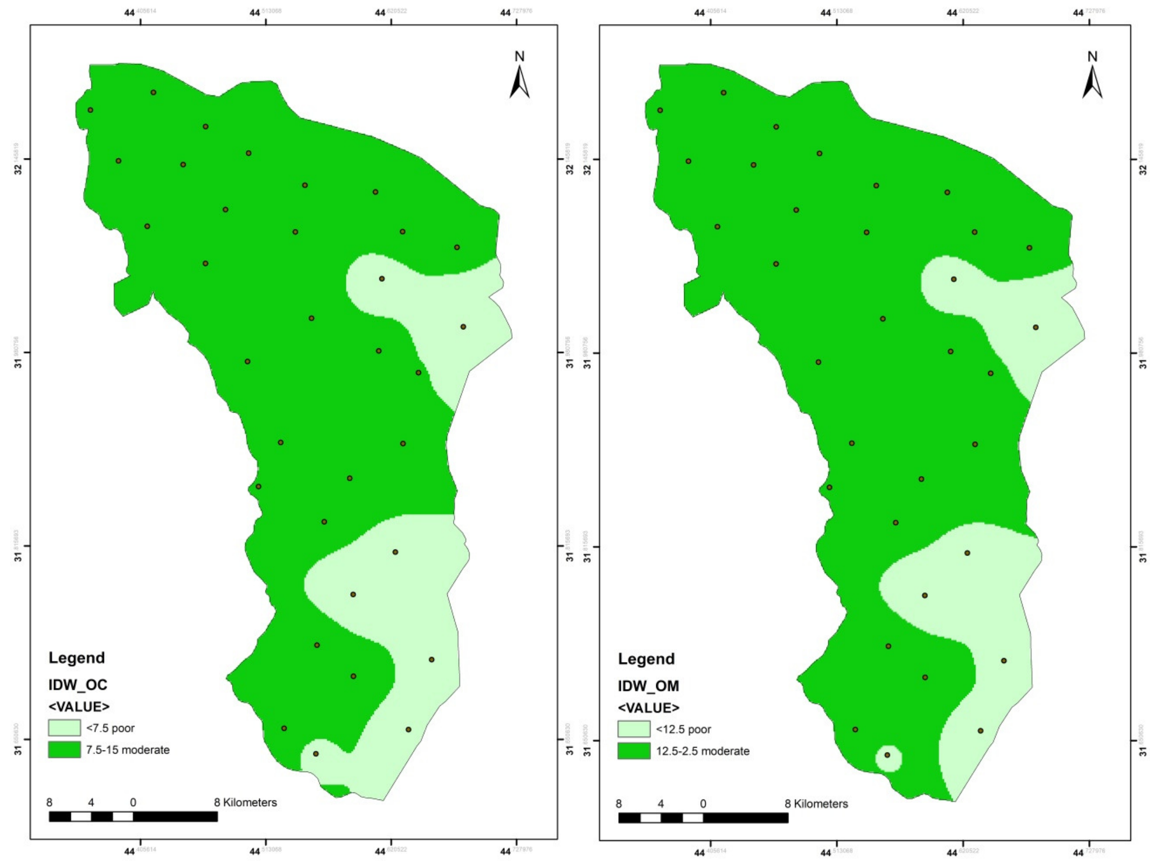

Fig. 2 : Spatial Distribution of Organic Matter and Organic Carbon Content in the Study Soils

As for the total nitrogen, its highest content was 0.16% in the sixth pedon in the second transects and thirteenth pedon in the third transects in the hydrosequences (Table 1). While the first pedon in the first transects and the fourteenth pedon in the third transects showed the lowest total nitrogen content compared to the study soil, and the high total nitrogen content in the thirteenth pedon may be due to the increase in biomass growth due to its proximity to the Euphrates River and water sources and the increase in biomass in the soil, it affects the increase in organic matter and thus total nitrogen, especially since that area is cultured with many crops, including Medics, wheat, and barley. This is also confirmed by Ghimire *et al.*, 2014 and Li *et al.*, 2005 in that the use of land and the crop growing of leguminous plants as agglutinated for long periods leads to an increase in total nitrogen due to the high content of organic matter in the soil.

As for the lowest total nitrogen content that appeared in the fourteenth pedon, shown the same decrease in the content of organic matter was accompanied by the increase of one of them accompanied by a relative increase in the other, as the total nitrogen content increased with the increase in the content of organic matter, and this is also confirmed by many researchers that there is a direct relationship between the organic matter content and total nitrogen content in the soil (Prado *et al.*, 2016; Mazzoncini *et al.*, 2011; Kravchenko *et al.*, 2009)

The previous table (3) shows the values of available nitrogen, phosphorous, and potassium in the soil, as the highest value of available nitrogen reached 77.00 mg. Kg^{-1} in the tenth pedon of the second transects, which is located at the end of the hydrosequences of the second transects, as the reason for this may be due to the fact that the available nitrogen is able to move with irrigation water or ground water and may be washed to lower areas with water courses in general as a result of irrigation or rainwater operations. The higher areas of the hydrosequences also showed a relatively low content of the available nitrogen and this is consistent with what Honeycutt *et al.*, 1990 found., Senthilkumar *et al.*, 2009; Ogeh and Ukodo, 2012. As for the available phosphorous in the soil presented in Table (3), it indicates that its highest value was located in the fifth pedon, which is located at the top of the hydrosequences of the first transects, also the thirteenth pedon in the second transects is a high value of available phosphorus, and the reason for this may be due to the increase in rural activity in the study area as well as to the severe agricultural conditions, since the soils of this pedon are planted with many crops such as wheat, barley, Medics. The fertilization plan may be a reason for the high values of available phosphorus in that area. available phosphorus also showed a good content at the ends of the, hydrosequences, where poor drainage and aerobic soil conditions may be bad, which may lead to high reductions in the soil, causing a slight increase in its reactivity, which may lead to the release of a part of the available phosphorus to increase its content compared to the rest of the sites. . As for the lowest values of available phosphorus, it did not follow a specific pattern, as it appeared in more than one pedon in the second and third transects, while the moderate content of available phosphorus was widespread in the rest of the study.

As for the available potassium content in the soil, it is noticed from Table (3) that its value between 117.0-359.0 mg. Kg^{-1}, as it was the lowest value in the sixth pedon, which is located at the beginning of the second transects of the hydrosequence. The soil of this pedon considered as weak agricultural use and this reduced the quantities of added fertilizers because they were not needed, while the highest value of available potassium was in the ninth pedon in the second transects which was at the end of the hydrosequences, which led to the movement of potassium and its transport with the movement of fluids in the soil body represented by the quantities of water on the one hand, during irrigation of crops and rain, if any, on the other hand (Winzeler *et al.*, 2008). The available potassium content did not show a clear trend in the spatial distribution, but it can be observed that the lower area of the hydrosequences were somewhat higher in their content of available potassium compared to the other two classes.

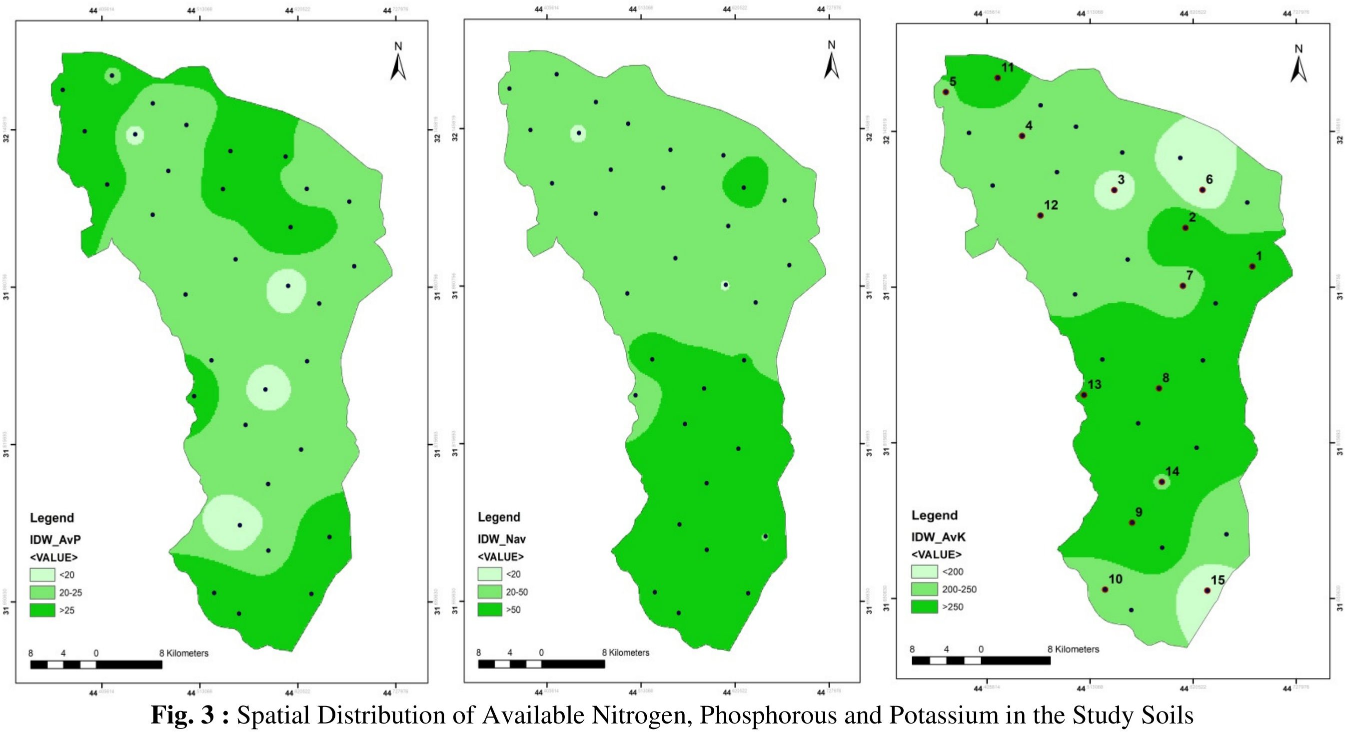

Fig. 3 : Spatial Distribution of Available Nitrogen, Phosphorous and Potassium in the Study Soils

Suggested soil fertility properties depending quality index

After determining the types of soil quality as they are presented in Table (2) that is found in section of the Materials and Work Methods, a suggestion was made to use the total of total properties in determining the quality class according to the fertility properties and for the purposes of fertility evaluation in the soil management plan and its uses. After collecting the limits of the upper, middle and lower types separately, and then determining the quality class as a measure of what appears in the types after its application. The following properties were adopted to determine the quality class: the content of organic matter or organic carbon, total nitrogen content, available nitrogen content, available phosphorous content, available potassium content

Assessing the Ranges of properties

These properties considered as part of the properties of evaluating soil quality, the good values of these properties refer to a good quality class. Table (4) presents the upper, middle, and lower limits for determining the class of soil quality as a proposal that can be added to or modified in the future by adopting other properties as needed and determined by the problem of the study area. For example, the soil interaction always has an effect on the available of many nutrients, but this properties is settled because it is almost constant in a single geographical area such as the Iraqi Mesopotamian plain.

Table 4 : The Upper, Middle and Lower Limits of the Fertility Properties and the Assessment of the Soil Quality Index Class

OM (%)	>2.5	2.5-1.25	<1.25
	3	2	1
TN (%)	>0.15	0.15-0.1	<0.1
	3	2	1
AvN (mg.kg^{-1})	>50	50-20	<20
	3	2	1
AvP (mg.kg^{-1})	>25	20-25	<20
	3	2	1
AvK (mg.kg^{-1})	>250	250-200	<200
	3	2	1
Total	15	10	5
	Good	moderate	Poor

This assessment was used to obtain the evaluation of the total properties of the study samples. Table (5) shows the results of this evaluation applied to the study samples. The grades were: 0-5 poor (P), 5-10 moderate (M), 10-15 good (G). Figure (4) also shows a map of the spatial distribution of soil quality classes according to the proposed system in this study. It is noticed from figure (4) that there are two classes of prevalence in the study area, namely the moderate type and the good type, depending on the proposed fertility properties. It is also noted that the good class was prevalent in the central to the south part of the project, while the moderate class prevailed in the northern to the central part of the project, and this is certainly due to the influence of the hydrosequences on the one hand and the distribution of general soil properties and fertility on the other hand, although The incomplete drainage class was prevalent in the south of the project, but the quality was good, since these areas were cultured with grain such as wheat, barley and rice, which made the ends of the hydrosequences appropriate in terms of the soil content of the elements available for the plant.

Table 5 : Results of the Suggested Soil Quality Assessment and Quality Class

Location	OM	TN	AvN	AvP	AvK	SUM	QI
1.	1	1	2	2	3	9	M
2.	2	1	3	2	1	9	M
3.	2	1	2	3	1	9	M
4.	2	1	1	1	2	7	M
5.	2	1	2	3	2	10	M
6.	1	1	2	3	3	10	M
7.	2	1	1	1	2	7	M
8.	2	2	3	1	3	11	G
9.	2	3	3	1	3	12	G
10.	2	3	3	3	2	13	G
11.	2	1	2	2	3	10	M
12.	2	1	2	2	2	9	M
13.	1	1	3	3	1	9	M
14.	2	1	2	3	3	11	G
15.	1	1	3	2	2	9	M
16.	2	1	2	2	2	9	M
17.	2	1	2	2	2	9	M
18.	2	1	2	3	2	10	M
19.	2	1	2	3	1	9	M
20.	2	1	2	2	2	9	M
21.	2	1	2	3	2	10	M
22.	2	1	2	3	2	10	M
23.	2	1	2	2	2	9	M
24.	2	1	3	2	3	11	G
25.	2	2	3	2	3	12	G
26.	1	1	2	3	2	9	M
27.	1	2	3	3	2	11	G
28.	2	2	3	2	3	12	G
29.	1	1	3	2	3	10	M
30.	2	1	3	2	3	11	G
31.	2	1	2	2	3	10	M
32.	2	1	2	2	2	9	M
33.	2	1	2	2	2	9	M

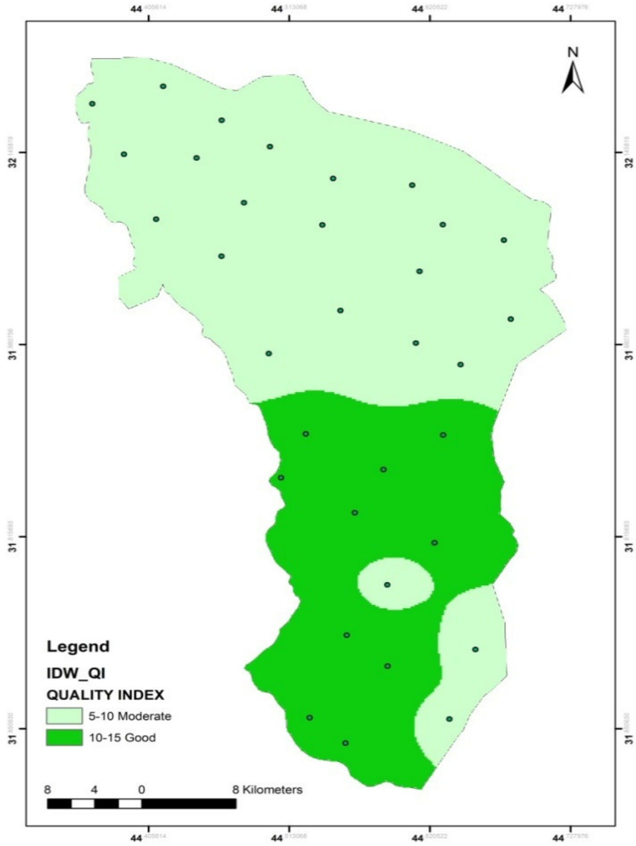

Fig. 4 : Classes of Soil Quality in the Study Area

Conclusions

- The results showed that the organic matter distribution map and organic carbon appear similar, as the highest content of organic matter and organic carbon was in the thirteenth pedon, which falls in the third transects.
- The results of the study showed the spatial distribution of some of the fertility properties in the Kifl Shenafiya project, under the influence of the hydrosequences concept, which could have a major role in developing soil management plans for this project.
- The available potassium content did not show a clear trend in the spatial distribution. However, it can be observed that the lower areas of the hydrosequences were somewhat higher in their content of available potassium compared to the other two classes.

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