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Comparison of Some Land Suitability Evaluating Methods for a Selected Gypsiferous Part in the Northern Karma Region for Irrigated Agriculture

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Abstract: To compare the efficiency of three systems to evaluate the suitability of Gypsiferous land for irrigated agriculture, an area of 8885.4 hectares was selected in the Tharthar region – Iraq within the Euphrates terrace, which formed at Pleistocene period and mainly consisted of gypsum, the study included a semi-detailed survey of the area's soil using the Free-lance method, by selecting three parallel transects, according to the variations in texture class, soil salinity and content of gypsum, five representative pedons locations were identified and morphologically described, also soil samples from each horizon were obtained, as well as we obtained water samples from the Euphrates river-Tharthar canal and every wells located in the study area, it's transferred to the laboratory and the required analyzes were performed. The result showed the predominance of the medium soil texture class and slightly saline soil class (S1) in the study area, with a decrease in the soil carbonate content, on the contrary the soil gypsum content was increased. All wall waters was salinity, which poses a danger to agricultural use, compared to the water of the Euphrates river. A discrepancy was observed between the obtained land suitability classes. While the Sys and Verheye, 1972 system showed two poor suitability classes, Sys *et al*. 1991 and Al-Baji *et al*. 2010 has improved the appropriateness of the varieties, but the Kadhim, 2012 system was the best in terms of application in order to include the quality of irrigation water within the classification, so its results were more close to the reality diagnosed during the field visits to the study area and the questionnaire from the land users of the region.

Keywords: Gypsiferous soils, Land evaluation systems, Suitability of the land, Tharthar area.

Introduction

Soils and their communities in lands are basic economic resources that have a variety of uses, foremost are agricultural usage, and this uses in themselves are diverse, and they are among the tasks of soil management. Soil management will not be able to perform its function unless it begins its efforts by first knowing the existing types of soils in the specific geographical area. (Baritz *et al*., 2018). Detection of soils and their geomorphological and pedological interpretation and the accompanying changes in the properties of soils chemically, physically and biologically is one of the most important tasks required to determine the administrative procedures to be implemented to manage these lands (Vincent *et al*., 2018).

Land evaluation is one of the most important systems adopted on an international scale with the aim of maintaining the sustainability of these resources as an important part of the agricultural planning process to formulate a near and long-term national policy.

The process of evaluating the land provides the information and recommendations necessary to determine the types of crops suitable for cultivation and to determine the appropriate areas for the cultivation of these crops, as well as the selection of appropriate management alternatives. This process requires the integration of information related to each of the land, its use and climate. Efficient agricultural planning processes require accurate and high-quality information and data about the various environmental and material-human resources in a way that is available to stakeholders in the agricultural sector (Aldabaa *et al*., 2010).

Al-Ani (2002) explained when studying the evaluation of lands with varied gypsum content in Salah al-Din Governorate for the purposes of irrigated agriculture, the suitability of the region's lands for the cultivation of wheat and barley crops at different levels compared to the cultivation of maize due to the determination of the severe climate as well as the depth factor and soil content of gypsum.

In a study carried out by Muhaimeed *et al*. (2016), when he studied the temporal change in land suitability for wheat cultivation at Al Shehemia project in Wasit Governorate that most of soil units are highly suitable for wheat growing with class S1 and consists about 85.34% from the total area, and 10.90% for N1 and N2 classes in 1972 year (Sys & Verheye, 1972; see Rashed, & Hassan 2019). Land suitability for cultivation this crop was increased to 92.37% for class S1 in 2014 due to the decrease in soil salinity.

The results of the evaluation of the characteristics of the land indicated that the main limiting factor for cotton cultivation in the projects of April 7, North Kut and Al Majjar Al Kabeer in Iraq is the soil content of calcium carbonate, with the appearance of the hazel variety as a major determinant factor within the projects of North Kut and Al Majjar Al Kabir, as well as soil salinity (Al-Bayati & Al-Azzawi (2017).

Abd El-Aziz (2018) was classified and evaluated the lands of Tushka region, Aswan Governorate, Egypt for agriculture by three evaluating methods, in, the capability of soils according to the Automated Land Evaluation System program (ASLE program) (Ismail *et al*., 2001; See Rashed & Hassan, 2019) was good (C2) and fair suitable (C3), moderate suitable (S3) using MicroLEIS (Cervatana model) and good, fair and poor using Modified Storie Index. Most of the selected crops were found to be the best grown ones on soils of the S2 and S3 suitability classes by ASLE program. Also, most of the selected crops were moderately (S3) and marginally suitable (S4) by MicroLEIS-ALMAGRA model (De la Rosa *et al*., 2004). The main limitation factors of the study area for crop production were soil texture and soil depth.

Al Jaberi & Al-Atab (2020) showed the suitability of Al Salam district-IRAQ lands for growing cereal crops to the presence of three varieties, which S1 (very suitable) Within soil series DM97 formed approximately 23.76% of the total area, and S3 (moderately suitable) in soil series MM11 and DM95 than formed 6.03 and 32.48 % respectively of soils in the study area. As for S4 (few suitable) included the soil series MM9, which constituted approximately 21.14

% of the total soil. The results shows three varieties of the land suitability for pasture crops which S2 within soil series DM97 formed 23.76% of the total soil series and S3 in soil series MM97 and DM95 were formed 6.03 and 32 respectively and N within soil series MM9, formed approximately 21.14% from study area.

Al Dulaimi *et al.* (2020) showed that the climate of the Zakhekha (West of Al-Anbar governorate) region is not specific to the growth of this crop, and the assessment of the suitability of the land for sesame cultivation by irrigation in the region has shown that most of the region's lands are within the moderately class S2 form 78.14% of the total area of the region and the fertility status was the limited factor, while the marginally class S3, it constituted 12.51%, while the currently inappropriate and future class N2 constituted 9.35%. Therefore, the current study aims to compare some methods of evaluating the suitability of the land for irrigated agriculture for a selected part of the Tharthar gypsum lands.

Material & Methods

Study sites

Study area is located between 3718000 – 3730000E longitudes and 358000 – 371000N latitudes, it's bounded from the north by Tharthar Lake and the west by Fallujah – Tharthar road (Fig. 1).

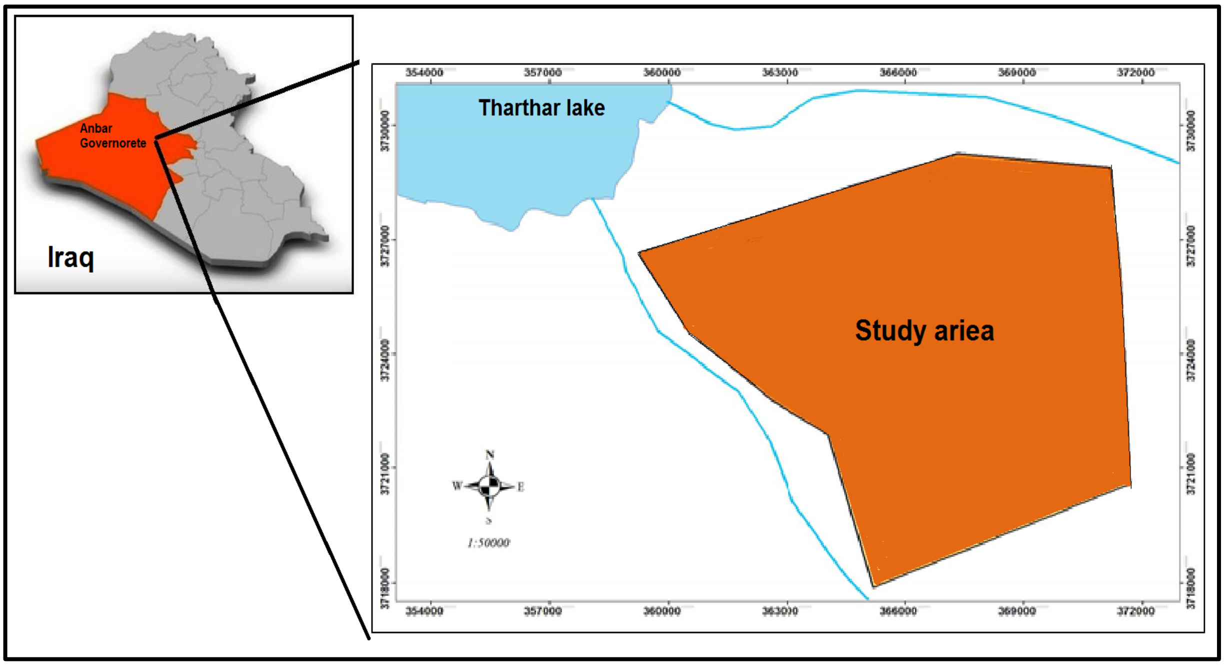

Fig. (1): The administrative location of the study area.

Preliminary execution

It was included collecting the following information:

A-Topographical and physiographic as well as geological maps

B-Climatic data

C-Information on the use of land for agriculture.

Physiographic and formations of the region

The height of the area ranges between 60-80m above sea level in fig. (2). The area is one of the Euphrates terrace formed during the Pleistocene period. It consists mainly of gypsum, which is mainly from lower Al Fars formations, and as a result of its dissolution and re-deposition, the secondary gypsum is formed in its current form is about three meters thick, on top of a gravel layer 1m thick, followed by a layer of sand. As for the topsoil, the wind sediment whose thickness varies according to the topography of the land.

The climate of the region

The climatic data for the study area were obtained from the Ramadi weather station for the period 2010-2020, it indicated that the region's climate was dry in summer and cold in winter, and that the highest temperature was 43.4C° in the July, while the lowest average temperature was 4.4 C° recorded in the January month, and the amounted of rainfall reached 117.5 mm. The rain starts from October and ends in May, and the highest average rainfall was 24.4mm in March. By observing the results in table (1), it is clear that drought is the dominant feature Contrast times throughout the year, which begins in May and ends at the end of October, this period is characterized by the absence of rain and accompanied by high rates of evaporation with a decrease in relative humidity. Based on the results of the Thornthwaite equation shown in table (2), it appears that the climate of the study area is dry.

The land use in the area

Agriculture in the region depends on irrigation, and the land is irrigated by pumping from the Tharthar-Euphrates canal or from groundwater by digging wells. The most important crops that are predominantly cultivated in the region are onions, melons, tomatoes, wheat, barley, alfalfa and corn, (field surveys indicated that onions and watermelon are the most successful crops in region). In addition to the existence of a part of the land by the cultivation of *Tamarix*, *Casuarina*, olive and *Eucalyptus* trees, which are irrigated by drip.

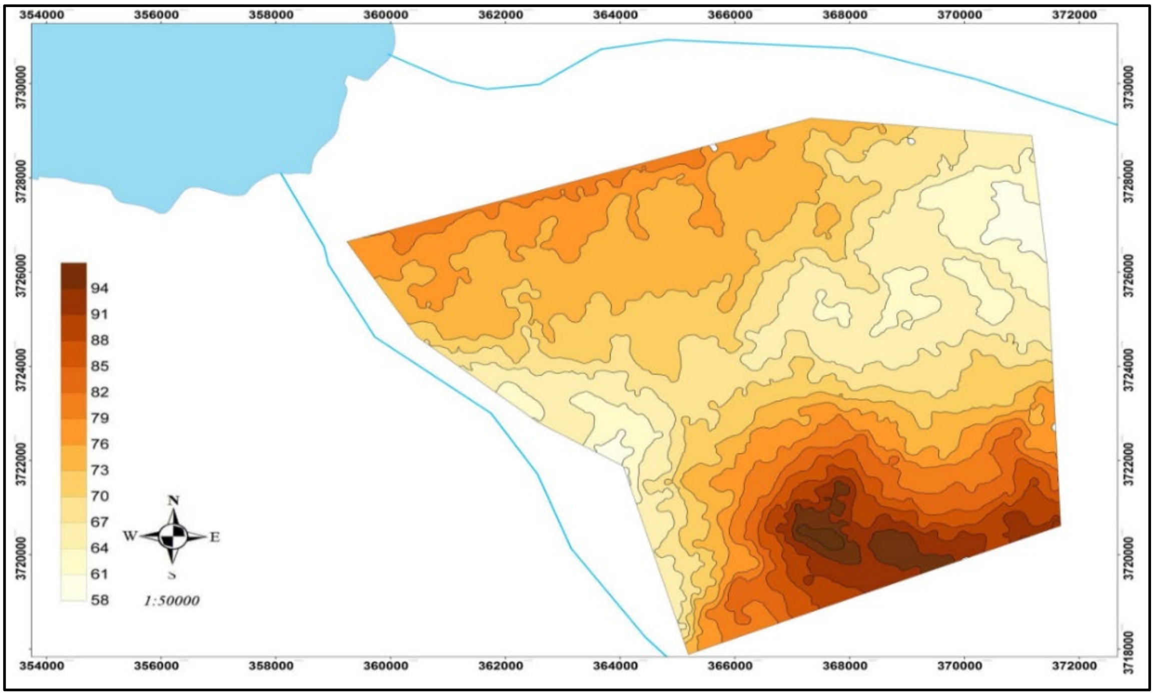

Fig. (2): The digital map of the study region.

Table. (1): Some climatic data for study area from the Ramadi metrological station for a period from 2010-2020.

Month	Monthly temperature average C°	Monthly minimum temperature average C°	Monthly maximum temperature average C°	Monthly rainfall average mm	Monthly average relative humidity %	Monthly rate of evaporative mm
January	9.5	4.4	15.6	21.5	86	73.1
February	2.0	6.0	8.6	17.2	78	9.3
March	16.1	9.5	23.1	24.4	73	184.5
April	21.7	14.9	28.9	15.1	66	216.3
May	28.1	20.1	30.1	4.0	53	403.8
June	32.7	23.7	40.9	-	40	533.8
July	34.8	25.8	43.4	-	37	600.5
August	34.2	25.0	43.3	-	9	523.0
September	30.0	22.1	39.5	-	45	370.5
October	24.6	16.2	33.0	1.6	54	247.0
November	16.8	15.5	29.0	15.0	70	134.0
December	11.0	5.7	17.5	18.7	84	61.4
Annual rate	21.8	15.7	29.4		57.9	
The sum				117.5		278.9

Table (2): Result of the Thornthwaite equation (Rain sufficiency) to determine the climate of the study area.

Climate station	Total rainfall (mm)	Annual temperature average (C)	Dryness coefficient mm/C°	Type of station climate
Al-Ramadi	117.5	21.8	3.45	dry

Thornthwaite equation: $D=\sum_{12} 1.65\left(\frac{R}{T+12.2}\right)^{10/9}$

D: dryness coefficient (mm/C), R: Total rainfall (mm) and T: Annual temperature average (C)

Field execution

It included conducting a semi-detailed survey of the area's soil using the Free-lance soil survey method by selecting three transects parallel and perpendicular to the sedimentation source, taking into account the passage from most of the ground elevations diagnosed in the area. Soil samples obtained by auger after fixing its geographical location by a GPS device and diagnosing the vertical variation in the characteristics of the texture class and salinity as well as soil gypsum content, and according to it the locations of the pedons were determined, taking into consideration the nature of the variation in the type and density of the natural vegetation cover of the examination site, the number of exanimated auger holes were reached 53. Based on it, five pedons where selected which representing the study area soils, and the fig. (3) shows the locations of the selected auger holes and pedons for the study. Soil was morphologically described according to the Soil Survey Staff. (2002). Soil samples bringing them to the laboratory for chemical and physical analyzes. In addition to obtaining water samples from the Euphrates river-Tharthar channel and from four wells in the area.

The water samples were kept in polyethylene bottles and transferred to the laboratory for chemical analysis (See fig. 3) shows the locations of the water samples.

Laboratory execution

The soil samples were air dried, crushed and sieved through a sieve with a diameter of 2 mm, and some physical and chemical properties were estimated, which were required by assessment the suitability of the land used later according to Page *et al.* (1982). Irrigation water samples were chemically analyzed according to the requirements of the food and Agriculture Organization of the United Nations (Ayers & Westcot, 1994).

Office execution

Soils were classified according to the American classification system (Soil Survey Staff, 2014) to the family level and completed for the series level according to system suggested by Al-Agidi (1981) for the Iraqi developed soils. Then the Soil classification maps produced using GIS.

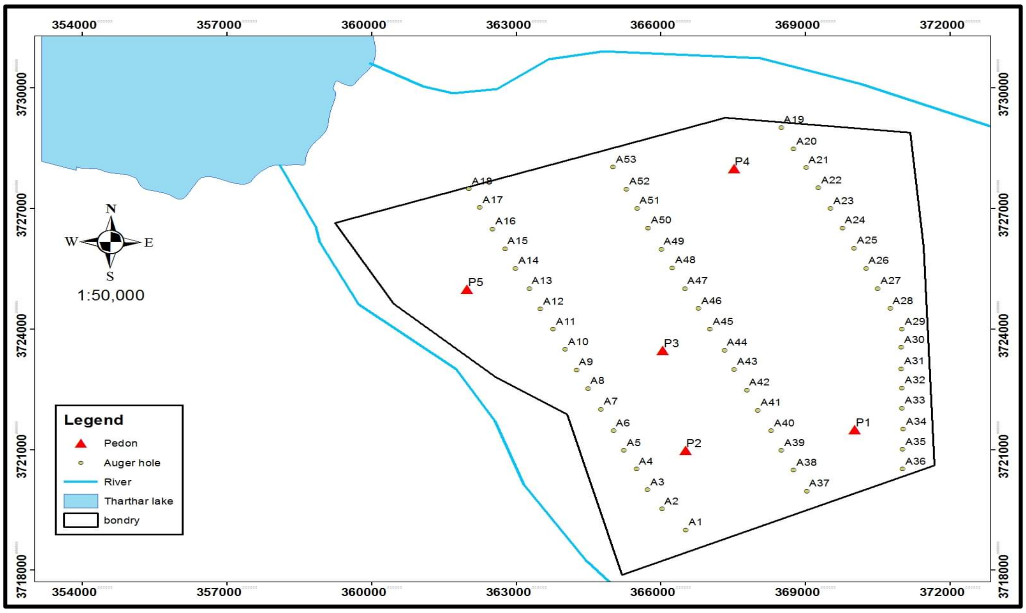

Fig. (3): Location of auger hole, the pedons, and irrigation water samples.

Available irrigation water was classified according to the International Food and Agriculture Organization, and determined its limitation for agricultural use.

The suitability of the lands of the area under study for irrigated agriculture was evaluated by three evaluation methods:

1- The Sys and Verheye, 1972 method
For irrigated farming, according to the following equation:

$$Ci = A.B.C.D.E.F.G \quad ...(1)$$

Where:

A: texture class, B: Soil depth, C: Soil carbonate content, D: Soil depth, E: Soil salinity, F: Drainage class, G: land sloping.

After extracting the values of the evidence for each indicator from special tables are multiplied by each other, and the percentage of the value of the index of suitability Ci is obtained, and compared with the value of the items shown in (Table 3).

Table (3): Suitability classes of land evaluation percentage according to Sys and Verheye, 1972 method.

Class No.	Soil condition	Percent of suitability index Ci
I	Excellent	80<
II	Suitable	80-60
III	Little suitability	60-45
IV	Often Non suitable	45-30
V	Non suitable	>30

2- The Sys *et al.* 1991 and Al-Baji *et al.* 2010 method.

The suitability of the land is evaluated in this method by dividing the factors affecting the suitability of the land for irrigated agriculture into four section, which are the physical properties including soil permeability, and chemical properties included the salinity and alkalinity state, drainage properties and environmental factors such as land slope, according to the following equation:

$$Ci = A + B/100 * C/100 * D/100 * E/100 * F/100 \quad \ldots(2)$$

Ci: land suitability index, A: texture class, B: land slope, C: soil carbonate content, D: drainage class, E: Soil salinity, F: soil depth.

To determine the suitability of the land for any of the irrigation methods, the Sys *et al.* (1991) equation is combined with the Albaji *et al.* (2010) to evaluate and compare the suitability of the land, and then compare the suitability of the land with table (4) to determine the type of suitability of those land

Table (4): Land suitability classes and the evaluation percentage according to the Sys *et al.* (1991) and Al-Baji (2010) method.

Index value	Class condition	Class symbol
>80	High suitability	S1
60-80	Moderately Suitable	S2
45-59	Marginal suitability	S3
30-44	Currently unsuitable	N1
29<	Often unsuitable	N2

3- Kadhim 2012 method

In this method the suitability of lands for irrigated agriculture calculated according to fallowing equation:

$$\ldots(3)\ Siw = Q\ x\ S1\ x\ A1$$

Where:

Si_w: The index to suitability of water for irrigated agriculture, Q: abundant water for irrigation, A_1: adjusted percentage of sodium adsorbed in irrigation water, S_1: irrigation water salinity

$$(4)\ Sis = D\ x\ T\ x\ C\ x\ G\ x\ W\ x\ S2\ x\ S3\ x\ A2\ \ldots$$

Where:

Si_s: index of land suitability for irrigated agriculture, D: depth of soil, T: soil texture class, C: soil carbonate content, G: soil gypsum content, W: groundwater table depth,

S_2: land's slope and topography, S_3: soil salinity, A_2: Soil exchangeable sodium percentage. The average values of the irrigation water and land suitability index were calculated by collection them and dividing the result by 2, considering that the two factors share the importance for irrigation purposes, and the suitability classes are found according to (Table 5).

Table (5): Land suitability classes and the evaluation percentage according to Kadhim 2012 method.

Land class	Limitation level	Value of class index	The evaluation
S1	Non limitation	%75<	98-100
S2	little	%50-75	85-98
S3	Moderate	%25-50	65-85
N1	Strong	%12-25	45-65
N2	Very strong	<%12	<45

Results & Discussion

Results of table (6) showed the dominance of silt particle in the soils of studied pedons, its ranged between 346-577 gm.Kg^{-1} recorded at Ayk horizon for P5 and Apk horizon for P1 respectively, followed by the sand particle with a content ranged between 116-452 gm. Kg^{-1} recorded at horizon Apk for P2 and horizon Ayk for P5 respectively, while the soil content from clay ranged between 163-360 gm.Kg^{-1} recorded at horizon Apk for P1 and horizon Bky for P3 respectively, the predominance of silt and clay particles may be attributed to the sedimentation conditions and the location of the pedon in relation to the sedimentation source and the contents and intensity of the momentum of the carrying water (Al-Bayati *et al.*, 2021), with predominance of the moderate soil texture classes.

Fig. (4) shows a map of the spatial distribution of soil texture classes for the study area, and table (7) shows the cartographic analysis of the map in fig. (4), its noted that the class 33/3 was formed the largest area in the region with a percentage of 34.4% (3047.6 hectare), followed with class 32/3 with a rate 31.6% (2807.7 hectare), while the class 23/3 recorded the lowest percentage 15.9% (1412.8 hectare) recorded in the northern part of the study area and close to Al- Tharthar lake.

The results of table (6) show the electrical conductivity values of pedons soils. It's varied between low and high salinity, also the values of this chemical property is varied vertically in the pedons with depth, this can be attributed to the nature of the exploitation of the soil, the heterogeneity of the soil texture and the lack of moisture (Saleh *et al.*, 2019). The highest electrical conductivity value which recorded was 15.1 dS.m^{-1} at the horizon Apk in P1, while the lowest value 2.5 dSm^{-1} was recorded at the horizon Apk in P2. These results were agreed with Al-Zubaidi & Pagel (1974) (See Awad & Hammadi, 2006).

Table (6): Some pedological characteristics of the soils of studied pedons.

Pedon No./Soil Series	Geographical location	Horizon	Land slope %	Drainage class	Depth cm	Particle Size distribution Gm.Kg^{-1}			Texture class	ECe	pH	OM	Lime	Gypsum	CEC Cmol(+)Kg^{-1}	ESP
						Sand	Silt	Clay				gm.Kg^{-1}				
P1 1/132XKW	370000E 3721500N	Apk	0-1	Well	0-16	260	577	163	Sil	15.1	7.9	6	240	10	17.1	6.1
		Bk			16-34	261	390	349	Cl	12.3	7.7	3	210	60	15.9	2.6
		Cy			34-65	262	573	165	Sil	8.6	7.4	1	40	450	7.3	1.8
The Mean weight						261	524	215	Sil	11.2	7.6	2.8	136.3	233.7	12.1	3.1
P2 2/132XKW	366800E 3721000N	Apk	0-1	Well	0-20	116	551	333	SiCl	2.5	7.9	5	240	10	15.3	1.1
		Bk			20-50	264	569	167	Sil	5.1	7.7	2	220	20	13.3	1.6
		Cy			50-78	265	567	168	Sil	5.5	7.5	1	15	390	8.4	2.3
The Mean weight						226	564	210	Sil	4.6	7.7	2.4	151.5	150.3	12.1	1.7
P3 3/122XKW	366000E 3723500N	Ak	0-1	Well	0-21	266	565	169	Sil	6.6	7.8	6	220	60	15.4	4.1
		Byk			21-50	263	377	360	Cl	6.4	8.0	3	310	430	12.5	3.6
		Cy			50-68	268	561	171	Sil	5.3	7.4	1	120	490	7.4	3.1
The Mean weight						265	484	251	L	6.2	7.8	3.4	231.9	331.6	12.0	3.6
P4 4/132XKW	367500E 3728000N	Ak	0-1	Well	0-18	269	559	172	Sil	3.3	8.0	5	220	60	13.0	1.9
		Byk			18-48	270	557	173	Sil	3.1	7.7	4	140	430	10.5	1.6
		Cy			48-69	171	508	321	SiCl	2.7	7.4	1	40	461	7.4	1.5
The Mean weight						240	542	218	Sil	3.0	7.7	3.3	130.4	342.9	10.2	1.6
P5 5/122XKW	362000E 3725000N	Ayk	0-1	Well	0-22	452	346	202	L	4.3	7.7	4	200	50	11.2	1.3
		Byk			22-47	273	551	176	Sil	5.5	7.6	2	160	462	9.9	2.5
		Cy			47-72	274	549	177	Sil	7.6	7.5	1	50	493	6.5	1.8
The Mean weight						328	488	184	L	5.9	7.6	2.3	134.0	346.9	9.1	1.9

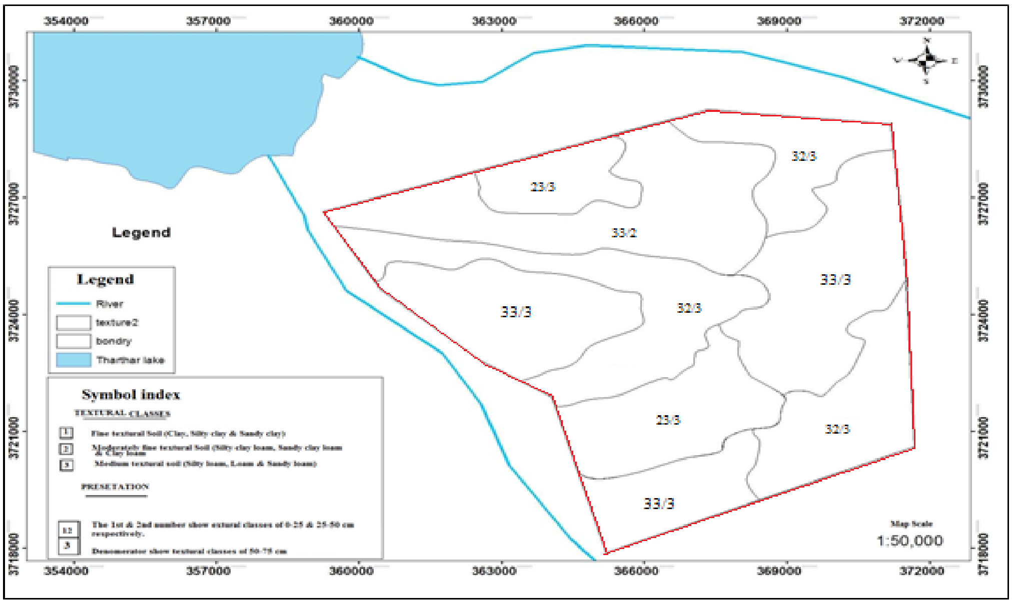

Fig. (4): The map of spatial distribution of texture classes which recorded in the study area for a depth of 0-75 cm.

Table (7): Cartographical analysis the map of spatial distribution of texture classes in the study area.

Texture class	Area (ha)	Percentage from area (%)
33/3	3047.6	34.3
23/3	1412.8	15.9
32/3	2807.7	31.6
33/2	1617.2	18.2
Total	8885.3	100

Fig. (5) shows the spatial distribution of salinity classes in the study area character horizontally between the pedons and vertically between the horizons of each pedon is due to be affected of the value of this chemical character with interaction of several factors, including the mineral composition, the concentration of salts, and the concentration of the hydrogen ion, as well as the variations in their geomorphological locations, whose all effects were reflected on the pattern and distribution of salts and carbonates in them with some significant differences between the studied pedons, whereas, P1 recorded the highest rate for this character P3.

It is noted from table (8) that the salinity class (S1) was recorded the highest percentage of the area 71.1% with an area of 6317.4 hectares, compared to the salinity class (S3) with a rate of 3.8% and an area of 337.6 hectares. The results of table (6) indicate that the values of soil reaction for all pedons soil were within the range 8.0-7.4, and according to the Soil Survey Staff (2002), the studied soils are within neutral to light alkaline class, this is due to the presence of large amounts of carbonate, also the presence of gypsum in most soils prevents it from having a sodic property. The reason for the variation in the values of this was recorded the lowest rate. Fig. (5) shows the spatial distribution of salinity classes in the study area character horizontally between the pedons and vertically between the horizons of each pedon is due to be affected of the value of this chemical character with interaction of several factors, including the mineral composition, the concentration of salts, and the concentration of the hydrogen ion, as well as the variations in their geomorphological locations, whose all effects were reflected on the pattern and distribution of salts and carbonates in them.

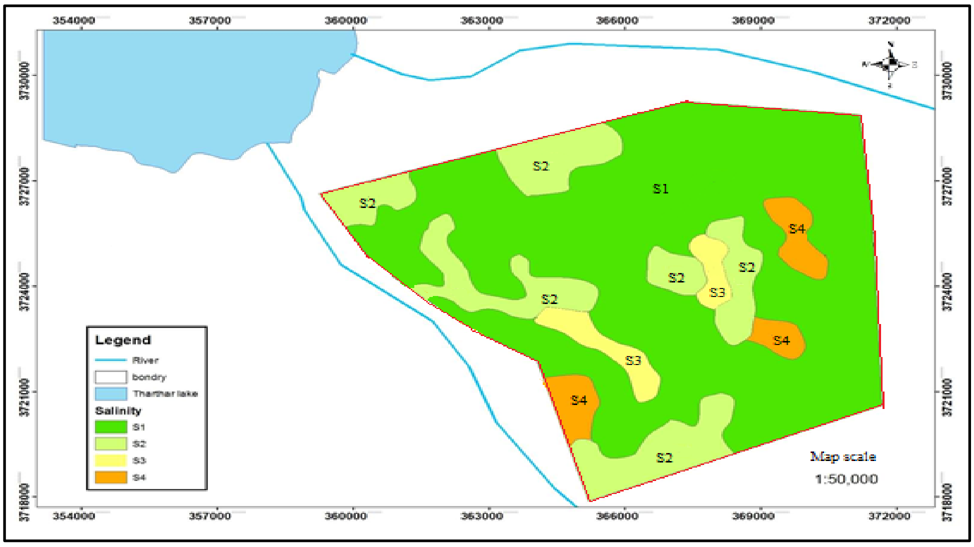

Fig. (5): Map of spatial distribution of salinity class in study area.

Table (8): Cartographical analysis of salinity map of the study area.

Salinity class	Area(ha)	Percentage from area (%)
S1	6317.4	71.1
S2	1794.8	20.2
S3	337.6	3.8
S4	435.5	4.9
Total	8885.3	100.0

The results of soil organic matter content (Table 6) showed increase the quantity of this property in the upper horizons and it was decreased with depth in the all studied pedons, the organic matter values was varied in arrange of 1-6gm.Kg^{-1}, and the mean weighted rate of this characteristic ranged between 2.3-33gm.Kg^{-1} recorded in P4 and P5 respectively, the decreased reason in the amount of organic matter is due to paucity of vegetation cover as well as the high temperatures within the desert conditions prevailing in region, which cause its oxidation and decomposition. The carbonate content in the studied soils varied within the range of 15-310 gm.Kg^{-1}, and it's content was decreased with depth in the pedons, due to increasing soil content of gypsum in it, the reason for this can be attributed to the genetic processes that obtain calcium carbonate as part of the parent material which was transported to the region by river deposits from northern Iraq, southern Turkey and western Iran. As well as weathered limestone within the Euphrates limestone formation, where disintegration processes contribute to solution hydrolysis and leaching as genetic processes influencing the formula for distribution of total carbonate in the region (Al-Bayati *et al*., 2021). The proportions of gypsum varied horizontally and vertically within pedons of study, due to influence of nature of the parent material and the geomorphology of surface which affected it. The soils content from gypsum was distributed in range of 10-493 gm.Kg^{-1} at the Apk horizon for P1 and horizon Cy for P5 respectively (Table, 7). Soil content from gypsum showed an increase with the depth at all studied pedons, the reason for this increasing is due to the gypsum constitutes the parent material for the soil of the region. The cationic exchange capacity results (Table, 6) showed values ranged between 6.5- 17.1 Cmol (+) Kg^{-1}, with clear decreasing in the values of this characteristic with increasing soil content of gypsum, the reason for this can be attributed to the lack of negative charges on the surface of gypsum crystals. The higher values for CEC was recorded in the surface horizons, which may be attributed to the high content of the soil from the organic matter with the low percentage of gypsum in this horizon.

The results of exchangeable sodium percentage in studied soils was ranged between 1.1-6.1, which was indicates that there is no risk of sodium in the soils of the region, these results agreed with Al-Dabbas *et al*. (2010).

Its noticeable from the result of table (9) that the electrical conductivity values of irrigation water in the region ranged between 2.4-18.8 dSm^{-1}, and according to the FAO system, all well water in the region values for this chemical property was exceeds 3 dSm^{-1} which are very dangerous for agricultural use. Except the Euphrates –Al-Tarthar canal water, which was within slightly to moderate risk class (0.7-3.0 dSm^{-1}), which indicates the need to take the necessary management when using these water for irrigation. In terms of the effect of both the salinity indicators and the sodium adsorption ratio, according the same water evaluation system, all types of water were not risk to the permeability of the soils in region.

As for the effect of the risk elements on sensitive crops, it is noted that they are dangerous when used in both surface irrigation and spraying methods, due to increase of sodium adsorption ratio in them, above appropriate limits according to the evaluation system. As for the risk of chloride ion, it is noticeable that the water of well G1 is risk for use in both irrigation systems because the concentration of chloride ion in it is more than 10 Mol.L^{-1}, while the water of other wells and the water of the Euphrates river canal were within the slightly to moderate risk for irrigation in both irrigation systems.

As for the effect and risk of the bicarbonate ion, the results in table (9) showed that all the water of the area are do not have a negative impact of this ion when used in both irrigation methods. As for water reaction values, it’s ranged between 7.3- 8.0, they were within the normal limits of water use for irrigation, which ranged 6.5-8.4. All values are less than “8.4”, which leads to the deposition of calcium carbonate in the soil when adding irrigation water, while if the value is greater than “8.4”, then adding irrigation water leads to the dissolution of calcium carbonate in the soil. Therefore, we do not expect any manifestations to occur abnormal growth of plants due to inappropriate pH values of the irrigation water used. It is noted from the results of the analysis of indicators of irrigation water available in the region is that there is no negative indicator determining its suitability for irrigation, and this is consistent with Jabbar & Al-Bayati (2022). What was observed when they studied the irrigation water available in the agricultural districts of the Ramadi district.

Evaluating the suitability of the region's lands for irrigated agriculture according to the selected systems:

1-Sys and Verheye system, 1972

It is clear from the results of table (10), Fig. (6) and table (13) that there are two types of land in the region which are poorly suitably (class III) and often unsuitable (class IV), the suitability index of the land according to this system ranged between 41.0-58.1, the main determining factor for suitability at class III in the first degree, the depth of the soil and soil content of gypsum, and the second degree the factor of texture class, alkalinity and salinity of the soil, as for the land class IV, the factor of soil content of gypsum recorded the dominance in terms of effect, followed by depth and lesser degree the soil texture class. In terms of the spatial distribution and what each land type occupies from the total study area, the class IV had a dominance with 65.7% and the remaining of area 34.3% was for the class III. The reason is that the high gypsum content of the soil is a limiting factor for plant growth, in addition to the limited depth of the soil, which causes a limitation in the size of the plant's root system and the ability of the plant to obtain its requirements for nutrients and moisture, which are important in conditions similar to those of the study area, which are characterized by drought. According to the results that were presented through the use of this system, it can be said that the Sys & Verheye (1972) system does not match the reality of the situation and that the determinants and scopes of this system must be re-reviewed and modifications made to it to suit the conditions of Iraqi soil (Al-Helou & Jubier, 2023).

2-Sys *et al.* (1991) system modified by Al Baja *et al.* (2010)

It is clear from the results of table (11), fig. (7) and table (13) that there are three suitable land classes for growing annual crops, S1, S2 and N1, where the values of the land suitability index ranged between 38.3-83.8, the determinants of the land class S2 were the depth of the soil, followed soil texture class. As for class N1, the main determinant was salinity as well as soil depth and texture class. In general, this system showed the dominance of class S1 in the region with area of 6890.4 hectares (77.5%), followed by class S2 with 14.1%, and the remaining of the study area 8.4%, was within the class N1, located in the southern part of the study area. Class S1 is considered one of the best lands for agriculture due to the limited factors determining plant growth in it, in terms of soil texture, drainage class, structure, and the salinity of its soil, and it was closest to the observations recorded during the reconnaissance rounds (Al-Jaberi & Al-Atab , 2020).

Table (9): Chemical analysis of the irrigation water sources in the study area.

Water sample No.	The affected Soil	ECw $dS.m^{-1}$	pH	Cations & anions						Adj. SAR $(Mol.L^{-1})^{1/2}$
				Ca^{++}	Mg^{++}	Na^{+}	$SO_4^{=}$	Cl^{-}	HCO_3^{-}	
				$Mol.L^{-1}$						
G1	P1	8.8	8.0	15.8	11.0	32.0	27.0	15.3	1.4	33.37
G2	P2	4.6	7.2	5.0	6.8	22.2	15.1	6.8	0.4	25.84
G3	P3	4.3	7.4	7.6	4.2	17.4	13.2	7.5	0.6	20.24
G4	P4	5.0	7.3	8.8	4.9	20.1	15.4	8.8	0.7	23.55
R	P5	2.4	7.8	6.9	1.8	6.2	7.8	3.5	1.1	9.03

Table (10): Land evaluation of study area according to Sys & Verheye (1972)' method.

Pedon No.	Parameters	Soil Texture class	Soil depth cm	$CaCO_3$ content %	$CaSO_4H_2O$ content %	Salinity and alkalinity	Drainage class	Slope %	Land Suitability index	Soil condition	Land class No.
P1	Actual value	Sil	65	13.6	23.4	11.2/3.1	Well	0-1	55.1	Little suitability	III
	Evaluation percent	90	80	100	85	90	100	100			
	Limitation level	1	3	1	3	2	1	1			
P2	Actual value	Sil	78	15.1	15.0	4.6/1.7	Well	0-1	58.1	Little suitability	III
	Evaluation percent	90	80	100	85	95	100	100			
	Limitation level	1	3	1	3	1	1	1			
P3	Actual value	L	68	23.2	33.2	6.2/3.6	Well	0-1	41.0	Often Non suitable	IV
	Evaluation percent	90	80	100	60	95	100	100			
	Limitation level	1	3	1	4	1	1	1			
P4	Actual value	Sil	69	13.0	34.3	3.0/1.6	Well	0-1	43.2	Often Non suitable	IV
	Evaluation percent	90	80	100	60	100	100	100			
	Limitation level	1	3	1	4	1	1	1			
P5	Actual value	L	72	13.4	34.7	5.9/1.9	Well	0-1	41.0	Often Non suitable	IV
	Evaluation percent	90	80	100	60	95	100	100			
	Limitation level	1	3	1	4	1	1	1			

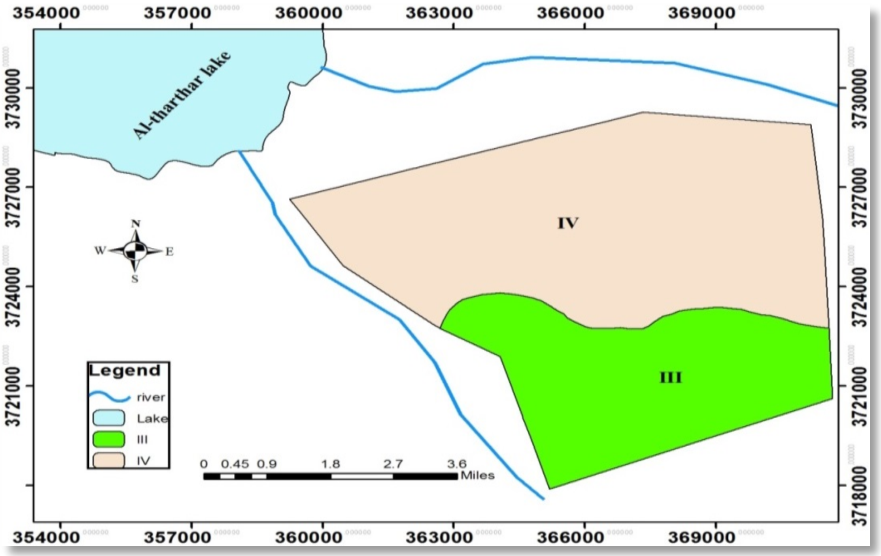

Fig. (6). Map of land suitability for irrigated agriculture according to Sys & Verheye (1972).

Table (11): Land evaluation of study area according to system of Sys *et al*. (1991) and Al Baja *et al*. (2010).

Pedon No.	Parameters	Q	S_1	A_1	Si_w	T	D	C	G	S_3	W	S_2	A_2	Si_s	Si_T	Land class No.	Limitation level
P1	Actual value	Available	8.8	33.4		Sil	65	13.6	23.4	11.2	Well	0-1	3.1				
	Evaluation percent	100	50	25	12.5	98	85	100	85	90	100	100	100	63.7	38.1	S3	Moderate
	Limitation level	1	3	4		1	2	0	2	3	D4	0	0				
P2	Actual value	Available	4.6	25.8		Sil	78	15.1	15.0	4.6	Well	0-1	1.7				
	Evaluation percent	100	75	50	37.5	98	85	100	85	95	100	100	100	67.3	52.4	S2	Little
	Limitation level	1	2	2		1	2	0	2	2	D4	0	0				
P3	Actual value	Available	4.3	20.2		L	68	23.2	33.2	6.2	Well	0-1	3.6				
	Evaluation percent	100	75	50	37.5	98	85	98	60	95	100	100	100	46.5	42.0	S3	Moderate
	Limitation level	1	2	2		1	2	1	3	2	D4	0	0				
P4	Actual value	Available	5.0	23.6		Sil	69	13.0	34.3	3.0	Well	0-1	1.6				
	Evaluation percent	100	75	100	75.0	98	85	100	60	100	100	100	100	50.0	62.5	S2	Little
	Limitation level	1	2	1		1	2	0	3	1	D4	0	0				
P5	Actual value	Available	2.4	9.0		L	72	13.4	34.7	5.9	Well	0-1	1.9				
	Evaluation percent	100	100	100	100	98	85	100	60	95	100	100	100	47.5	73.8	S2	Little
	Limitation level	1	1	1		1	2	0	3	2	D4	0	0				

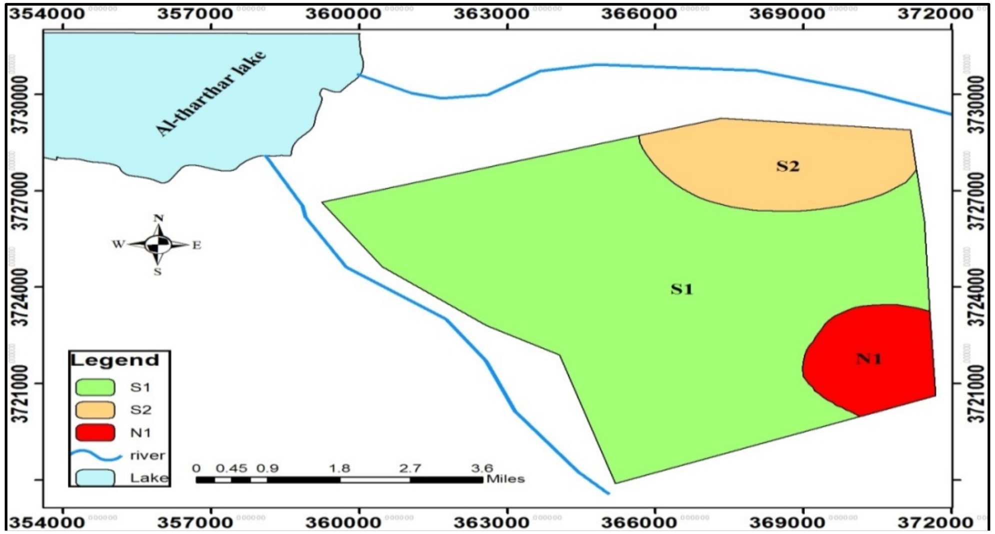

Fig. (7): Map of land suitability for irrigated agriculture according to Sys *et al*. (1991) and Al Baja *et al*. (2010).

Table (12): Land evaluation of study area according to Mohamed Kadhim system (2012).

Pedon No.	Parameters	Soil Texture class	Soil depth Cm	$CaCO_3$ content %	Salinity	Drainage class	Slope %	Land Suitability index	Soil condition	Land class No.
P1	Actual value	SiL	65	13.6	11.2	Well	0-1	38.3	Currently unsuitable	N1
	Evaluation percent	90	85	100	50	100	100			
	Limitation level	1	3	1	3	1	1			
P2	Actual value	SiL	78	15.1	4.6	Well	0-1	83.8	High suitability	S1
	Evaluation percent	90	85	100	95	100	100			
	Limitation level	1	3	1	2	1	1			
P3	Actual value	L	68	23.2	6.2	Well	0-1	83.8	High suitability	S1
	Evaluation percent	90	85	100	95	100	100			
	Limitation level	1	3	1	2	1	1			
P4	Actual value	SiL	69	13.0	3.0	Well	0-1	68.9	Moderately Suitable	S2
	Evaluation percent	90	85	100	100	100	100			
	Limitation level	1	3	1	1	1	1			
P5	Actual value	L	72	13.4	5.9	Well	0-1	83.8	High suitability	S1
	Evaluation percent	90	85	100	95	100	100			
	Limitation level	1	3	1	2	1	1			

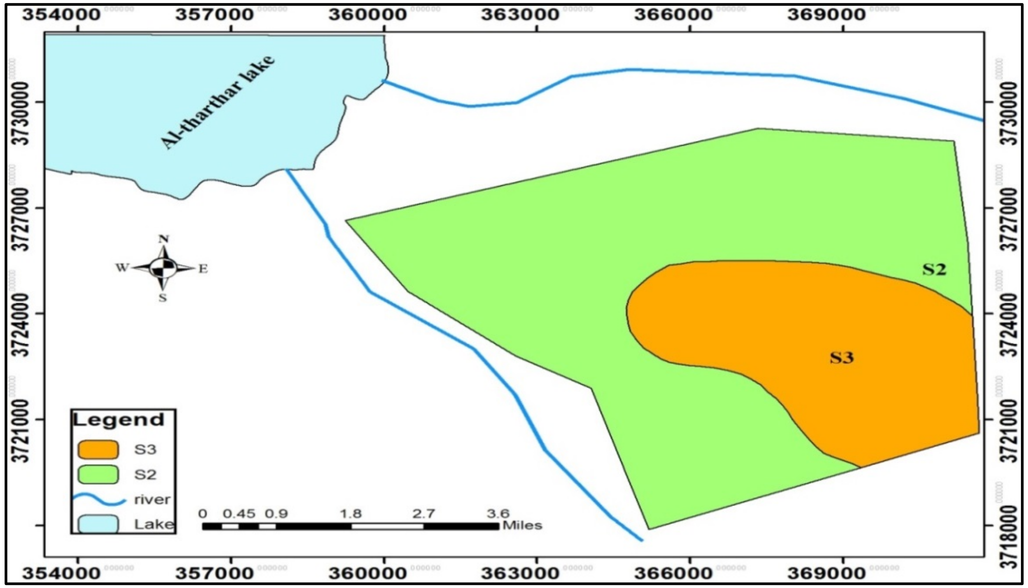

Fig. (8): Map of land suitability for irrigated agriculture according to Mohamed Kadhim (2012)'s system.

Mohamed Kadhim (2012) system

The results of table (12), fig. (8) and table (13) indicated the presence of two classes S2 and S3, the dominance was for class class S2 (with low determinant) with area of 6177.2 hectares (69.6% from total studied area). While the class S3 (with a medium determinant) constituted 30.4%, the land suitability index (Sis) was ranged between 46.5-63.7 recorded at P1 and P3 respectively, The soil content of gypsum was the main limiting factor as showed at P3 and P4 followed by soil depth. It is noticeable from the results of land evaluation according to this system that the irrigation water in terms of abundance, salinity and the sodium adsorption ratio plays an important role with equal ratio of impact.

The water suitability index (Siw) values ranged between 12.5-100.0 recoded at sites P1 and P5 respectively, which affected directly in values of total land suitability index (SiT), that it became a determining factor at sites P1, P2 and P3, while it was contrary on sites P4 and P5, it caused an increasing of land suitability index for irrigated agriculture, which indicates the important of quality irrigation water in evaluating the suitability of land for cultivation. The concentration of ions in irrigation water is the main factor. It determines the amount of water added to the soil, which is responsible for determining the salinity of the soil and the concentration of cat ions and an ions in it, and the ionic composition of irrigation water can it affects the quality of the ions prevalent in the soil solution, as relying on the use of water with a high concentration of a certain ion can leads to the dominance of that ion on the surfaces of the exchange complex and thus affects the readiness and absorption of nutrients, the other, therefore, taking the characteristics of irrigation water when evaluating lands is an important factor in evaluating lands correctly. This result is consistent with the findings of Al-Helou & Jubier (2023) regarding the superiority of the Mohamed Kadhim system (2012) in assessing the irrigation suitability of the lands of the Abu Gharq district within the Babil Governorate compared to the systems of Sys & Verhrye (1972) and Sys *et al.* (1991).

Table (13): Cartographical analysis of land suitability map for irrigated agriculture according to the three evaluation system adopted in research.

Land class	Area(ha)	Percentage from total area (%)
Sys & Verheye, 1972		
III	3044.5	34.3
IV	5840.8	65.7
Sys *et al*., 1991 and Al Baji *et al*., 2010		
S1	6890.4	77.5
S2	1258.6	14.1
N1	736.3	8.4
Mohamed Kadhim, 2012		
S2	6177.2	69.6
S3	2708.1	30.4
Total area 8885.3 ha		

Conclusion

The results obtained by comparing three systems of land suitability have shown a discrepancy in the class obtained: where the system of Sys & Verheye (1972) showed two poor suitability classes. The system of Sys *et al*. (1991) and Al-Baji, (2010) improved suitability classes. But the system of Mohamed Kadhim (2012), was the best in terms of application it take into account the quality of irrigation water in the region within classification, and its results were more close to the reality diagnosed during the field visits to study area and questionnaire from the land users in region. Where it is noted in the field that the average production of wheat in region was 5600 Kg.hectare^{-1}.

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Contributions of authors

A.H.I.A.: Editing, revision, statistical analysis and Interpretation of results.

H.H.F.A.: Writing and reviewed the final manuscript.

M.K.A.: Methodology, and writing the manuscript.

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Conflict of interest

The authors declare that the present study was performed in the absence of any conflict of interest.

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مقارنة بعض طرائق تقييم ملائمة الأرض لجزء جبسي مختار في شمال منطقة الكرمة للزراعة الاروائية

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المستخلص: لمقارنة كفاءة ثلاثة أنظمة لتقييم مدى ملاءمة الأراضي الجبسية للزراعة الاروائية، تم اختيار مساحة قدرها 8885.4هكتار في منطقة الثرثار – العراق ضمن مصطبة الفرات التي تشكلت في العصر الجليدي وتتكون بشكل رئيسي من الجبس، وتضمنت الدراسة مسح شبه تفصيلي لتربة المنطقة بطريقة المسح الحر، من خلال اختيار ثلاثة مسارات متوازية، وفقاً للاختلافات في صنف النسجة وملوحة التربة ومحتوى التربة من الجبس، تم تحديد خمسة مواقع ممثلة للبيدونات ووصفها مورفولوجياً، واستحصال عينات التربة الممثلة لكل افق، وكذلك استحصال عينات من مياه نهر الفرات – قناة الثرثار ومن كل الآبار الواقعة في منطقة الدراسة، ونقلها إلى المختبر لإجراء التحاليل اللازمة. أظهرت النتائج سيادة صنف التربة المتوسطة النسجة وصنف التربة قليلة الملوحة (S1) في منطقة الدراسة، مع انخفاض في محتوى التربة من الكربونات، على العكس من زيادة محتوى التربة من الجبس. وكانت جميع مياه الابار مالحة، مما يشكل خطراً على الاستخدام الزراعي، مقارنة بمياه نهر الفرات. ولوحظ وجود تناقض بين اصناف ملاءمة الأراضي التي تم الحصول عليها. فبينما أظهر نظام (Sys and Verheye, (1972 صنفين من الملاءمة الضعيفة، فان نظام Sys *et al.* (1991) و Al-Baji *et al.* 2010. قد حسن في ملاءمة الأصناف، إلا أن نظام Mohamed Kadhim (2012 كان الأفضل من حيث التطبيق من خلال إدراج نوعية مياه الري ضمن التصنيف فكانت نتائجه أقرب إلى الواقع الذي تم تشخيصه خلال الزيارات الميدانية لمنطقة الدراسة والاستبيان من مستخدمي الأراضي في المنطقة.

الكلمات المفتاحية: الترب الجبسية، انظمة تقييم الاراضي، ملائمة الارض، منطقة الثرثار.