JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(7), 75–87
https://doi.org/10.12911/22998993/163349
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.03.25
Accepted: 2023.05.15
Published: 2023.05.24

Land Suitability Assessment for Wheat Production Using Analytical Hierarchy Process and Parametric Method in Babylon Province

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ABSTRACT
This study was carried out to show the extent to which the land is productive due to the effect that climatic changes and the increase in population growth are the reasons that led to an increase in the demand for food, especially in developing countries. Therefore, a scientific way must assess the land suitability for growing crops. This research aimed to provide an integrated approach to the process of analyzing the suitability of agricultural lands for crop growth. Wheat in the Nile region of Babylon Governorate, was studied using the analytical hierarchy model (AHP) and compared with the parametric method and the actual crop in the field, as twelve soil criteria were determined (electrical conductivity, soil interaction, cation exchange capacity, exchangeable sodium ratio, soil texture, lime, gypsum, organic carbon, drainage, soil depth, slope, flooding) and three criteria were added in the AHP method due to their importance in Iraqi soils, which are (total nitrogen, availability phosphorus, crop variety). The results were extracted and showed that all the results of the study using the parametric method within the very unsuitable class for cultivation, N2, 72.5%, with an area of 37,734.07 hectares, and the unsuitable class, N1, 27.5%, with an area of 14,312.92 hectares, either by using the method. According to the analytical hierarchy process and giving varying importance to the soil criteria above, it was found that 37.5% are very suitable S1 with an area of 19517.62 hectares, 42.5% suitable for agriculture S2 with an area of 22119.97 hectares, and 20% moderately suitable S3 with an area of 10409.4 hectares. These results were similar to the agricultural reality of the regions under study.

Keywords: land evolution, soil salinity, wheat, soil properties, crop variety.

INTRODUCTION

Land suitability evaluation predicts land performance based on various land use types (Zonneveld, 1989). Land suitability at the field scale changes in each part of a local area because of variations in its topo-positions and soil properties. Hence, it is necessary to evaluate, classify, and manage land units to improve land productivity based on local potentials and limitations (Food and Agriculture Organization (FAO) 1990). It is similarly a foundation for the management and planning of sustainable land resources, since it enables to determine whether or not the quality of resources is degrading (Dumanski et al., 2002; Mohana et al., 2009). Predicting the capability and limitations of the land for crop productivity and yield is the primary goal of land suitability study before irrigated agriculture (Ingle et al., 2021; Hassan et al., 2021).

An evaluation map of the appropriateness of the land has been created using several techniques. It was common practice to deal with soil properties, topography, and climatic data using the parametric method (Sys et al. 1993) and a framework provided by FAO (1976). As a result, the analytical hierarchy process (AHP) integrates multi-criteria elements that offer scores for land suitability assessments in several dimensions (Banai 2005). Saaty (1980) recommended

AHP approach as one of the best techniques for managing diverse components and showing the connections between agroecological and environmental factors in a hierarchical structure (1980). Additionally, a novel method for assessing the suitability of a piece of land is presented by integrating the AHP method with a geographic information system (GIS) (Akinci et al., 2013; Ostvari et al., 2019). AHP is widely used and recognized as one of the most effective ways of determining the weights of factors as an MCDA strategy. An essential step in determining the suitability of a piece of land is weighing the elements that determine its features. Future complications will arise from varying levels of land features influencing the appraisal of the property's suitability. (Elsheikh et al., 2013). Saaty (1980) developed an AHP. GIS has been used as the optimum strategy for controlling many heterogeneous agents (Akıncı et al., 2013).

A study conducted by Rabia and Terribile (2013) on land suitability used a particular group of roads to ensure its future productivity. As computational methods are widely used to assess land suitability, a new equation was proposed in this study to improve the results of land suitability in line with reality. The study was conducted on the wheat crop and compared with the traditional standard methods, as the gollowing parameters: organic matter, calcium carbonate, pH, slope, texture, drainage, depth, EC, and location, were selected as factors affecting land suitability for wheat production in the study area and showed results. The proposed equation has indicators close to reality that are higher than the other methods, as organic matter, pH, and slope are the determining factors for wheat production in the study area in general. Dedeoglu and Dengiz, (2019) confirmed a study in Turkey to show the suitability of lands for the wheat crop using the AHP method if 10 physical, chemical and topographic criteria were chosen that directly affect wheat cultivation in that region. The results showed that 32.05% of the study area is very appropriate and moderately appropriate, while 67.95% was appropriate to a certain degree and inappropriate. It became clear from this study that the most influencing factors are soil depth, texture and slope.

In Iraq, wheat (*Triticum aestivum* L.), which is grown in winter, is an important field crop. Wheat production in recent years is estimated at 6,238 ha for the winter season of 2022, an increase of 43.6% over the previous year. Nineveh governorate ranked first, with an estimated production of 1417 thousand tons, or 22.7% of the total production, followed by Wasit governorate, where production was estimated at 811 thousand tons, or 13% of the total production, followed by the governorates of Salah al-Din and Kirkuk, with an estimated production of 627,633 thousand tons. respectively, at a rate of 10.1% of the total production, while the remaining governorates, including Babylon, accounted for 44.1% of the total production. The total areas cultivated with the wheat crop for 2022 in all governorates of Iraq are 181.9 thousand hectares. The highest yield according to the cultivated areas was in Kirkuk governorate: 265 $kg \cdot ha^{-1}$, and the lowest yield was in Al-Muthanna governorate, which amounted to 152.6 $kg \cdot ha^{-1}$. The highest wheat productivity was in 2014, and the lowest was in 2018 (Directorate of Agricultural Statistics, 2020).

This research used just AHP methods, which had excellent results for managing the weights of land attributes and determining the land suitability value. Therefore, combining AHP with GIS approaches could be a powerful way to improve the accuracy of determining if a piece of land is suitable for growing a particular crop.

MATERIAL AND METHODS

Study area

This study was conducted in central Iraq in the provinces of Babylon, (Fig. 1). The study site covers an area of about 52047 ha for the province of Babil. Wheat crop is grown in some parts of the study area. On the basis of a classification method, Entisols and Inceptisols (US Department of Agriculture, 2016) it was found that, the average monthly temperature varies From 12 to 37.81 degrees Celsius. The lowest and highest temperatures occur in January and July, respectively.

Soil sampling and analysis

Thirty soil samples were collected from depths between 0 and 30 cm, air-dried and sieved through a 2 mm sieve. The samples were taken according to the soil series, for each series 3 surface samples representing the components of each map unit (Minasny and McBratney, 2006) was used to take samples. All chemical and physical analyses necessary to conduct the land evaluation process were performed.

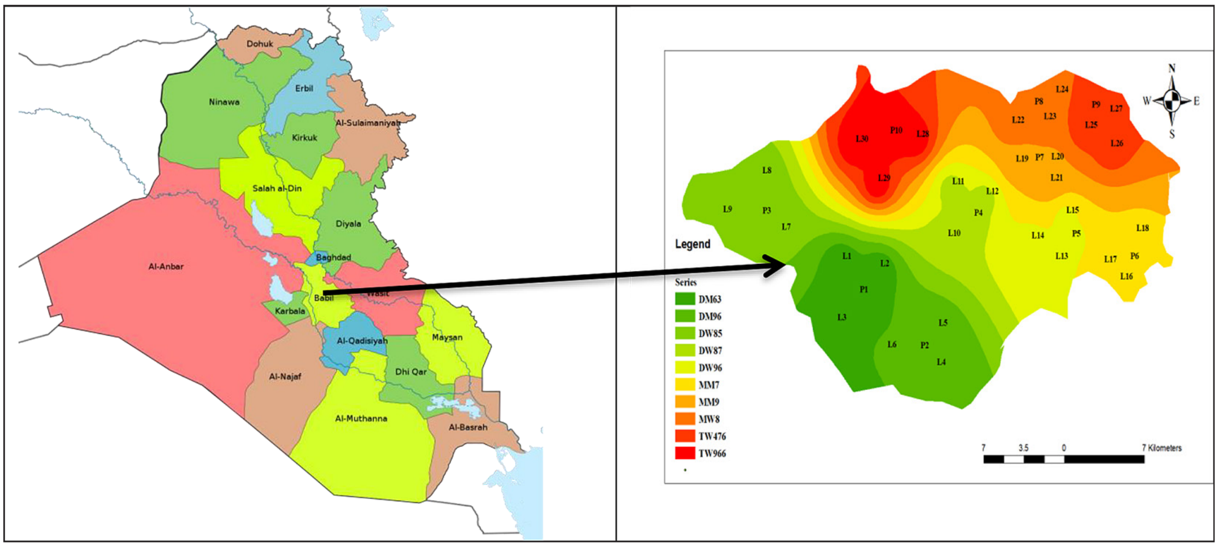

Figure 1. Map of the study area and soil sample location

Table 1. Soil physical properties for the study area

Surface sample	E	N	Clay	Silt	Sand	Texture	P_B	P_p	Porosity
			gm·kg^{-1}	gm·kg^{-1}	gm·kg^{-1}		Mg·m^{-3}	Mg·m^{-3}	%
1	32°56’42”	44°79’64”	165	472	363	Loam	1.43	2.63	45.63
2	32°57’21”	44°79’27”	161	482	357	Loam	1.4	2.61	46.36
3	32°56’39”	44°79’39”	168	480	352	Loam	1.41	2.6	45.77
4	32°57’11”	44°68’00”	321	468	211	Clay loam	1.29	2.63	50.95
5	32°55’93”	44°70’07”	322	470	208	Clay loam	1.28	2.64	51.52
6	32°56’75”	44°74’12”	331	460	209	Clay loam	1.32	2.61	49.43
7	32°58’58”	44°87’94”	344	441	215	Clay loam	1.27	2.58	50.78
8	32°59’46”	44°91’34”	351	446	203	Clay loam	1.3	2.6	50
9	32°58’64”	44°88’70”	353	449	198	Clay loam	1.28	2.57	50.19
10	32°57’27”	44°85’93”	356	521	123	Silty clay loam	1.34	2.61	48.66
11	32°56’93”	44°85’39”	361	533	106	Silty clay loam	1.3	2.62	50.38
12	32°58’52”	44°85’21”	360	535	105	Silty clay loam	1.29	2.61	50.57
13	32°55’79”	44°85’73”	368	347	285	Clay loam	1.26	2.6	51.54
14	32°57’28”	44°79’83”	370	354	276	Clay loam	1.25	2.64	52.65
15	32°54’51”	44°83’90”	362	350	288	Clay loam	1.3	2.62	50.38
16	32°57’00”	44°79’89”	375	396	229	Clay loam	1.31	2.62	50
17	32°58’06”	44°81’48”	372	398	230	Clay loam	1.33	2.64	49.62
18	32°57’00”	44°79’89”	368	401	231	Clay loam	1.29	2.64	51.14
19	32°57’03”	44°79’38”	361	408	231	Clay loam	1.26	2.6	51.54
20	32°54’73”	44°79’46”	355	413	232	Clay loam	1.27	2.63	51.71
21	32°54’52”	44°80’22”	359	412	229	Clay loam	1.3	2.61	50.19
22	32°56’82”	44°79’88”	398	352	250	Clay loam	1.31	2.63	50.19
23	32°56’82”	44°78’67”	390	361	249	Clay loam	1.32	2.64	50
24	32°56’77”	44°77’85”	392	357	251	Clay loam	1.3	2.64	50.76
25	32°58’32”	44°74’45”	189	234	577	Sandy loam	1.25	2.61	52.11
26	32°58’27”	44°74’31”	190	241	569	Sandy loam	1.28	2.55	49.8
27	32°57’67”	44°75’78”	191	244	565	Sandy loam	1.29	2.57	49.81
28	32°56’82”	44°75’90”	248	253	499	Sandy clay loam	1.38	2.63	47.53
29	32°56’22”	44°77’73”	240	248	512	Sandy clay loam	1.36	2.6	47.69
30	32°57’43”	44°76’12”	239	254	507	Sandy clay loam	1.33	2.64	49.62

Data physical and chemical of soil used

The coefficients that were carried out to evaluate the suitability of land for crop production are (pH), electrical conductivity (ECe), organic carbon (OC), soil texture, soil drainage, lime, gypsum, cation exchange capacity, exchangeable sodium ratio, total nitrogen, and available phosphorus, slope, soil depth, flooding and crop variety (Tables 1, 2, 3 and 4) based on a relevant literature review.

Land evaluation according to the AHP system

The AHP analytical hierarchy process is used as one of the multi-criteria decision-making tools (Multi-Criteria Decision Making – MCDM) or Multi Criteria Evaluation – MCE. At this stage, the hierarchical structure of the study is formed according to several levels. The main criteria are represented, while the third level of the pyramid represents the secondary criteria, as the principle of the method is based on double comparisons between the studied criteria matrices to determine the weight of each factor that controls the suitability analysis, through a binary comparison of the criteria matrices, then values (weights) are given for each studied criterion. According to its relative importance and impact on the appropriation process, the values (weights) range from 1 to 9, as the number y1 means that the two criteria

Table 2. Soil chemical properties for the study area

Surface sample	EC	pH	ESP	CEC	O.M	Total N.	AV. P.	$CaCO_3$	$CaSO_4$
	$dS \cdot m^{-1}$			$Cmol_c \cdot kg^{-1}$ soil	$gm \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$gm \cdot kg^{-1}$	$gm \cdot kg^{-1}$
1	3.9	7.39	3.35	23.1	9.1	729	12.9	33.21	11.72
2	3.2	7.52	4.21	22.6	8.7	720	12.5	32.92	11.63
3	3.7	7.41	4.45	22.1	9.2	733	13.3	32.88	11.69
4	5.2	7.27	4.92	26.3	7.1	620	11.2	33.4	21.13
5	5.6	7.31	5.07	25.1	7.5	613	10.6	33.9	21.28
6	4.8	7.25	4.13	24.9	8	631	10.9	32.6	21.21
7	6.3	7.43	5.79	23.4	8.6	698	13	30.7	11.18
8	7.1	7.51	6.35	22.9	9.2	720	12.6	29.9	11.28
9	6.4	7.48	5.66	23.6	8.1	715	12.8	31.2	11.23
10	4.1	7.42	3.61	26.21	8.2	512	11.3	33.93	20.92
11	3.2	7.4	3.29	26.93	8.9	530	10.8	33.1	20.9
12	3.7	7.39	3	25.82	9.3	524	11.2	34.18	19.03
13	8.1	7.58	8.46	23.92	9.8	567	12.7	30.12	19.52
14	8.8	7.52	8.06	23.61	9	552	12.1	30.92	16.41
15	8.4	7.63	7.32	24.12	9.3	536	12.5	29.87	15.46
16	16.3	7.61	13.18	21.32	7.8	779	15.1	34.5	9.53
17	16.9	7.64	13.55	21.23	8.2	782	16	33.8	9.58
18	16.4	7.55	13.24	22.13	8	780	15.2	34.2	9.49
19	5.85	7.68	4.34	23.52	9.4	771	12.4	32.42	11.08
20	5.98	7.59	4.99	23.95	8.5	762	11.7	31.75	10.97
21	5.39	7.64	4.8	23.86	9.6	769	11.8	31.93	11.03
22	17.23	7.52	14.45	23.15	9.8	402	8.8	29.18	20.38
23	19.35	7.7	14.19	22.38	9.5	410	9.6	29.15	19.27
24	19.12	7.59	13.02	22.19	9.1	421	9.1	30.12	20.28
25	23.82	7.88	13.45	18.17	8	142	2.3	27.73	11.75
26	23.15	7.69	12.79	18.92	9.3	149	2.1	27.28	11.93
27	24.93	7.72	12.74	18.85	8.2	144	2.2	28.1	12.21
28	21.35	7.73	11.66	20.03	9	128	2.1	33.96	14.7
29	20.91	7.7	10.28	18.92	9.5	130	2	33.88	14.49
30	20.75	7.72	12.7	20.31	9.3	125	2.3	34.12	14.43

Table 3. Pairwise comparison scale

AHP scale of Importance for comparison pair (a_{ij})	Numeric rating	Reciprocal (decimal)
Extreme importance	9	1/9(0.111)
Very strong to extremely	8	1/8(0.125)
Very strong Importance	7	1/7(0.143)
Strongly to very strong	6	1/6(0.167)
Strong importance	5	1/5(0.200)
Moderately to strong	4	1/4(0.250)
Moderate importance	3	1/3(0.333)
Equally to Moderately	2	1/2(0.500)
Equal importance	1	1 (1.000)

studied (I, j) have the same effect and 9 reveals that one of the criteria is of high importance in the process of appropriation and evaluation as shown in Table 3. (Saaty and Vargas, 2013; Saaty, 1980; Malczewski, 1999; Feizizadeh et al., 2014).

Weight determination using the AHP method from MCDA

The AHP method is considered among the best available approaches of MCDA, which was used for assessing and analyzing land-use suitability for different crops (Jain et al., 2020; Maddahi et al., 2016 and Mugiyo et al., 2021). The pairwise comparison matrix was created based on the relative importance of one criterion over another for determining the parameter weights, as per the AHP preference scale (Table 4).

$$A = \begin{bmatrix} a11 & a12 & a1n \\ a21 & a22 & a2n \\ an1 & an2 & ann \end{bmatrix} \quad (1)$$

In the pairwise matrix, the sum of each column was represented as follows in Table 5:

$$aij = \sum_{i=1}^{n} aij \quad (2)$$

Then, each value in the matrix was divided by the respective column sum to create a standardized pairwise matrix Table 6:

$$bij = \frac{aij}{\sum_{i=1}^{n} aij} = \begin{bmatrix} b11 & b12 & b1n \\ b21 & b22 & b2n \\ bn1 & bn2 & bnn \end{bmatrix} \quad (3)$$

Lastly, the sum of the standardized matrix column was divided by the total number of criteria considered (n) to create the weighted matrix of the priority criteria:

$$wij = \frac{\sum_{i=1}^{n} bij}{n} = \begin{bmatrix} w11 \\ w12 \\ w1n \end{bmatrix} \quad (4)$$

Table 4. Pairwise comparison matrix

Parameter	OM	PH	EC	$CaCO_3$	CEC	ESP	SLOPE	Texture	Drainage	Soil depth	Avlp. P	Tot. N	$CaSO_4$	Flooding	Crop class
OM	5/5	5/6	5/9	5/3	5/5	5/5	5/1	5/9	5/5	5/1	5/7	5/7	5/3	5/3	5/9
PH	6/5	6/6	6/7	6/3	6/5	6/5	6/1	6/7	6/5	6/1	6/7	6/7	6/3	6/3	6/7
EC	9/5	9/6	9/7	9/3	9/5	9/5	9/1	9/7	9/5	9/1	9/7	9/7	9/3	9/3	9/7
$CaCO_3$	3/5	3/6	3/9	3/3	3/5	3/5	3/1	3/9	3/5	3/1	3/7	3/7	3/3	3/3	3/9
CEC	5/5	5/6	5/9	5/3	5/5	5/5	5/1	5/9	5/5	5/1	5/7	5/7	5/3	5/3	5/9
ESP	5/5	5/6	5/9	5/3	5/5	5/5	5/1	5/9	5/5	5/1	5/7	5/7	5/3	5/3	5/9
SLOPE	1/5	1/6	1/9	1/3	1/5	1/5	1/1	1/9	1/5	1/1	1/7	1/7	1/3	1/3	1/9
Texture	9/5	9/6	9/9	9/3	9/5	9/5	9/1	9/9	9/5	9/1	9/7	9/7	9/3	9/3	9/9
Drange	5/5	5/6	5/9	5/3	5/5	5/5	5/1	5/9	5/5	5/1	5/7	5/7	5/3	5/3	5/9
Soil depth	1/5	1/6	1/9	1/3	1/5	1/5	1/1	1/9	1/5	1/1	1/7	1/7	1/3	1/3	1/9
Avlp. P	7/5	7/6	7/9	7/3	7/5	7/5	7/1	7/9	7/5	7/1	7/7	7/7	7/3	7/3	7/9
Tot. N	7/5	7/6	7/9	7/3	7/5	7/5	7/1	7/9	7/5	7/1	7/7	7/7	7/3	7/3	7/9
$CaSO_4$	3/5	3/6	3/9	3/3	3/5	3/5	3/1	3/9	3/5	3/1	3/7	3/7	3/3	3/3	3/9
Flooding	3/5	3/6	3/9	3/3	3/5	3/5	3/1	3/9	3/5	3/1	3/7	3/7	3/3	3/3	3/9
Crop class	9/5	9/6	9/9	9/3	9/5	9/5	9/1	9/9	9/5	9/1	9/7	9/7	9/3	9/3	9/9

Table 5. Pairwise comparison continued

Para-meter	OM	PH	EC	$CaCO_3$	CEC	ESP	SLOPE	Texture	Drange	Soil depth	Avlp. P	Tot. N	$CaSO_4$	Flooding	Crop class	Average
OM	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
PH	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
EC	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
$CaCO_3$	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CEC	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
ESP	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
SLOPE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Texture	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Drange	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Soil depth	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Avlp. P	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Tot. N	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
$CaSO_4$	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Flooding	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Crop class	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

The original consistency vectors were obtained by multiplication of the pairwise matrix by the weight vectors:

$$\begin{bmatrix} a11 & a12 & a1n \\ a21 & a22 & a2n \\ an1 & an2 & ann \end{bmatrix} X \begin{bmatrix} w11 \\ w12 \\ w1n \end{bmatrix} = \tag{5}$$
$$= \begin{bmatrix} a11w11 & a12w12 & a1nw1n \\ a21w21 & a22w22 & a2nw1n \\ an1wn1 & an2wn2 & annw1n \end{bmatrix} = \begin{bmatrix} v11 \\ v12 \\ v1n \end{bmatrix}$$

Furthermore, the principal eigenvector (λ_{max}) was computed by averaging the elements of the consistency vector:

$$\lambda_{max} = \sum_{i=1}^{n} avij = 15.03182 \tag{6}$$

Eigenvalues were computed by averaging the respective rows of each matrix, these values were also mentioned as relative weights. In the AHP method, while executing the pairwise comparisons of criteria, a certain level of variation may follow. To tackle this problem, consistency ratio (CR) was used for preventing bias through criteria weighting. As a solution, eigenvectors and the largest eigenvalue of the respective

Table 6. Calculation of weights for each soil parameter

Para-meter	OM	PH	EC	$CaCO_3$	CEC	ESP	SLOPE	Texture	Drange	Soil depth	Avlp. P	Tot. N	$CaSO_4$	Flooding	Crop class	Weighted sum value
OM	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.95
PH	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.10	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1.17
EC	0.11	0.12	0.12	0.11	0.11	0.11	0.11	0.15	0.11	0.11	0.11	0.11	0.11	0.11	0.12	1.76
$CaCO_3$	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.57
CEC	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.96
ESP	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.96
SLOPE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.19
Texture	0.11	0.12	0.12	0.11	0.11	0.11	0.11	0.15	0.11	0.11	0.11	0.11	0.11	0.11	0.12	1.76
Drange	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.95
Soil depth	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.19
Avlp. P	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1.34
Tot. N	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1.34
$CaSO_4$	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.57
Flooding	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.57
Crop class	0.11	0.12	0.12	0.11	0.11	0.11	0.11	0.15	0.11	0.11	0.11	0.11	0.11	0.11	0.12	1.76

Table 7. Multiply the average by every property of the soil

Parameter	Pairwise	Weighted sum value	Average	Max
OM	5	0.954605	0.0635427	15.02305
PH	6	1.168254	0.0776009	15.05465
EC	9	1.756187	0.1166505	15.05511
$CaCO_3$	3	0.572155	0.0380843	15.02337
CEC	5	0.958079	0.0637699	15.02401
ESP	5	0.958079	0.0637699	15.02401
SLOPE	1	0.189947	0.0126434	15.02343
Texture	9	1.756187	0.1166505	15.05511
Derange	5	0.954605	0.0635427	15.02305
Soil depth	1	0.189947	0.0126434	15.02343
Avlp. P	7	1.337818	0.0890525	15.0228
Tot. N	7	1.337818	0.0890525	15.0228
$CaSO_4$	3	0.572155	0.0380843	15.02337
Flooding	3	0.574848	0.0382619	15.02401
Crop class	9	1.756187	0.1166505	15.05511
Average				15.03182

matrix were computed, and the consistency index (CI) was examined using the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} = 0.002273 \quad (7)$$

Here, λ_{max} represents the maximum eigenvalue of the pairwise comparison matrix and n is the number of criteria in each PWCM. Finally, the uniformity of the PWCM was examined using the random consistency index (RI) value, as shown in Table 9. CR was computed by using the method given below.

$$CR = \frac{CI}{RI} = 0.001439 \quad (8)$$

To be valid, its consistency ratio should be ≤0.10. If the acquired value is larger than 0.10, it is essential to develop the PWCM.

Aggregation of the weight and standardized rated criterion map

The weighted overlay method was used to aggregate standardized rated criteria and weighted criteria to map the suitable land based on the equation below. These maps were reclassified based on a parametric model of a land index to generate FAO land classes which convert suitability values into classes to produce the final map (Table 4).

$$LS = \sum_{i=0}^{n} \text{Wi Xi} \quad (9)$$

where: LS is the land suitability;
Wi is the weight of factor;
Xi is the criterion score of factor *i*.

So last equation became:

$$\begin{aligned} L.S = {} & ECe \cdot 0.116 + Texture \cdot 0.116 + \\ & + Crop\ Class \cdot 0.116 + Total\ N \cdot 0.089 + \\ & + Available\ P \cdot 0.089 + pH \cdot 0.077 + CEC \cdot \\ & \cdot 0.0637 + ESP \cdot 0.0637 + Drainage \cdot \\ & \cdot 0.0635 + O.M \cdot 0.0635 + CaCO_3 \cdot 0.038 + \\ & + CaSO_4 \cdot 0.038 + Flooding \cdot 0.038 + \\ & + Soil\ Depth \cdot 0.0126 + Slope \cdot 0.0126 \end{aligned} \quad (10)$$

Land evaluation by parametric metod

Properties that affect the suitability of land for growing wheat, were identified. The standard multiplication method mentioned in Sys et al. (1993) was used by using the estimate of each property and extracting the final value of land suitability using the equation below to assess the land suitability. For the selected crops with each other for the purpose of obtaining the final assessment of the land evaluation, through which the land suitability is determined, as the equation below was used to obtain the suitability of the soil in the manner used in this study:

$$\begin{aligned} & Land\ Suitability\ (L.S) = A1 \cdot \\ & \cdot A2 \ldots\ldots An/102n\text{-}2 \\ & A1 \ldots\ldots An\ (parameters) \end{aligned} \quad (11)$$

RESULTS AND DISSCUSION

Evaluation of the suitability of soil properties for the cultivation of wheat crops using parametric method

The results in Tables 8 refer to the general properties of the lands of the Nile region in the province of Babylon, and the standard multiplication method proposed by Sys et al. (1993) was adopted for the purpose of showing the suitability of the lands for the productivity of the wheat crop, as the results show the evaluation of the properties for the purposes of cultivating the wheat crop in the study area and as follows.

Topographical: According to the soil properties requirements tables adopted by Sys et al. (1993), the slope was estimated at (95) and did not constitute a determining factor for the wheat yield in the study area. Soil depth: It is very suitable for wheat cultivation, and it was given a rating of (100) and it did not constitute an influencing factor for suitability. Soil texture: It was an influential factor in some locations of the study area for the wheat crop, and the texture factor was estimated between (50–97.5) for the wheat crop Kahella & Suliman (2021). Carbonate Content: Based on Sys et al. (1993), it can be said that the carbonate minerals content factor is a simple affecting factor for the growth of the wheat crop, as the estimated values for the wheat crop ranged between (75.95–88.82). Gypsum percentage: gypsum in the soil of the study area was generally low and did not exceed 2%, and the gypsum content factor was given an estimate ranging between

Table 8. The land suitability (Sys et al. 1993) site of Babylon, Nile region, for wheat crop

LOC.	PH	EC	ESP	TEX	Depth	GYPS	$CaCO_3$	OC	CEC	Slope	Flooding	Drange	Suitability	Class
1	96.1	73.75	98.88	90	100	98.05	76.98	76.53	93.88	95	100	97.5	31.68	N1
2	94.71	82.5	98.6	90	100	98.06	77.7	75.81	93.25	95	100	97.5	34.59	N1
3	95.9	76.25	98.52	90	100	98.05	77.8	76.72	92.63	95	100	97.5	32.55	N1
4	97.3	56	98.36	97.5	100	96.48	76.5	72.9	100	95	100	97.5	26.04	N1
5	96.9	48	98.31	97.5	100	96.45	75.25	73.63	100	95	100	97.5	22.07	N2
6	97.5	62.5	98.62	97.5	100	96.46	78.5	74.53	100	95	100	97.5	30.63	N1
7	95.7	38.88	98.07	97.5	100	98.14	83.25	75.63	94.25	95	100	97.5	19.19	N2
8	94.85	35.88	97.88	97.5	100	98.12	85.1	76.72	93.63	95	100	97.5	18.04	N2
9	95.2	38.5	98.11	97.5	100	98.13	82	74.72	94.5	95	100	97.5	18.45	N2
10	95.8	71.25	98.8	97.5	100	96.51	75.18	74.9	100	95	100	97.5	33.09	N1
11	96	82.5	98.9	97.5	100	96.52	77.25	76.17	100	95	100	97.5	40.17	S3
12	96.1	76.25	99	97.5	100	96.83	74.55	76.9	100	95	100	97.5	36.37	N1
13	93.85	32.13	97.18	97.5	100	96.75	84.7	77.81	94.9	95	100	97.5	16.01	N2
14	94.71	29.5	97.31	97.5	100	97.26	82.7	76.35	94.51	95	100	97.5	14.25	N2
15	93.14	31	97.56	97.5	100	97.42	85.13	76.9	100	95	100	97.5	16.22	N2
16	93.42	12.5	95.61	97.5	100	98.41	73.75	74.17	91.65	95	100	97.5	4.97	N2
17	92.99	12.5	95.48	97.5	100	98.4	75.5	74.9	91.54	95	100	97.5	5.11	N2
18	94.28	12.5	95.59	97.5	100	98.42	74.5	74.53	92.66	95	100	97.5	5.15	N2
19	92.42	43	98.55	97.5	100	98.15	78.95	77.08	94.4	95	100	97.5	19.94	N2
20	93.71	40.4	98.34	97.5	100	98.17	80.63	75.44	94.94	95	100	97.5	19.06	N2
21	92.99	52.2	98.4	97.5	100	98.16	80.18	77.44	94.83	95	100	97.5	24.93	N2
22	94.71	12.5	95.18	97.5	100	96.6	85.82	77.81	93.94	95	100	97.5	6.17	N2
23	92.14	12.5	95.27	97.5	100	96.79	85.85	77.26	92.98	95	100	97.5	5.91	N2
24	93.71	12.5	95.66	97.5	100	96.62	84.7	76.53	92.74	95	100	97.5	5.88	N2
25	89.57	12.5	95.52	50	100	98.04	87.27	74.53	87.71	95	100	50	1.42	N2
26	92.28	12.5	95.74	50	100	98.01	87.72	76.9	88.65	95	100	50	1.54	N2
27	91.85	12.5	95.75	50	100	97.96	86.9	74.9	88.56	95	100	50	1.47	N2
28	91.71	12.5	96.11	72.5	100	97.55	75.1	76.35	90.04	95	100	50	1.91	N2
29	92.14	12.5	96.57	72.5	100	97.58	75.3	77.26	88.65	95	100	50	1.93	N2
30	91.85	12.5	95.77	72.5	100	97.59	74.7	76.9	90.39	95	100	50	1.92	N2

(96.45–98.40) for the wheat crop (Martin et al., 2016). Salinity: Soil salinity values ranged from (3.2–24.93) dS·m^{-1} in the study region. Comparing these values with the requirements of the wheat crop confirms the existence of very severe determinants for the cultivation of wheat crops based on Sys et al. (1993), and according to the requirements tables salinity suitability estimates ranged between (12.5–81.88) for the wheat crop (Hamad et al., 2021). Soil interaction pH: Soil interaction values ranged between (7.25–7.88), and these values are considered suitable for the growth and cultivation of wheat crop, considering this factor as a simple determining factor for all study soil sites. The suitability values for wheat crop ranged between (89.57–97.50). Exchangeable Sodium percentage ESP: sodium adsorption ratio values ranged between (3–14.45), and the suitability values for wheat ranged between (95.18–99). Cation exchangeable capacity: CEC The values of Cation exchangeable capacity in the study area ranged between (18.17–26.93) Cmolc·kg^{-1} Soil and these values are good. An estimate of the suitability for the study area was given between (87.71–100) for the wheat crop (Rahal & Alhumairi, 2019; Al-Obaidi, 2023). Organic carbon ratio: It was The suitability values ranged between (72.90–77.81) for the wheat crop (Hussien and Abdulbaqi, 2022; Abdulridha & Essa, 2023; Abbas & Al-Jarrah, 2023). Drainage: The degree of drainage was good to medium in the soils of the study area, and an estimate of (97.5) was given for the soft-weave soils for the wheat crop and (50) for the coarse-weave soils for the wheat crop. It was a determining factor in all soil sites of the study area for the wheat

Table 9. The land suitability AHP, site of Babylon, Nile region, for wheat crop

LOC.	PH	EC	ESP	TEX	Depth	GYPS	$CaCO_3$	OC	CEC	Slope	Flooding	Drange	N	P	Crop	Suit	Class
1	7.457	8.603	6.306	10.5	1.264	3.734	2.932	4.863	5.986	1.201	3.826	6.195	8.385	6.634	11.67	89.55	S1
2	7.35	9.624	6.288	10.5	1.264	3.735	2.959	4.817	5.947	1.201	3.826	6.195	8.353	6.456	11.67	90.18	S1
3	7.442	8.895	6.282	10.5	1.264	3.734	2.963	4.875	5.907	1.201	3.826	6.195	8.399	6.813	11.67	89.96	S1
4	7.551	6.532	6.272	11.37	1.264	3.674	2.913	4.632	6.377	1.201	3.826	6.195	7.997	5.877	11.67	87.35	S1
5	7.52	5.599	6.269	11.37	1.264	3.673	2.866	4.678	6.377	1.201	3.826	6.195	7.972	5.61	11.67	86.09	S1
6	7.566	7.291	6.289	11.37	1.264	3.674	2.99	4.736	6.377	1.201	3.826	6.195	8.036	5.744	11.67	88.23	S1
7	7.426	4.535	6.254	11.37	1.264	3.737	3.171	4.805	6.01	1.201	3.826	6.195	8.275	6.679	2.916	77.67	S2
8	7.361	4.185	6.242	11.37	1.264	3.737	3.241	4.875	5.97	1.201	3.826	6.195	8.353	6.501	2.916	77.24	S2
9	7.388	4.491	6.257	11.37	1.264	3.737	3.123	4.748	6.026	1.201	3.826	6.195	8.335	6.59	2.916	77.47	S2
10	7.434	8.311	6.3	11.37	1.264	3.676	2.863	4.759	6.377	1.201	3.826	6.195	7.612	5.922	2.916	80.03	S1
11	7.45	9.624	6.307	11.37	1.264	3.676	2.942	4.84	6.377	1.201	3.826	6.195	7.676	5.699	2.916	81.37	S1
12	7.457	8.895	6.313	11.37	1.264	3.688	2.839	4.886	6.377	1.201	3.826	6.195	7.655	5.877	2.916	80.76	S1
13	7.283	3.747	6.197	11.37	1.264	3.685	3.226	4.944	6.052	1.201	3.826	6.195	7.808	6.545	5.833	79.18	S2
14	7.35	3.441	6.206	11.37	1.264	3.704	3.15	4.852	6.027	1.201	3.826	6.195	7.755	6.278	5.833	78.45	S2
15	7.228	3.616	6.221	11.37	1.264	3.71	3.242	4.886	6.377	1.201	3.826	6.195	7.698	6.456	5.833	79.13	S2
16	7.25	1.458	6.097	11.37	1.264	3.748	2.809	4.713	5.845	1.201	3.826	6.195	8.563	7.614	5.833	77.79	S2
17	7.216	1.458	6.089	11.37	1.264	3.748	2.875	4.759	5.837	1.201	3.826	6.195	8.574	8.015	5.833	78.26	S2
18	7.316	1.458	6.096	11.37	1.264	3.748	2.837	4.736	5.909	1.201	3.826	6.195	8.567	7.659	5.833	78.02	S2
19	7.172	5.016	6.285	11.37	1.264	3.738	3.007	4.898	6.02	1.201	3.826	6.195	8.535	6.412	11.67	86.61	S1
20	7.272	4.713	6.271	11.37	1.264	3.739	3.071	4.794	6.054	1.201	3.826	6.195	8.503	6.1	11.67	86.04	S1
21	7.216	6.089	6.275	11.37	1.264	3.738	3.053	4.921	6.047	1.201	3.826	6.195	8.528	6.145	11.67	87.54	S1
22	7.35	1.458	6.07	11.37	1.264	3.679	3.268	4.944	5.99	1.201	3.826	6.195	6.697	4.916	11.67	79.9	S2
23	7.15	1.458	6.075	11.37	1.264	3.686	3.27	4.909	5.929	1.201	3.826	6.195	6.768	5.201	11.67	79.97	S2
24	7.272	1.458	6.1	11.37	1.264	3.68	3.226	4.863	5.914	1.201	3.826	6.195	6.866	5.023	11.67	79.93	S2
25	6.95	1.458	6.091	5.833	1.264	3.734	3.324	4.736	5.593	1.201	3.826	3.177	4.018	2.841	2.916	56.96	S3
26	7.161	1.458	6.105	5.833	1.264	3.733	3.341	4.886	5.653	1.201	3.826	3.177	4.099	2.787	2.916	57.44	S3
27	7.128	1.458	6.106	5.833	1.264	3.731	3.31	4.759	5.648	1.201	3.826	3.177	4.041	2.814	2.916	57.21	S3
28	7.117	1.458	6.129	8.457	1.264	3.715	2.86	4.852	5.742	1.201	3.826	3.177	3.856	2.787	2.916	59.36	S3
29	7.15	1.458	6.158	8.457	1.264	3.716	2.868	4.909	5.653	1.201	3.826	3.177	3.879	2.761	2.916	59.4	S3
30	7.128	1.458	6.107	8.457	1.264	3.717	2.845	4.886	5.764	1.201	3.826	3.177	3.821	2.841	2.916	59.41	S3

crops. Flooding: A score of (100) was given for this characteristic in relation to the wheat crop, as there is no possibility of flooding or inundation occurring in the study area.

From the results above, which described the contribution of 12 factors to the suitability of the land for wheat productivity, as they were distributed between very specific, medium and simple effective, and that the most important and determining factors for productivity are (soil texture, content of carbonate minerals, soil salinity and the percentage of organic carbon).

Classifying soil suitability for wheat cultivation in the Nile region

The final results of the evaluation of the prevailing soil units in the Nile region, which are shown in Table (29) Figure 2, indicated that 2.5% of the total area of the study area, which occupied an area of 14312.92 hectares, within the unsuitable class S3, also 27.5% of the total area of the study area, which occupied an area of 14312.92 hectares, within the unsuitable class, to a limited degree, N1, because all soil units in this class do not suit the requirements. special for the wheat crop and to a large extent, as indicated by Sys et al. (1993) to the fact that these soils are located within the flat topographic sites and have physical, chemical and fertility properties that are not good, while the appropriate type N2, that is, the unsuitable, constitutes 70% of the total area of the study area and occupied An area of 36432.9 hectares, where some soil units suffer from some minor constraints, which can be improved by following some appropriate, simple and economically inexpensive administrative methods (Muhaimeed et al., 2014; Othman and Nasser, 2019).

Evaluation of the suitability of soil properties for the cultivation of wheat crops using the AHP method

Results in Table 9 show to the general properties of the lands of the Nile region in Babylon province, and the hierarchical analysis method AHP was adopted to indicate the suitability of the lands for the productivity of the wheat crop. follows.

Topographical: I was given a value of 1/9 with a weight of 1.264%, and given that the value of the regression is 1% with a weight equal to 95 when using the Sys et.al., 1993 equation, so the final result was 1.201% and it is considered very appropriate for the wheat crop (Al-Akaidi, 1986 and Al-Akaili, 2021). Soil depth: The results shown in Table 9 indicated that the characteristic of soil depth was given an importance of 1/9 with a weight of 1.264% for the wheat crop, noting that it was given an estimate of 100 when using the equation of Sys et al. (1993), and these results are consistent with the findings of Muhaimeed. et al. (2014) and Al-Qassab (2015). Soil texture: It was given the importance of 9/9 with a weight of 11.66%, and this value changes according to the class of soil texture depending on the weights obtained from the wheat crop requirements table according to Sys et al. (1993), as it amounted to 5.833% for each of L27, L26, L25 and 8.457%

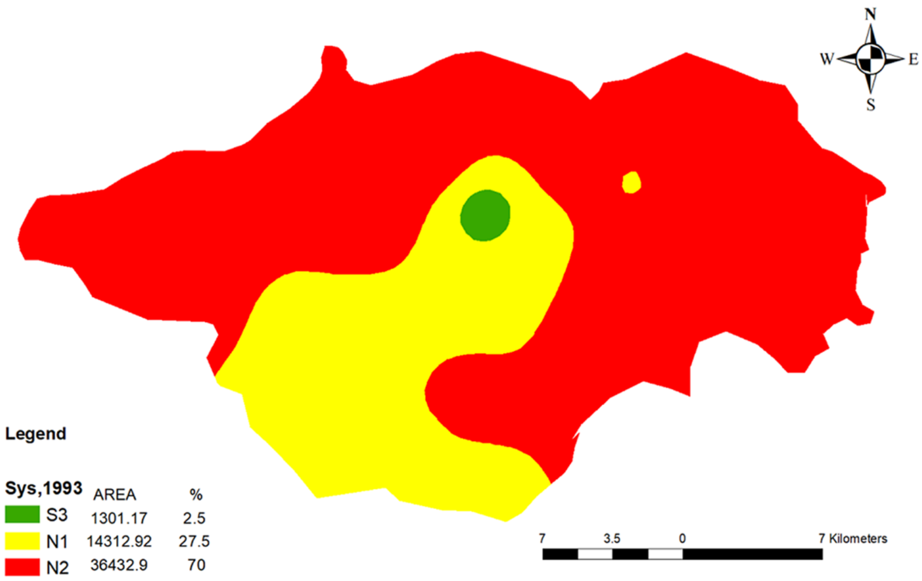

Figure 2. Land suitability using the methods developed by Sys et al. (1993)

for each. Of L30, L29, L28, which is equivalent to a weight of 72.5 when using the equation of Sys et.al., 1993, and amounted to 10.5% for each of L3, L2, and L1, while the rest of samples, which start with L4 and end with L24, amounted to 11.37%. Calcium carbonate: was given the importance of 9/3 with a weight of 3.808% and it is considered a effective factor for productivity due to the high content of calcium carbonate in these soils, as its values ranged between (26.18–34.50)% and it weighed 73.75–88.82 when using the Sys et al. (1993) equation For wheat crop, the highest weight value reached is 3.808%, and thus we note that its value ranged from 2.865 for the L12 sample to 3.341% for the L26 sample for the wheat crop. Gypsum was given importance by 3/9 with a weight of 3.808%. All soil units showed a very high suitability, ranging from 3.673% to 3.747% due to the low soil content in the study area. Soil salinity: was given the importance of 9/9 with a weight of 11.66% and it is considered effective factor for productivity as its values ranged between 3.2–24.93 dSm^{-1} and it was with a weight between 12.5–82.5 for the wheat yield when using the equation of Sys et al. (1993) and in these varying proportions it is considered a effective factor Influential and when using the AHP method, I give the utmost importance, we note that the highest weight value reached by salinity is 11.66%, and thus its values ranged between 1.458–9.551% for the wheat crop. Soil interaction: Its significance was 6/9 with a weight of 7.76%. Therefore, all soil units were very suitable and its value ranged from 6.917% to 7.504% for the wheat crop Exchangeable cation capacity: It was given an importance of 9/5 with a weight of 6.376%, and the weights ranged from 5.593% to 6.377%, with a very appropriate degree. It also gave weights that ranged between 87.71–100 when using the equation of Sys et al. (1993). Thus, it is considered very appropriate and did not It is considered an effective factor for the cultivation of wheat crop. Organic carbon: give importance 9/5 with a weight of 6.354%, and we note that the values of organic carbon by weight using AHP were between 4.712% to 5.117% for the wheat crop. Drainage: give an importance of 9/5 with a weight of 6.354% and it.

Changes according to the type of drainage for each soil unit, as an amount of 6.195% was given to all site study as its weight was 50–97.5 when using the equation of Sys et al. (1993) because the drainage was good to medium In this region for the wheat crop. Flooding: was given a significance of 9/3 with a weight of 3.326%, so its weight value was according to Sys et al. (1993) 100, but using the AHP method, its value was 3.826% for the wheat crop due to the absence of the possibility of flooding or inundation in that area.

Total nitrogen: was given an importance of 9/7 with a weight of 8.905%, and its weight ranged from 3.821% for the sample L30 to 8.399% for the sample L3 for the wheat crop. The fertile side of the soil. Available Phosphorus: It was given the importance of 9/7 with a weight of 8.905%, and its weight value ranged from 2.761% for the sample L29 to 8.015% for the sample L17 in relation to the wheat crop. This factor was introduced as a new measure for calculating the suitability of the lands when using the AHP method. Crop variety: give importance by 9/9 with a weight of 11.66%, and this value changes depending on the cultivar of the crop, as its values reached 11.66% for each of L24, L23, L22, L21, L20, L19, L6, L5, L4, L3, L2, L1, with a weight It is equal to 100% when compared to the weights of Sys et al. (1993), and the cultivated wheat variety was Adina, as it reached 5.833% for samples L18, L17, L16, L15, L14, L13, with a weight equal to 50% when compared to the weights of Sys, and the cultivated wheat variety was Rasheed as it reached 2.916% for the rest of the samples, with a weight equal to 25% when compared to the weights of Sys et al. (1993).

Land suitability classification for wheat cultivation in Nile region

The results in Table 9 and Figure 3 show the evaluation of the suitability of the land for the wheat crop to the dominance of three varieties that represent the condition of the area's land suitability for the cultivation of the wheat crop, as follows.

Class S1: lands belonging to this class were property as suitable lands for the cultivation of the wheat crop surface samples, they were L21, L20, L10, L12, L11, L10, L6, L5, L4, L3, L2, L1 within S1, i.e. within the limits of this class.

Class S2: lands belonging to this cultivar were properties as medium suitable for the cultivation of wheat crop due to the presence of some severe and very severe determinants, especially soil salinity and the carbonate minerals factor, respectively, within the chemical and physical conditions of the soil, according to what was mentioned in Sys et al. (1993), of which they cannot be removed in the future, especially the carbonate minerals. And

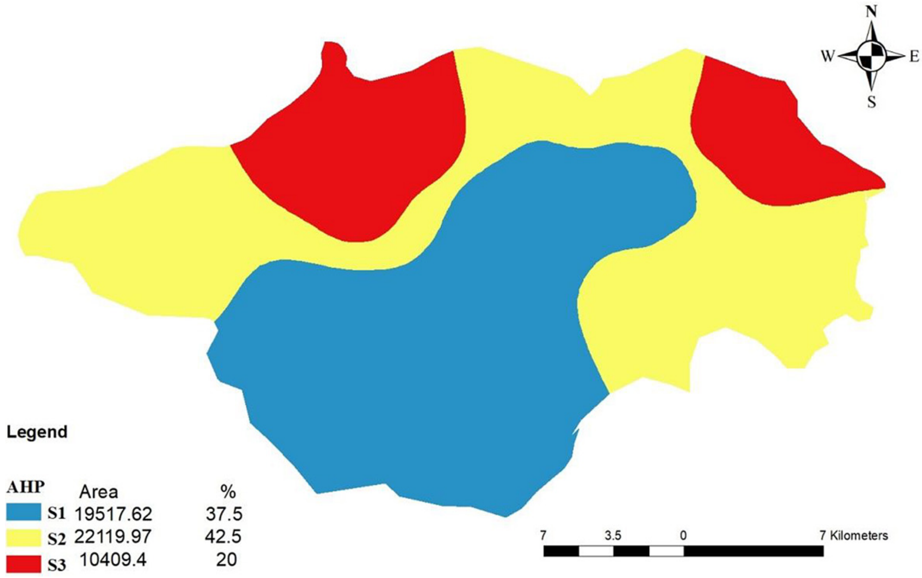

Figure 3. Spatial distribution of land-suitable cultivars for wheat cultivation in Nile region using the AHP method

medium determinants by the exchange capacity factor of positive ions, and this class represents, L24, L23, L22, L18, L17, L16, L15, L14, L13, L9, L8, L7 within S2, i.e. within the limits of this category as this class constituted an area of 22119.97 hectares, with a rate of 42.5% From the lands of the study area, as for the surface samples.

Class S3: lands belonging to this cultivar were properties as being suitable to a limited degree for the cultivation of wheat crop due to the presence of some very severe determinants, including soil salinity, carbonate minerals, and soil texture. The cultivar covers an area of 10409.4 hectares, or 20% of the study area, while the rest of the surface samples were within S3, i.e. within the limits of this cultivar (Dedeoğlu & Dengiz, 2019).

CONCLUSION

It is clear from the above study that the parametric method is not feasible with Iraqi soils, especially for the wheat crop, because it gives all criteria the same importance, especially since some criteria are fixed for Iraqi soils and some have the highest values such as flooding and soil depth, so it was found necessary to vary the importance of these properties Using the AHP method and giving weight to each criterion and adding three criteria (total nitrogen, phosphorus, and cultivated crop variety) to obtain values that are very close to the actual reality of land productivity.

REFERENCES

1. Abbas, E.H., Al-Jarrah, O.B. 2023. The Relationship between Organic Matter and Soil Reflectance at Ramadi, Iraq. The Iraqi Geological Journal, 12–17.
2. Abdulridha, A.N., Essa, S.K. 2023. Use of organic matter and sand in improving properties of some soils of holy karbala governorate affected by phenomenon of cracking. Iraqi Journal of Agricultural Sciences, 54(1), 268–281.
3. Akinci, H., Ozalp, A.Y., Turgut, B. 2013. Agricultural land suitability analysis using GIS and AHP technique. Comput. Electron. Agric., 97, 71–82.
4. Al-Jubouri, A.K., Wheib, K.A. 2020. Effect of soil salinity on spectral reflectance of red and NIR wavelengths in al-salamiyat project. Plant Arch, 20, 1359–1365.
5. AL-Obaidi, M.A.J. 2023. The effect of soil burning on the chemical and physical properties of soil and potassium status in northern Iraq. Eastern Journal of Agricultural and Biological Sciences, 3(1), 17–29.
6. Banai R. 2005. Land resource sustainability for urban development: spatial decision support system prototype. Environ Manag, 36(2), 282–296.
7. Dedeoğlu, M., Dengiz, O. 2019. Generating of land suitability index for wheat with hybrid system aproach using AHP and GIS. Computers and Electronics in Agriculture, 167, 105062.
8. Dedeoğlu, M., Dengiz, O. 2019. Generating of land suitability index for wheat with hybrid system aproach using AHP and GIS. Computers and Electronics in Agriculture, 167, 105062.
9. Dumanski, J., Bindraban, P.S., Pettapiece, W.W., Bullock, P., Jones, R.J.A., Thomasson, A. 2002. Land classification, sustainable land management,

and ecosystem health. In: Encyclopaedia of Life Support Systems. Oxford, UK, II: EOLSS Publishers.

10. Elsheikh, R., Shariff, A.R.B.M., Amiri, F., Ahmad, N.B., Balasundram, S.K., Soom, M.A.M. 2013. Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops. Comput. Electron. Agric., 93, 98–110.
11. FAO. 1990. Guidelines for Soil Profile Description, 3rd ed. Food and Agriculture Organization of the United Nations, Rome, Italy.
12. FAO. 1976. A Framework for Land Evaluation. Food and Agriculture Organization of the United Nations, Soils Bulletin No. 32. FAO, Rome.
13. Feizizadeh, B., Jankowski, P., Blaschke, T. 2014. A GISbased spatially explicit sensitivity and uncertainty analysis approach for multicriteria decision analysis. Comput Geosci, 64, 81–95.
14. Hamad, A.I., Jubeir, A.R., Oliwi, M.S. 2021. Spatial distribution of the western jadwal soils properties and suitability evaluation for wheat crop cultivation by geomatics technology. Iraqi Journal of Agricultural Sciences, 52(3), 712–723. DOI: 10.36103/ijas.v52i3.1363
15. Hassan, D.F., Ati, A.S., Neima, A.S. 2021. Calibration and evaluation of aquacrop for maize (*Zea Mays* L.) under different irrigation and cultivation methods. Journal of Ecological Engineering, 22(10).
16. Hussein, F.I., Abdu lbaqi D.S., Al Maamouri. 2022. The role of fulvic and humic acids and phosphate fertilizer levels on phosphorous uptake and maize yield in calcareous soil. Iraqi Journal of Soil Science, 22(2).
17. Ingle, S.N., Nagaraju, M.S.S., Gadge, P.S., Deshmukh, D.P., Dange, N.R. 2021. GIS based land use suitability of diversified cropping systems in bareli watershed. International Journal of Economic Plants, 8(4), 231–236.
18. Jain, R., Chand, P., Rao, S.C., Agarwal, P. 2020. Crop and soil suitability analysis using multi-criteria decision making in drought-prone semi-arid tropics in India. J. Soil Water Conserv., 19, 271–283.
19. Kahella, A.S.R.A., Suliman, A.A. 2021. Spatial variability of desert soil in Najaf Governorate, iraq using geostatistics. Plant Archives, 21(1), 71–81.
20. Maddahi, Z., Jalalian, A., Zarkesh, M.M.K., Honarjo, N. 2016. Land suitability analysis for rice cultivation using a GIS-based fuzzy multi-criteria decision making approach: Central part of Amol district, Iran. Soil Water Res., 12, 29–38.
21. Malczewski, J., 1999. GIS and Multicriteria Decision Analysis. John Wiley and Sons, New York.
22. Martin, P. 2016. Fearing a flood. Retrieved from The Globe and Mail: http://www.theglobeandmail.com/news/mosul-dam-could-/perachanyminute-as-kill-as-many millioniraqis/artc-Le295691079.
23. Minasny, B., McBratney, A.B. 2006. A conditioned Latin hypercube method for sampling in the presence of ancillary information. Comput. Geosci., 32, 1378–1388.
24. Mohana, P., Mariappan, N.V.E., Manoharan, N. 2009. Land suitability analysis for the part of Parambikulam Aliyar command area, Udumalpet Taluk using remote sensing.
25. Mugiyo, H., Chimonyo, V.G.P., Sibanda, M., Kunz, R., Nhamo, L., Masemola, C.R., Dalin, C., Modi, A.T., Mabhaudhi, T. 2021. Multi-criteria suitability analysis for neglected and underutilised crop species in South Africa. PLoS ONE 2021, 16, e0244734.
26. Muhaimeed A.S., Ahmed A., AL Falihi, Eimad AL-Aini, Auras M. Taha. 2014. Developing land suitability maps for some crops in Abu-Ghraib using remote sensing and GIS. Journal of Remote Sensing and GIS, 2(l), 2052–5583.
27. Ostovari Y., Honarbakhsh A., Sangoony H., Zolfaghari F., Maleki K., Ingram B. 2019. GIS and multi-criteria decision-making analysis assessment of land suitability for rapeseed farming in calcareous soils of semi-arid regions. Ecol Ind, 103, 479–487.
28. Othman, A.K., Samer N.N. 2019. Evaluation the individual's share of urban land use for the holy city of Karbala. Journal of Planner and Development, 24(1), 23–42.
29. Rabia, A.H., Terribile, F. 2013. Introducing a new parametric concept for land suitability assessment. International Journal of Environmental Science and Development, 4(1), 15.
30. Rahal, N.S., Alhumairi, B.A.J. 2019. Modelling of soil cation exchange capacity for some soils of east gharaf lands from mid-Mesopotamian plain (Wasit province/Iraq). International Journal of Environmental Science and Technology, 16(7), 3183–3192.
31. Rasheed, A.G., Razaq, I.B.A., Al-Kaysi, S.C. 2017. The effect of organic matter application on phosphorus status in the calcareous soil. Baghdad Science Journal, 14(1), 107–116.
32. Saaty, T.L. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation; McGraw-Hill International: New York, NY, USA, 1980.
33. Saaty, T.L. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation; McGraw-Hill International: New York, NY, USA, 1980.
34. Saaty, T.L. Vargas, L.G. 2013. Decision making with the analytic network process. Int. Ser. Operat. Res. Manage. Sci. 195, 295–318.
35. Sys, I.V.R.E., Debaveye, J. 1993. Land Evaluation, Part 3: Crop Requirement. Agricultural Publication-N7. General Administration for Development Cooperation, Brussels.
36. USDA. 2016. United States Department of Agriculture. USDA National Resources Conservation Service, Washington, DC.
37. Zonneveld, I.S. 1989. The land unit – a fundamental concept in landscape ecology, and its applications. Landscape Ecology, 3, 67–86.