EVALUATION OF LAND SUITABILITY FOR IRRIGATED WHEAT CULTIVATION USING TWO DIFFERENT METHODS IN NORTHERN ALI AL-GHARBI DISTRICT

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ABSTRACT

This study aimed to evaluate the suitability of land for irrigated wheat cultivation in the Ali Al-Gharbi area in Maysan Governorate.A semi detailed soil survey was conducted covering an area of 77244.66 hectares. 15 pedons were described and 40 surface samples were collected. The study area included three physiographic units: the riverbed unit, the river basin unit, and the depressions unit. Land suitability assessment was conducted following the methodologies outlined by Sys et al., 1993, and the approach proposed by Al-Rubaie (10). This evaluation encompassed soil characteristics, topography, and irrigation water needs. The results indicated that the determining factor for wheat cultivation is soil salinity and calcium carbonate content. Climate suitability results for wheat cultivation within category S1 reached a rating of (98.8)%, according to the assessment. However, according to the suitability categories outlined by Sys et al., 1993, the unsuitable areas (N2) for cultivation covered an area of 76,336.36 hectares, accounting for 98.82% of the study area, while the suitable category (S1) covered an area of 908.30 hectares, representing 1.18% of the study area. According to the proposal by Al-Rubaie (10), water availability fell within the limited suitability category S3, with a rating of (66.74)%. The final suitability assessment placed the area within the unsuitable category N1, covering 75,572.73 hectares and representing 97.84% of the study area, and the limited suitability category S3, covering 1,671.93 hectares and representing 2.16% of the study area.

Keywords: land suitability evaluation, soil properties, wheat crop.

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طرائق تقييم ملائمة الارض لزراعة الحنطة اروائياً باستخدام طريقتين مختلفتين شمال علي الغربي

اسماء رشيد عنبر — باحثة
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المستخلص

ان الهدف من البحث هو لتقييم ملائمة الاراضي للزراعة الاروائية لمحصول الحنطة في منطقة علي الغربي بمحافظة ميسان، تم اجراء مسح ميداني شبه مفصل لمساحة 77244.66 هكتار، تم وصف 15 بيدون واخذت 40 عينة سطحية، شملت منطقة الدراسة ثلاث وحدات فيزيوغرافية هي وحدة كتوف الانهار ووحدة حوض النهر ووحدة المنخفضات. اجري تقييم ملاءمة الأراضي على وفق ما ورد في Sys at el,1993 ومقترح الربيعي،2012 الذي شمل متطلبات التربة والطبوغرافية ومتطلبات مياه الري. اظهرت النتائج ان العامل المحدد لزراعة الحنطة هو ملوحة التربة وكربونات الكالسيوم، كما بينت نتائج ملاءمة المناخ لزراعة الحنطة ضمن الصنف S1 بتقييم بلغ (98.8)%، اما أصناف الملاءمة حسب Sys at el,1993 فكانت ضمن الصنف غير الملاءمة N2 بمساحة 76336.36 هكتار وبنسبة 98.82% والصنف S1 بمساحة 908.30 هكتار وبنسبة 1.18% من مساحة منطقة الدراسة، اما حسب مقترح الربيعي، 2012 فقد كانت المياه ضمن الصنف محدود الملاءمة S3 بتقييم (66.74)% اما التقييم النهائي للملاءمة فكان ضمن الصنف عديم الملاءمة N1 بمساحة 75572.73 هكتار وبنسبة 97.84% وضمن الصنف محدود الملاءمة S3 بمساحة 1671.93 هكتار وبنسبة 2.16% من مساحة منطقة الدراسة، ان مقترح الربيعي 2012 كان افضل من نظام Sys at el,1993 في تقييم الملائمة بسبب المديات الموضوعة لصفات التربة.

الكلمات المفتاحية: تقييم ملائمة الأرض، خصائص التربة، محصول الحنطة

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INTRODUCTION

Land suitability is one of the methods for soil evaluation. The Food and Agriculture Organization (FAO) stated that land suitability is the fitness of a specific type of land for a defined use (20, 26). Land evaluation is the assessment of land performance when used for a specific agricultural purpose and involves the implementation and interpretation of surveys on soil, vegetation cover, and climatic data. It is an essential part of land use planning processes (7, 8, 17, 22, 31). The south of Iraq area is in the very high class of danger for desertification in terms of climate quality index (13). Land suitability evaluation serves as the first stage in agricultural land use planning and is usually conducted repeatedly to ensure that the type of land use is appropriate for a particular area. Land suitability evaluation involves both qualitative and quantitative assessments, taking into account climate, hydrology, terrain, vegetation cover, and soil characteristics in the qualitative evaluations of land suitability (19, 21). In contrast, the results of quantitative assessments are more precise in predicting crop production (2, 16). To update soil surveys, create new maps, and identify the main constraints and problems facing the region's soils, as well as to prepare land classification maps, the objectives are as follows:

1- Evaluate the land suitability for cereal crops according to the formula Sys et al., (30) and Al-Rubaie (10) and classify the land.

2- Create spatial distribution maps of land suitability for agricultural purposes and land classifications for the soils of the study area using remote sensing technologies and Geographic Information Systems (GIS).

MATERIALS AND METHODS

Location of the study area: The study area is part of the alluvial plain containing the deposits of the Tigris River, marshes, and swamps. It represents the northern part of the Ali Al-Gharbi district, which is located in the northeastern part of Maysan Governorate in southeastern Iraq. The area is estimated to cover 77244.66 hectares, constituting about 4% of Maysan Governorate's total area of 16,072 km². It is bordered by Wasit Governorate to the north and west, while to the south, it is bordered by the Al-Amarah district and the Ali Al-Sharqi sub-district. To the west, it is bordered by the Tigris river, and the eastern and northeastern borders are formed by the Iranian lands and their highlands. The area extends between the longitudes 46° 25'51.17" E and 46°55'21.00846" E, and the latitudes 32° 17'19.653" N and 32° 37'4.256" N, as shown in Figure 1.

Field and office work

Soil survey and determination of the study area: The study area was visited eight times during the period from January 16, 2023, to June 17, 2023, with the aim of determining the locations of pedons in the area. The study area was surveyed based on aerial photographs and satellite imagery from 2022. It was observed that most of these areas are not agriculturally utilized and are abandoned lands, except for some lands adjacent to the Tigris river.

Preparation of Inputs for land evaluation of the study area: The suitability of the study area for wheat cultivation was evaluated using 10 criteria, applying the formula by Sys et al., (30). The criteria include soil texture, soil depth, slope, calcium carbonate content, gypsum content, soil salinity (EC), ESP percentage, drainage condition and organic matter. The evaluation took into account recommendations for extracting the weights of input factors from soil properties, with a focus on using the straight-line equation (5, 9, 15, 27, 32).

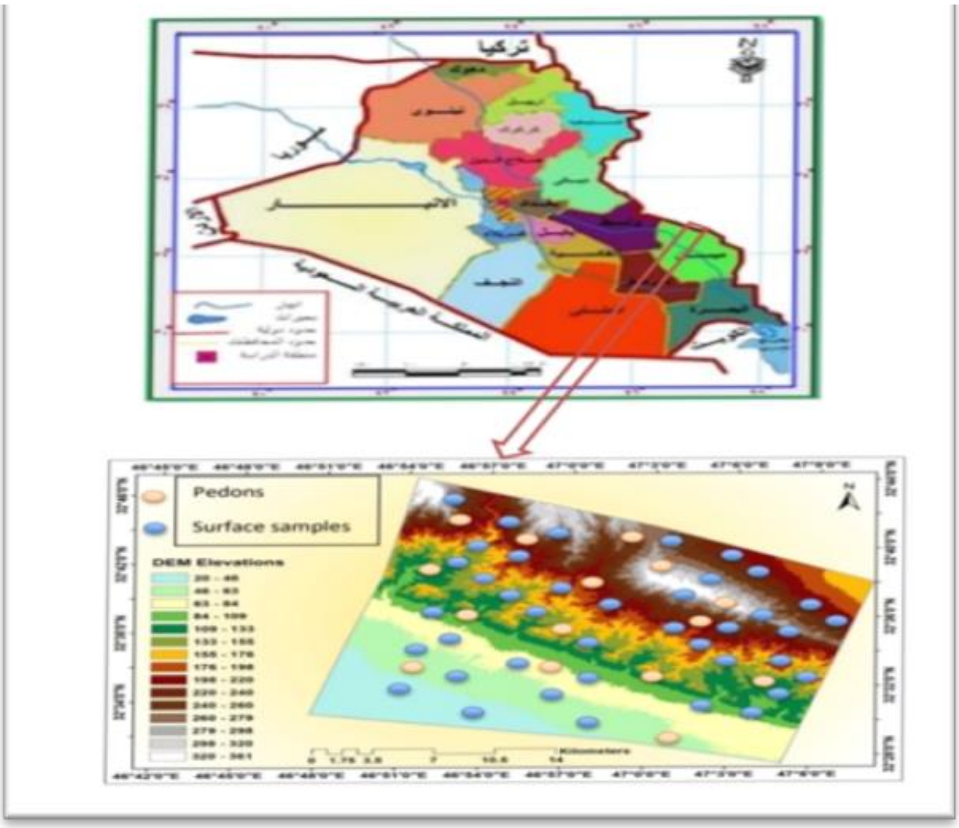

Figure 1. The study area and sample locations on the digital elevation model

Evaluation of land suitability for wheat cultivation according to Sys *et al.*, (9) method: The soil and topographical requirements for the wheat crop were based on Sys *et al.*, (30). The characteristics were evaluated according to their ranges, each according to its value. The weights of the characteristics were derived by multiplying them by the depth weight of the pedons in the study, as shown in In this stage, the soil properties were calculated for their suitability for wheat cultivation according to the equation by Sys *et al.* (2, 6, 30) This was achieved by multiplying the suitability ratings of the individual land characteristics with each other to obtain the final estimate of land suitability, which determines the suitability class of the land according to Equation (1):

$$Rs = A \times B \times C \times D \times E \times F \times G \times H \times I \times L \ldots \quad (1)$$

Where:

Rs: Suitability value. A: Soil Depth rating. B: pH rating

C: ECe (Electrical Conductivity) rating

D: Texture rating

E: Gypsum percentage rating

F: Organic Carbon rating

G: CEC (Cation Exchange Capacity) rating

H: Slope rating

I: Calcium Carbonate percentage rating

J: Drainage rating

Evaluation of land suitability for wheat cultivation according to the method proposed by Al-Rubaie (2): This method relied on the characteristics shared by previous equations and considered them essential in the evaluation process. The values of each factor in the equation were assessed based on the ratings provided in some equations or by combining multiple ratings while taking into account the conditions of Iraqi soils. As the previous equations and land classification systems lacked an irrigation water factor, which has a significant impact on both the quantity and quality of water in land productivity, it was proposed to add this factor to the proposed equation. The equation took the following form:

$$Si_w = Q.\ S1.\ A1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$Sis = D.\ T.\ C.\ G.\ W.\ S_2.\ S_3.\ A_2 \ldots\ldots (3)$$

Where:

Si_w: Irrigation water suitability index for agricultural irrigation

Sis: Land suitability index for agricultural irrigation

Q: Irrigation water availability

S1: Irrigation water salinity

A1: Sodium adsorption ratio (SAR) in irrigation water

D: Soil depth
T: Soil texture
C: Soil calcium content
G: Soil gypsum content
W: Groundwater depth and condition
S2: Land slope and topography
S3: Soil salinity
A2: Exchangeable sodium percentage (ESP) in soil

The average values of the irrigation water and land suitability indices were obtained by summing them and dividing the result by 2, considering that water and land factors share equal importance in the evaluation for irrigation purposes.

RESULTS AND DISCUSSION

Classification of land suitability for irrigated wheat cultivation:Evaluation of the study area's climate for irrigated wheat cultivation: The results indicated that the climate in the study area is not a limiting factor for irrigated wheat cultivation. The climate index reached 84.8, indicating that the climate is suitable for wheat cultivation according to the final rating (R) for the climate factor, which was 98.8. This places the climate within the S1 category, which is the very suitable climate class for wheat cultivation (12, 14, 28).

Evaluation of soil and land topography suitability for wheat cultivation: The results indicated that the limiting factors for wheat cultivation according to this system are soil salinity, calcium carbonate, and calcium sulfate due to their high concentrations in the soils of the study area (1, 3, 4), as shown in Tables (1) and (2).

Results of suitability evaluation for irrigated wheat cultivation in the study area: The suitability of pedons and surface samples was combined to determine the overall suitability classes for the study area. This involved creating a range that aligns with both. The results of the land characteristics evaluation, as shown in Tables (1) and (2), indicated that the limiting factors for wheat cultivation are calcium carbonate, gypsum (calcium sulfate), soil salinity, and organic matter (organic carbon) to a significant degree. Additionally, other characteristics such as slope and drainage conditions were also limiting factors in some pedons. The following suitability classes were identified:

N2: Permanently not suitable lands

These lands are unsuitable for wheat cultivation due to very severe limiting factors such as high levels of gypsum, calcium carbonate, and salinity, as well as less severe factors like soil texture and organic matter. This class covers an area of 76,336.36 hectares, which accounts for 98.82% of the total study area.

N1: Currently unsuitable lands

This class includes lands that are currently unsuitable for wheat cultivation due to less severe limiting factors compared to the previous class, primarily soil salinity, as well as soil texture and organic matter. This class covers 1.18% of the total study area, amounting to 908.30 hectares, as shown in Figure (2) and Table (3). The suitability of this class can be improved through management practices aimed at reducing soil salinity, such as enhancing drainage systems, using modern irrigation techniques, applying leaching requirements with irrigation water, and adding organic matter to improve soil fertility. These measures have resulted in the following suitability classes, as shown in Figure (3) and Table (4), which depict the distribution and cartographic analysis of these classes:

S3: Marginally suitable lands

This class includes lands with limited suitability for wheat cultivation. It covers an area of 5,081.77 hectares, which is 6.58% of the total study area.

N1: currently unsuitable lands

These lands remain unsuitable for wheat cultivation despite management efforts, covering an area of 70,540.08 hectares, which is 91.32% of the total study area.

N2: Permanently not suitable lands

This class includes lands that remain highly unsuitable for wheat cultivation, covering an area of 1,622.81 hectares, which is 2.10% of the total study area. Administrative measures taken to improve soil characteristics have not been sufficient to elevate these pedons to a higher suitability class due to the high levels of calcium carbonate and gypsum.

Table 1. Evaluation of Wheat Crop Suitability for Irrigated Cultivation According to Sys et al., (30)

Pedon	Climate (c)	Slope %	Drainage	Tex.	Depth Cm	$CaCO_3$ %	$CaSO_4$ %	Apparent CEC Cmol(+).Kg^{-1}.clay	pH	S.O.C %	ECe dS m^{-1}	ESP %	Land Index	Land Class
P1	84.8	1_2	Well	SiL	118	31.57	13.78	7.05	7.61	0.08	11	8.39		
Actual	98.8	90	100	100	100	81.08	52.44	85	94.83	60	66.25	97.2	11.77	N2
Potential	98.8	100	100	100	100	81.08	52.44	100	94.83	100	100	100	39.84	N1
P2	84.8	1_2	Well	L	116	42.39	14.22	6.56	7.36	0.07	7.91	6.28		
Actual	98.8	90	100	95	100	57.61	51.56	85	97	60	85.23	97.91	10.36	N2
Potential	98.8	100	100	95	100	57.61	51.56	100	97	100	100	100	27.04	N1
P3	84.8	2_4	Well	SiL	112	41.24	29.33	7.96	7.41	0.04	21.62	15.07		
Actual	98.8	72.5	100	100	100	58.76	25	85	96.58	60	25	94.86	1.23	N2
Potential	98.8	100	100	100	100	58.76	25	100	96.58	100	100	100	14.02	N2
P4	84.8	1_2	Well	L	110	33.83	12.25	7.87	7.14	0.06	42.17	12.85		
Actual	98.8	90	100	95	100	75.43	55.5	85	98.83	60	25	95.72	4.27	N2
Potential	98.8	100	100	95	100	75.43	55.5	100	98.83	100	100	100	38.83	N1
P5	84.8	1_2	Well	SCL	102	48.79	19.97	5.22	7.43	0.28	4.8	14.93		
Actual	98.8	90	100	85	100	51.21	40.06	85	96.41	60	93	95.02	6.74	N2
Potential	98.8	100	100	85	100	51.21	40.06	100	96.41	100	100	100	16.61	N2
P6	84.8	0_1	mod-well	L	119	39.37	16.03	9.59	7.55	0.02	60.57	8.4		
Actual	98.8	97.5	95	95	100	61.58	47.94	85	95.41	60	25	97.2	3.03	N2
Potential	98.8	100	100	95	100	61.58	47.94	100	95.41	100	100	100	26.44	N1
P7	84.8	0_1	Poor	SCL	76	28.63	11.29	10.27	7.36	0.03	109.75	21.73		
Actual	98.8	97.5	60	85	91.5	86.37	57.42	85	97	60	25	82.11	2.26	N2
Potential	98.8	100	100	85	100	86.37	57.42	100	97	100	100	100	40.4	S3
P8	84.8	1_2	Exces.-well	SiL	132	45.86	19.33	16.32	7.49	0.19	6.26	5.62		
Actual	98.8	90	100	100	100	54.14	41.34	85.4	95.91	60	89.35	98.12	8.57	N2
Potential	98.8	100	100	100	100	51	41.34	100	95.91	100	100	100	19.98	N2
P9	84.8	0_1	Poor	CL	125	35.09	17.53	7.11	7.52	0.03	13.91	7.24		
Actual	98.8	97.5	60	100	100	72.28	44.94	85	95.66	60	50.45	97.59	4.51	N2
Potential	98.8	100	100	100	100	72.28	44.94	100	95.66	100	100	100	30.7	N1
P10	84.8	0_1	mod-well	SiL	150	49.78	25.14	27.43	7.57	0.16	3.88	9.07		
Actual	98.8	97.5	95	100	100	50.22	25	100	95.25	60	95.15	96.98	6.06	N2
Potential	98.8	100	100	100	100	50.22	25	100	95.25	100	100	100	11.82	N2
P11	84.8	0	Poor	L	130	41.74	11.56	12.11	7.63	0.02	50.55	20.28		
Actual	98.8	100	60	95	100	58.26	56.88	85	94.5	60	25	84.53	1.9	N2
Potential	98.8	100	100	95	100	58.26	56.88	100	94.5	100	100	100	29.39	N1
P12	84.8	0	Poor	C	138	46.72	20.17	5.68	7.63	0.03	60.4	10.95		
Actual	98.8	100	60	100	100	53.28	25	85	94.5	60	25	96.35	0.92	N2
Potential	98.8	100	100	100	100	53.28	25	100	94.5	100	100	100	12.44	N2
P13	84.8	0_1	mod-well	L	114	40	16.13	10.69	7.57	0.04	20.2	7.92		
Actual	98.8	97.5	95	95	100	60	47.74	85	95.25	60	25	97.36	2.94	N2
Potential	98.8	100	100	95	100	60	47.74	100	95.25	100	100	100	25.61	N1
P14	84.8	0	Poor	CL	139	40.16	18.98	9.79	7.65	0.04	52.59	6.07		
Actual	98.8	100	60	100	100	59.84	42.04	85	94.17	60	25	97.98	1.75	N2
Potential	98.8	100	100	100	100	59.84	42.04	100	94.17	100	100	100	23.41	N2
P15	84.8	0_1	mod-well	L	112	49.07	12.24	10.51	7.66	0.02	14.69	5.87		
Actual	98.8	97.5	95	95	100	50.93	55.52	85	94	60	46.55	98.04	5.38	N2
Potential	98.8	100	100	95	100	50.93	55.52	100	94	100	100	100	24.95	N2

Table 2. Suitability of surface samples for current and future wheat cultivation according to Sys et al., (30)

No.		Climate	Slope	pH	ECe	CEC app.	S.O.C	$CaCO_3$	$CaSO_4$	ESP	Texture	Land Index	Land Class
1	Actual	98.8	90	97.33	25	85	78.31	66.25	45.4	95.01	85	3.5	N2
	Potential	98.8	100	97.33	100	100	100	66.25	45.4	100	85	24.58	N2
2	Actual	98.8	90	95.91	37.11	85	76.31	57.9	63	97.43	85	6.2	N2
	Potential	98.8	100	95.91	100	100	100	57.9	63	100	85	29.38	N1
3	Actual	98.8	90	98.91	96.03	85	82.48	92.5	94	95.39	60	29.47	N1
	Potential	98.8	100	98.91	100	100	100	92.5	94	100	60	50.98	S3
4	Actual	98.8	90	90.33	25	85	76.86	87.3	56.4	96.28	60	3.73	N2
	Potential	98.8	100	90.33	100	100	100	87.3	56.4	100	60	26.37	N1
5	Actual	98.8	90	92	70.81	85	67.58	75.75	57.4	95.23	100	13.78	N2
	Potential	98.8	100	92	100	100	100	75.75	57.4	100	100	39.52	N1
6	Actual	98.8	90	94.67	93.5	85	79.4	81.75	59.8	95.4	85	21.06	N2
	Potential	98.8	100	94.67	100	100	100	81.75	59.8	100	85	38.87	N1
7	Actual	98.8	90	93	25	85	71.38	74.75	53	96.87	85	4.09	N2
	Potential	98.8	100	93	100	100	100	74.75	53	100	85	30.94	N1
8	Actual	98.8	90	91	96.05	85	100	59.9	96	95.4	100	36.24	N1
	Potential	98.8	100	91	100	100	100	59.9	96	100	100	51.7	S3
9	Actual	98.8	90	94.33	28.41	85	85	64.5	42.6	95.39	85	3.84	N2
	Potential	98.8	100	94.33	100	100	100	64.5	42.6	100	85	21.77	N2
10	Actual	98.8	90	92.83	25	85	78.96	75	50.6	96.77	85	4.32	N2
	Potential	98.8	100	92.83	100	100	100	75	50.6	100	85	29.59	N1
11	Actual	98.8	90	96.5	30.63	85	74.14	63.5	42.6	95.18	95	4.05	N2
	Potential	98.8	100	96.5	100	100	100	63.5	42.6	100	95	24.5	N2
12	Actual	98.8	90	96.58	25	85	80.48	62.75	63.5	92.94	100	5.44	N2
	Potential	98.8	100	96.58	100	100	100	62.75	63.5	100	100	38.02	N1
13	Actual	98.8	97.5	99.83	94.78	85	80.92	88.1	61	95.36	95	30.52	N1
	Potential	98.8	100	99.83	100	100	100	88.1	61	100	95	50.36	S3
14	Actual	98.8	97.5	93.5	25	88.09	74.57	87.1	57.4	95.51	60	4.24	N2
	Potential	98.8	100	93.5	100	100	100	87.1	57.4	100	60	27.71	N1
15	Actual	98.8	97.5	99	89.88	85	82.95	97.29	25	25	100	3.67	N2
	Potential	98.8	100	99	100	100	100	97.29	25	100	100	23.79	N2
16	Actual	98.8	97.5	99	30.25	85	72.69	62	54.6	85.89	100	5.18	N2
	Potential	98.8	100	99	100	100	100	62	54.6	100	100	33.11	N1
17	Actual	98.8	97.5	99	96.01	85	78.85	87.2	63	97.29	100	32.8	N1
	Potential	98.8	100	99	100	100	100	87.2	63	100	100	53.73	S3
18	Actual	98.8	97.5	95.41	25	85	64.71	62.25	43.6	88.04	95	2.87	N2
	Potential	98.8	100	95.41	100	100	100	62.25	43.6	100	95	24.31	N2
19	Actual	98.8	97.5	97.41	56.95	85	64.17	73.25	47.8	96.28	60	5.9	N2
	Potential	98.8	100	97.41	100	100	100	73.25	47.8	100	60	20.22	N2
20	Actual	98.8	97.5	96.5	62.88	85	65.44	84.5	53.6	95.33	60	8.42	N2
	Potential	98.8	100	97.41	100	100	100	84.5	53.6	100	60	26.15	N1
21	Actual	98.8	97.5	96.66	96	85	78.78	85.8	57.4	97.41	85	24.41	N2
	Potential	98.8	100	97.41	100	100	100	85.8	57.4	100	85	40.29	S3

No.		Climate	Slope	pH	ECe	CEC app.	S.O.C	$CaCO_3$	$CaSO_4$	ESP	Texture	Land Index	Land Class
22	Actual	98.8	97.5	97.25	93	85	89.71	86.8	59.6	94.96	95	31	N1
	Potential	98.8	100	97.41	100	100	100	86.8	59.6	100	95	47.3	S3
23	Actual	98.8	100	97.08	88.08	85	78.6	76.25	53	97.32	100	22.2	N2
26	Actual	98.8	100	98.91	84.31	85	78.34	92.4	56.8	95.01	95	25.99	N1
	Potential	98.8	100	98.91	100	100	100	92.4	56.8	100	95	48.72	S3
27	Actual	98.8	100	93	77.94	85	74.36	98.44	59.6	96.23	95	24.28	N2
	Potential	98.8	100	93	100	100	100	98.44	59.6	100	95	51.21	S3
28	Actual	98.8	100	96.41	88.93	85	78.24	67	25	94.2	95	8.44	N2
	Potential	98.8	100	96.41	100	100	100	67	25	100	95	15.16	N2
29	Actual	98.8	100	99.6699	85.38	85	70.95	76.75	55.6	95.23	95	19.57	N2
	Potential	98.8	100	99.66	100	100	100	76.75	55.6	100	95	39.92	N1
30	Actual	98.8	100	96.91	25	85	79.58	63.75	48.8	94.73	100	4.77	N2
	Potential	98.8	100	96.91	100	100	100	63.75	48.8	100	100	29.79	N1
31	Actual	98.8	100	95.66	25	85	71.6	61	53.6	95.46	100	4.49	N2
	Potential	98.8	100	95.66	100	100	100	61	53.6	100	100	30.9	N1
32	Actual	98.8	100	88.67	25	85	70.51	59.2	51.4	95.54	100	3.82	N2
	Potential	98.8	100	88.67	100	100	100	59.2	51.4	100	100	26.66	N1
33	Actual	98.8	100	94.17	25	85	76.31	62	55.2	95.53	100	4.93	N2
	Potential	98.8	100	94.17	100	100	100	62	55.2	100	100	31.84	N1
34	Actual	98.8	100	92.83	25	85	78.96	75	51.6	95.42	85	4.83	N2
	Potential	98.8	100	92.83	100	100	100	75	51.6	100	85	30.17	N1
35	Actual	98.8	100	92.17	25	85	79.21	75.25	50.2	96.61	85	4.75	N2
	Potential	98.8	100	92.17	100	100	100	75.25	50.2	100	85	29.24	N1
36	Actual	98.8	100	93.83	26.69	85	79.79	74.75	53.8	92.94	85	5.33	N2
	Potential	98.8	100	93.83	100	100	100	74.75	53.8	100	85	31.69	N1
37	Actual	98.8	100	98.25	28.19	85	81.57	75	56	64.78	100	5.16	N2
	Potential	98.8	100	98.25	100	100	100	75	56	100	100	40.77	S3
38	Actual	98.8	100	94.17	48	85	71.46	89	64	83.31	100	12.87	N2
	Potential	98.8	100	94.17	100	100	100	89	64	100	100	53	S3
39	Actual	98.8	100	94	59.25	85	78.16	84.5	68	82.65	100	17.36	N2
	Potential	98.8	100	94	100	100	100	84.5	68	100	100	53.36	S3
40	Actual	98.8	100	94.67	75.94	85	71.42	89	58.2	84.25	100	18.82	N2
	Potential	98.8	100	94.67	100	100	100	89	58.2	100	100	48.45	S3

Table 3. Current Suitability Classes for Wheat Cultivation and Their Areas According to Sys et al., (30)

Class	Class Index Value	Suitability Class	Area ha.	Area %
N2	0-25	Permanently not suitable	76336.36	98.82
N1	25-40	Currently unsuitable	908.30	1.18
		Total Area	77244.66	

Table 4. Future Suitability Classes for Wheat Cultivation and Their Areas According to Sys et al., (30)

Class	Class Index Value	Suitability Class	Area ha	Area %
N2	0-25	Permanently not suitable	1622.81	2.10
N1	25-40	Currently unsuitable	70540.08	91.32
S3	40-60	Marginally suitable	5081.77	6.58
		Total Area	77244.66	100.00

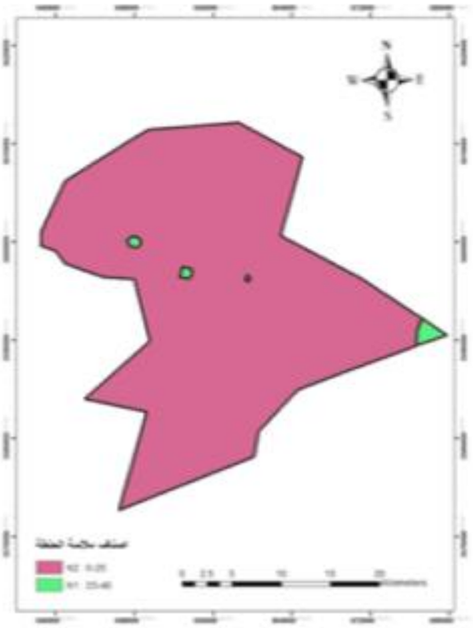

Figure 2. Current Suitability Classes for Wheat Cultivation According to Sys et al., (9)

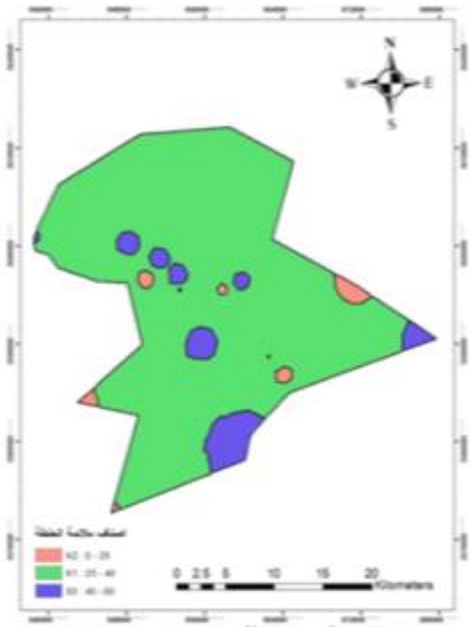

Figure 3. Future Suitability Classes for Wheat Cultivation According to Sys et al., (9)

Evaluation of land suitability for irrigated wheat cultivation according to the Proposal by Al-Rubaie (10): This method relies primarily on assessing both water and soil conditions together. Values for the irrigation water suitability index and the land suitability index are extracted and combined, considering them equally important in the assessment. The evaluation method includes the following steps:

Evaluation of irrigation water

The assessment of irrigation water is based on its salinity and alkalinity according to the American classification of 1954. Additionally, the water quantity factor and its availability are assessed based on the specific requirements regarding water availability, water salinity, and the adjusted sodium adsorption ratio (SAR). The values for these attributes are assessed according to their respective criteria levels. It is noted from Table (8) that the determination coefficient for irrigation water in the study area falls within Class S3, with an estimate of (66.74), indicating limited suitability. The decrease in its suitability class is attributed to the high salinity of the water and the values of SAR estimation, which were (34.4 and 79) respectively, as shown in Tables (5) and (6) illustrating the chemical analysis characteristics of the Tigris river water in the study area and its estimates as per Al-Rubaie (10).

Table 5. Chemical analysis values of irrigation water in the study area

Sample	EC $dS.m^{-1}$	Na^+ $meq.L^{-1}$	Mg^{++} $meq.L^{-1}$	Ca^{++} $meq.L^{-1}$	$CO3^=$ meq.L-1	$HCO3^-$ meq.L-1	SAR
Tigris river	1.86	7.78	5.4	6.2	0	6.7	3.23

Table 6. Results of Water Evaluation According to Al-Rubaie (10)

Sample	Water values			Estimation degree			Index value	Estimate	Class
	Availability	Salinity	SAR.adj	Availability	Salinity	SAR.adj			
W1	100	1.86	8.08	100	34.4	79	27.18	66.74	S3

3-2-2 Evaluation of soil and topographic characteristics according to Al-Rubaie (10): The evaluation of soil characteristics was conducted based on depth for each pedon, dividing the depths into intervals of 20 cm. Each depth was assigned a corresponding weight coefficient according to Table (7), and the characteristic was multiplied by the weight coefficient of the corresponding depth, as shown in Table (8). Additionally, the surface samples indicated in Table (9) were evaluated based on a depth of 30 cm. The results revealed that the determining factors for wheat cultivation in the study area are primarily soil properties such as calcium, gypsum, and salinity, with groundwater and alkalinity being of lesser importance, varying in suitability across the study sites.

Table 7. Number of soil depth layers and weight factors for different depths

Depth cm	Soil layers	Weighing factor
120 – 100	6	(0.25 – 0.5 – 0.75 – 1.0 – 1.5 – 2.0)
100 – 80	5	(0.25 – 0.5 – 1.0 – 1.5 – 1.75)
80 – 0	4	(0.25 – 0.75 – 1.25 – 1.75)
60 – 40	3	(0.5 – 1.0 – 1.5)
40 – 20	2	(0.75 – 1.25)
20 – 0	1	(1.0)

Table 8. Evaluation of Soil Characteristics for the Pedons of the Study Area for Wheat Cultivation According to Al-Rubaie (10)

	Pedon	Depth	Water Table	Slope	Texture	lime	Gypsum	ECe	ESP
P1	Actual	97.35	81.92	95	84.44	79.68	60.8	70.24	94.16
	Potential	100	100	100	84.44	79.68	60.8	100	100
P2	Actual	96.7	72.43	95	86.56	62.45	58.39	85.06	94.98
	Potential	100	100	100	86.56	62.45	58.39	100	100
P3	Actual	95.4	72.03	84.17	80	63.96	40	40	77.39
	Potential	100	100	100	80	63.96	40	100	100
P4	Actual	94.75	71.21	95	90.37	76.45	64.69	41.98	82.54
	Potential	100	100	100	90.37	76.45	64.69	100	100
P5	Actual	92.15	69.58	95	87.37	52.39	45.81	90.09	73.91
	Potential	100	100	100	87.37	52.39	45.81	100	100
P6	Actual	97.68	73.05	99.25	97.87	68.03	54.77	40	92.45
	Potential	100	100	100	97.87	68.03	54.77	100	100
P7	Actual	81.66	66.03	99.25	95.34	84.53	70.6	40	61.16
	Potential	100	100	100	95.34	84.53	70.6	100	100
P8	Actual	100	73.7	99	80	60.28	46.2	90.66	98.59
	Potential	100	100	100	80	60.28	46.2	100	100
P9	Actual	100	73.44	99.25	93.93	75.53	52.35	57.92	97.85
	Potential	100	100	100	93.93	75.53	52.35	100	100
P10	Actual	100	74.38	99.25	88.47	53.86	42.97	95.34	90.8
	Potential	100	100	100	88.47	53.86	42.97	100	100
P11	Actual	100	73.85	99.25	95.51	62.68	67.49	40	64.57
	Potential	100	100	100	95.51	62.68	67.49	100	100
P12	Actual	100	73.93	99.25	84.37	59.97	55.71	40	83.77
	Potential	100	100	100	84.37	59.97	55.71	100	100
P13	Actual	96.05	72.03	99.25	96.3	65.66	54.11	40	93.96
	Potential	100	100	100	96.3	65.66	54.11	100	100
P14	Actual	100	73.97	99.25	81.58	67.21	46.37	40	98.48
	Potential	100	100	100	81.58	67.21	46.37	100	100
P15	Actual	95.4	71.62	99.25	97.42	55.21	64.95	51.76	98.52
	Potential	100	100	100	97.42	55.21	64.95	100	100

Table 9. Evaluation of soil characteristics for surface samples for wheat cultivation according to the requirements of Al-Rubaie (10)

NO.		Slope	EC	Depth	Water Table	CaCO3	CaSO4	ESP	Texture
1	Actual	95	40	97.94	72.88	70	51.75	77.55	96.7
	Potential	100	100	100	100	70	51.75	100	96.7
2	Actual	95	40	97.94	72.88	62.01	73.67	98.08	91.5
	Potential	100	100	100	100	62.01	73.67	100	91.5
3	Actual	95	98.41	96.48	72.88	89.88	97.13	80.43	65
	Potential	100	100	100	100	89.88	97.13	100	65
4	Actual	95	40	96.48	72.88	86.5	65.67	87.7	80
	Potential	100	100	100	100	86.5	65.67	100	80
5	Actual	95	73.65	96.48	72.88	77.6	67.33	79.2	96.05
	Potential	100	100	100	100	77.6	67.33	100	96.05
6	Actual	95	96.05	96.48	72.88	82.4	71.33	80.48	91.5
	Potential	100	100	100	100	82.4	71.33	100	91.5
7	Actual	95	40	96.48	72.88	76.8	61.25	93.52	91.5
	Potential	100	100	100	100	76.8	61.25	100	91.5
8	Actual	95	98.42	96.48	72.88	63.91	99.84	80.45	99
	Potential	100	100	100	100	63.91	99.84	100	99
9	Actual	95	40	96.48	72.88	68.6	48.25	80.43	91.5
	Potential	100	100	100	100	68.6	48.25	100	91.5
10	Actual	95	40	96.48	72.88	77	58.25	92.48	91.5
	Potential	100	100	100	100	77	58.25	100	91.5
11	Actual	95	40	96.48	72.88	67.8	48.25	78.85	96.7
	Potential	100	100	100	100	67.8	48.25	100	96.7
12	Actual	95	40	96.48	72.88	67.2	74	74.93	76.3
	Potential	100	100	100	100	67.2	74	100	76.3
13	Actual	99.25	97.71	96.48	72.88	87.02	72.33	80.18	96.7
	Potential	100	100	100	100	87.02	72.33	100	96.7
14	Actual	99.25	40	96.48	72.88	86.37	67.33	81.33	80
	Potential	100	100	100	100	86.37	67.33	100	80
15	Actual	99.25	91.34	96.48	72.88	96.57	40	40	99.15
	Potential	100	100	100	100	96.57	40	100	99.15
16	Actual	99.25	40	96.48	72.88	66.6	63.25	66.13	96.05
	Potential	100	100	100	100	66.6	63.25	100	96.05
17	Actual	99.25	98.41	96.48	72.88	86.43	73.67	97.55	99.15
	Potential	100	100	100	100	86.43	73.67	100	99.15
18	Actual	99.25	40	96.48	72.88	66.8	49.5	68.8	96.7
	Potential	100	100	100	100	66.8	49.5	100	96.7
19	Actual	99.25	61.95	96.48	72.88	75.6	54.75	87.7	80
	Potential	100	100	100	100	75.6	54.75	100	80
20	Actual	99.25	67.3	96.48	72.88	84.6	62	79.98	80
	Potential	100	100	100	100	84.6	62	100	80
NO.		Slope	EC	Depth	Water Table	CaCO3	CaSO4	ESP	Texture
21	Actual	99.25	98.4	96.48	72.88	85.52	67.33	98.06	91.5
	Potential	100	100	100	100	85.52	67.33	100	91.5
22	Actual	99.25	95.4	96.48	72.88	86.17	71	77.45	96.7
	Potential	100	100	100	100	86.17	71	100	96.7
23	Actual	100	89	96.48	72.88	78	61.25	97.9	96.05
	Potential	100	100	100	100	78	61.25	100	96.05
24	Actual	100	97.74	96.48	72.88	91.44	73	80.33	96.7
	Potential	100	100	100	100	91.44	73	100	96.7
25	Actual	100	90.75	96.48	72.88	90.66	74.67	76.45	96.7
	Potential	100	100	100	100	90.66	74.67	100	96.7
26	Actual	100	84.45	96.48	72.88	89.81	66.33	77.6	96.7
	Potential	100	100	100	100	89.81	66.33	100	96.7
27	Actual	100	79.35	96.48	72.88	98.34	71	87.24	96.7
	Potential	100	100	100	100	98.34	71	100	96.7
28	Actual	100	90.1	96.48	72.88	70.6	98.53	76.5	96.7
	Potential	100	100	100	100	70.6	98.53	100	96.7
29	Actual	100	85.49	96.48	72.88	78.4	64.5	79.2	96.7
	Potential	100	100	100	100	78.4	64.5	100	96.7
30	Actual	100	40	96.48	72.88	68	56	77.18	96.05
	Potential	100	100	100	100	68	56	100	96.05
31	Actual	100	40	96.48	72.88	65.8	62	80.95	96.05
	Potential	100	100	100	100	65.8	62	100	96.05
32	Actual	100	40	96.48	72.88	63.24	59.25	81.55	96.05
	Potential	100	100	100	100	63.24	59.25	100	96.05
33	Actual	100	40	96.48	72.88	66.6	64	81.45	96.05
	Potential	100	100	100	100	66.6	64	100	96.05
34	Actual	100	40	96.48	72.88	77	59.5	80.68	91.5
	Potential	100	100	100	100	77	59.5	100	91.5
35	Actual	100	40	96.48	72.88	77.2	57.75	90.95	91.5
	Potential	100	100	100	100	77.2	57.75	100	91.5
36	Actual	100	40	96.48	72.88	76.8	62.25	74.93	91.5
	Potential	100	100	100	100	76.8	62.25	100	91.5
37	Actual	100	40	96.48	72.88	77	65	40	99.15
	Potential	100	100	100	100	77	65	100	99.15
38	Actual	100	53	96.48	72.88	87.6	74.33	62.98	91.8
	Potential	100	100	100	100	87.6	74.33	100	91.8
39	Actual	100	64.25	96.48	72.88	84.6	77	62.18	99.15
	Potential	100	100	100	100	84.6	77	100	99.15
40	Actual	100	77.75	96.48	72.88	87.6	68.67	64.1	99.15
	Potential	100	100	100	100	87.6	68.67	100	99.15

Evaluation of soil suitability for wheat cultivation based on Al-Rubaie (10): The results shown in Tables (10) and (12) and Figure (4) indicate that there are three suitability classes for the land based on the requirements outlined in Al-Rubaie (10), as follows:

1- Class N2: Land unsuitable for wheat cultivation due to severe factors such as high levels of calcium, gypsum, and soil salinity. This class occupies an area of 28,898.00 hectares, accounting for 37.41% of the study area.

2- Class N1: Land unsuitable for wheat cultivation due to severe factors, including high levels of calcium, gypsum, and soil salinity. This class occupies an area of 47,441.99 hectares, representing 61.42% of the study area.

3- Class S3: Land in this class has limited suitability for wheat cultivation. It occupies an area of 904.67 hectares, accounting for 1.17% of the study area. Administrative measures taken to improve soil properties have led to the emergence of the following classes in the future, as illustrated in Tables (11) and Figure (5):

1- Class S3: Land in this class has limited suitability for wheat cultivation. It occupies an area of 56,180.80 hectares, representing 72.73% of the study area.

2- Class S2: Land moderately suitable for wheat cultivation. It occupies an area of 21,063.86 hectares, accounting for 27.27% of the study area.

Table 10. Current soil suitability classes for wheat cultivation and their areas according to Al-Rubaie (10)

Class	Class Index Value	Suitability Class	Area ha	Area %
N2	> 45	Very strongly level	28898.00	37.41
N1	45 – 65	Strongly level	47441.99	61.42
S3	65 – 85	Moderately level	904.67	1.17
		Total Area ha	**77244.66**	**100.00**

Table 11. Future Soil Suitability Classes for Wheat Cultivation and Their Areas According to Al-Rubaie (10)

Class	Class Index Value	Suitability Class	Area ha	Area %
S3	**65 – 85**	**Moderately level**	**56180.80**	**72.73**
S2	**85 – 98**	**Slightly level**	**21063.86**	**27.27**
		Total Area ha.	**77244.66**	**100.00**

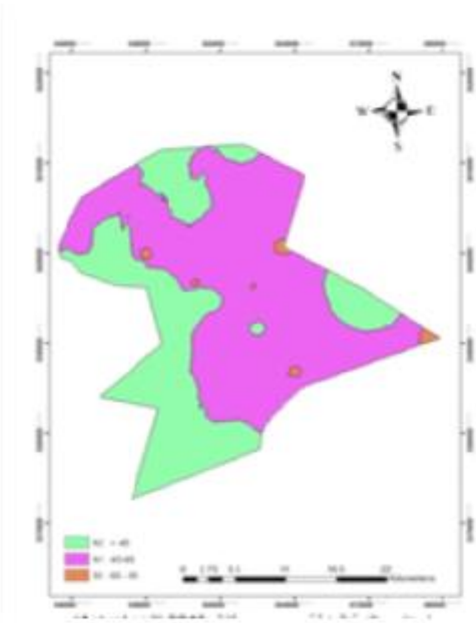

Figure 4. Current Soil Suitability Classes for Wheat Cultivation According to Al-Rubaie (10)

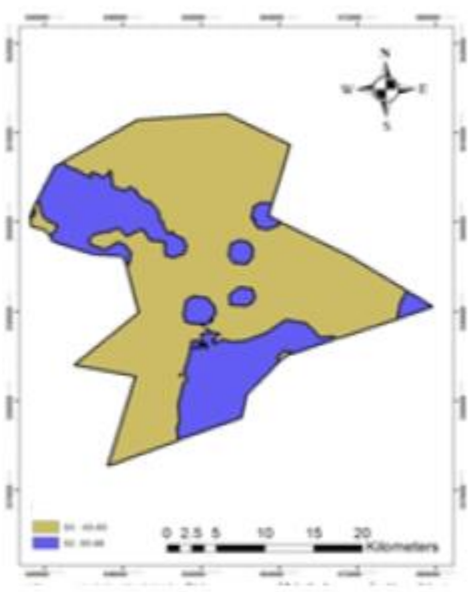

Figure 5. Future Soil Suitability Classes for Wheat Cultivation According to Al-Rubaie (10)

Conclusions

The results indicated that using the Sys et al. 1993 method classified the study area as N2 and N1, while using the Al-Rubaie (10) method classified the study area as N1 and S3. The suitability classes according to the Sys *et al,*. (29) method did not match the actual productivity of the study area due to the specified limitations of the studied attributes. Also Some suitability classes resulting from using the Al-Rubaie (10) system showed a slight agreement with the actual conditions of the study area.

Recommendations

It is essential to use land evaluation systems that are more realistically aligned with the conditions of Iraqi soils. Setting the ranges by Sys *et al.* (30) and Al-Rubaie (10) for evaluating soil attributes need to be adjusted to better fit the conditions of Iraqi soils.

Land suitability analysis for crop cultivation in A newly developed area in Wadi Al-Natrun, Egypt

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