

## SUITABILITY OF SOME DESERT SOILS IN AL-MUTHANA GOVERNORATE FOR WHEAT CROP PRODUCTION USING SYS AND ANALYTICAL HIERARCHY PROCESS AHP METHODS

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### ABSTRACT

This study aimed to present a comprehensive approach to analyze the suitability of agricultural lands for wheat production. This study was conducted in the desert of Al-Mauthanaa Governorate, using the Analytic Hierarchy Process (AHP) model and compared with the Sys1993 method. Ten soil properties were selected for the study: soil texture, soil depth, slope, calcium carbonate content, Gypsum, soil salinity, exchangeable sodium percentage (ESP), organic matter, and stoniness. The results of using the Sys method showed that, approximately 6.1% of the total area of the study was classified as S3 suitability class, covering an area of 98 hectares. around 31.1% of the total area of the study was classified as limited suitability classes (N1) with an area of 499 hectares, while the remaining land area, of 62.6%, was classified as unsuitable class (N2) occupying an area of 1003 hectares due to various constraints. According to the Analytic Hierarchy Process method and assigning varying importance to the above soil criteria, it was found that approximately 4% of the total area was classified as moderately suitable class (S2) because there are some limitations, covering an area of 63 hectares. Around 96% of the total area of the study region are classified as highly suitable class (S1) for wheat cultivation, covering an area of 1537 hectares.

**Key words:** AHP, land evaluation, soil properties, suitability.



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### INTRODUCTION

Land suitability is one of the means for assessing soil, and the Food and Agriculture Organization (FAO) has mentioned that land suitability is the fitness of a particular type of land for a specific use (Roberts, 2022). The total cultivated area in Iraq is estimated to be 6 hectares, with more than 90% being arid or semi-arid soil, according to the Food and Agriculture Organization's estimations. Land evaluation is the assessment of land performance when used for a specific agricultural purpose, involving the implementation and interpretation of soil surveys, vegetation cover, and climatic data, and it is an essential part of land use planning processes (Feizizadeh, *et al.*, 2012). Desert

soils occupy vast areas in the world, comprising one fifth of the land area of the Earth's surface, mostly in Africa and Asia. In Iraq, desert soils cover more than half of its area, estimated at one million hectares (Jain, *et al.*, 2020). Assessing land suitability serves as the first stage in agricultural land use planning, typically conducted repeatedly to ensure whether the land use type is appropriate for a particular area. Land suitability assessment involves qualitative and quantitative evaluations, where climate, hydrology, topography, vegetation cover, and soil characteristics are taken into account in qualitative assessments of land suitability, while quantitative assessment results are more accurate in predicting crop production (Ashraf,

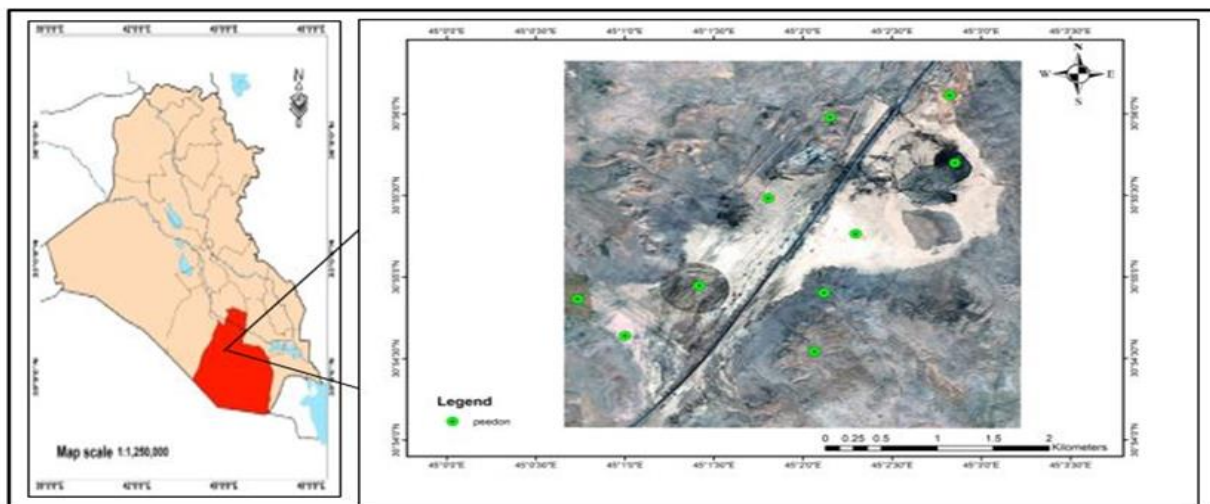
2010; Cengiz and Akbulak, 2009). The obtained results indicated that the highly suitable class (S1) covered an area of 97.31% of the total project area, while the moderately suitable class (S2) accounted for 2.3% of the total project area. The researchers also pointed out that the organic matter content was a determining factor, whereas climatic characteristics were highly suitable (S1) and moderately suitable (S2). The results of the study conducted by Abdulqawi *et al.*, 2019 Using the Analytic Hierarchy Process (AHP) in assessing land degradation relies objectively on determining the key factors influencing the evaluation. (Mahdi and Salah 2019) to assess the suitability of desert soils for agriculture with various crops in the Wadi El Natrun region in Egypt, showed that 65% of the study area is classified as (S2) and (S3). When using the standard addition method for wheat crop according to the Sys *et al.*, 1993 method, the highly suitable class S1 and the moderately suitable class S2 were the dominant classes according to the addition method. The results of the study conducted by the primary objective of studying the suitability of land before cultivation is to predict the land's capacity and its suitability for crop productivity (Hassan *et al.*, 2022.) Mohammed *et al.*, 2010 showed variations in

the suitability degree for wheat crop. The S1 class accounted for 37.50% of the total area, covering 15,917.62 hectares. It was found that 42.5% of the total area, occupying 22,119.97 hectares, fell within the S2 class. The results indicated land suitability for wheat crop when using the Sys *et al.* 1993 equation, with approximately 2.5% of the total study area, covering 1,301.1 hectares, falling within S3, while 27.5% of the total study area, occupying 14,312.92 hectares, fell within N1. Additionally, 70% of the study area, covering 36,432.9 hectares, fell within the N2 class. This study aimed to present a comprehensive approach to analyze the suitability of agricultural lands for wheat production in the desert of Al-Muthanna Governorate.

## MATERIALS AND METHODS

### Location and study area

The study area is located northwest of Muthanna Governorate, about 65 km from the center of Muthanna city, with an area of about 1600 hectares and is Located between latitudes 45°30' and 45°31' in the north and longitudes 50°44' and 45°15' in the east, with the Salhubiyah pasture station in the center, bordered by the Euphrates River in the north and the Salman oasis and station in the southwest, the study area ranges from 30-70 meters above sea level as shown in Figure 1.



**Figure 1. Study location and sampling**

**Preparation of the inputs for land Evaluation of the study area:** The suitability of the study area for growing soil characteristics wheat crop was assessed through 10 properties using the formula of Sys

*et al.*, (1993) (soil texture, soil depth, slope, Gypsum, soil salinity, EC, ESP natural drainage, organic matter, and stonin) taking into account the recommendations for extracting input weights from soil

characteristics, the most important of which was the use of the straight line equation (Mohammed et al., 2010; Bodaghabadi et al., 2019; Mugiyo et al., 2021).

**Evaluation of land suitability for wheat production according to the method of Sys et. al., (30):** In this stage, the soil characteristics and suitability for wheat production were evaluated according to the formula of Sys *et al.*, 1993 by multiplying the land suitability assessment estimates for the selected transformer with each other for the purpose of obtaining the final land assessment estimate, which determines the land suitability class according to equation (1).

$$Rs=A*B*C*D*E*F*G*H*I*L... (1)$$

Rs: Suitability :

A: Soil Depth Assessment Index

B: ESP Index

C: ECe Salinity Assessment Index

D: Soil Texture Assessment Index

E: Gypsum% Gypsum Evaluation Index

F: Organic Carbon Assessment Index

G: stones Index

J: Drainage Assessment Index

H: Slope Assessment Index

I: Calcium Carbonate %CaCO<sub>3</sub> Index

Index Suitability Class

100-85S1: very suitable

85-60S2: moderately suitable

60-40S3: marginally suitable

40-25N1: Currently unsuitable

25-0N2 Permanently Not suitable

**Land valuation according to Analytical Hierarchical Process (AHP) land Evaluation:**

The Analytical Hierarchy Process (AHP) is used as one of the tools for Multi Criteria Decision Making (MCDM) or Multi Criteria Evaluation (MCE). In this stage, the hierarchical structure of the study is formed according to several levels, the first level represents the study issue, the second level represents the main criteria, and the third level of the pyramid represents the secondary criteria. The principle of the method is based on paired comparisons between the studied criteria matrices to determine the weight of each factor that controls the fit analysis, through a paired comparison of the criteria matrices, then give values (weights) to each studied criterion according to its importance in the fit process, and the values (weights) range from 1 to 9, as the number 1 means that the two studied criteria i. j have the same effect and 9 reveals that one of the criteria is of high importance in the fit and evaluation process (Hassan *et al.*, 2021; Mohammed and Suliman, 2023) As in Table (1).

**Table 1. Measures of preferences for pairwise comparisons Taylor, (2002)**

Relative Importance	Definition	Description
1	Equally important	Two factors contributing uniformly to the predefined goal.
3	Moderately important	Experience and judgment are negligibly in favor of one as compared to the another
5	Strongly important	Experience and judgement strongly in favor of one in comparison to the other
7	Very strong import	Experience and judgments very strongly favor one over another. Its necessity is revealed in practice.
9	Extremely important	The sign favoring one as compared to the other parameter is of the maximum possible validity
2, 4, 6, 8	Intermediate	When compromise is needed
Reciprocals		Less importance 1/9 1/7 1/5 1/3 1 3 5 7 9 ← Less Importance → more

For example, if we take the dichotomy (soil texture, soil depth) and soil depth was considered more important than slope and received a value of 9, while slope when compared to soil depth received the treatment

1/9 = 0.11, in this study to implement the pairwise comparison matrix, experts were asked to calculate the relative importance of the factors and criteria involved in the evaluation and suitability process As in Table,

**Table 2. Results of the two factor differential measurement Taylor,(2002)**

AHP Scale of Importance for comparison pair (a <sub>ij</sub> )	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)

**Weighting using MCDA's AHP method**

The AHP method is among the best methods available for MCDA, which has been used to evaluate and analyze the suitability of land use for different crops (Malczewski, 1999; Maddahi *et al.*, 2016). The binary comparison matrix was constructed based on the relative

importance of one criterion over another to determine the weights of characters according to the AHP preference scale as in Tables (3) and (4).

$$=A = \begin{bmatrix} a_{11} & a_{12} & a_{1n} \\ a_{21} & a_{22} & a_{2n} \\ a_{n1} & a_{n2} & a_{nn} \end{bmatrix} \dots(2)$$

**Table 3. Pairwise comparison matrix**

C	OM	EC	CaCO3	CaSo4	ESP	slope	Texture	Drainage	soil Depth	R.Freq
OM	7/7	7/7	7/5	7/5	7/3	7/5	7/9	7/3	7/1	7/4
EC	7/7	7/7	7/5	7/5	7/3	7/5	7/9	7/3	7/1	7/4
CaCO3	5/7	5/7	5/5	5/5	5/3	5/5	5/9	5/3	5/1	5/4
CaSo4	5/7	5/7	5/5	5/5	5/3	5/5	5/9	5/3	5/1	5/4
ESP	3/7	3/7	3/5	3/5	3/3	3/5	3/9	3/3	3/1	3/4
SLOPE	5/7	5/7	5/5	5/5	5/3	5/5	5/9	5/3	5/1	5/4
Texture	9/7	9/7	9/5	9/5	9/3	9/5	9/9	9/3	9/1	9/4
Drainage	3/7	3/7	3/5	3/5	3/3	3/5	3/9	3/3	3/1	3/4
soil Depth	1/7	1/7	1/5	1/5	1/3	1/5	1/9	1/3	1/1	1/4
R.Freq	4/7	4/7	4/5	4/5	4/3	4/5	4/9	4/3	4/1	4/4

**Table 4. Pairwise comparison result for each adjective and its comparison with other adjectives**

	OM	EC	CaCO3	CaSo4	ESP	SLOPE	Texture	Drainage	soil Depth	R.Freq
OM	1	1	1.4	1.4	2.33	1.4	0.77	2.33	7	1.75
EC	1	1	1.4	1.4	2.33	1.4	0.77	2.33	7	1.75
CaCO3	0.71	0.71	1	1	1.66	1	0.55	1.66	5	1.25
CaSo4	0.71	0.71	1	1	1.66	1	0.55	1.66	5	1.25
ESP	0.43	0.43	0.6	0.6	1	0.6	0.33	1	3	0.75
SLOPE	0.71	0.71	1	1	1.66	1	0.55	1.66	5	1.25
Texture	1.28	1.28	1.8	1.8	3	1.8	1	3	9	2.25
Drainage	0.43	0.43	0.6	0.6	1	0.6	0.33	1	3	0.75
soil Depth	0.14	0.14	0.2	0.2	0.33	0.2	0.11	0.33	1	0.25
R.Freq	0.57	0.57	0.8	0.8	1.33	0.8	0.44	1.33	4	1
SUM	6.98	6.98	9.8	9.8	16.3	9.8	5.4	16.3	49	12.25

In the binary matrix, the sum of each column is represented as follows:

$$a_{ij} = \sum_{i=1}^n a_{ij} \dots(3)$$

Then, each value in the matrix was divided by the sum of the relevant column to create a standard binary matrix as shown in Table (5).

**Table 5. Calculate the weights for all soil characters by dividing their values by the total**

	OM	EC	CaCO3	CaSo4	ESP	SLOPE	Texture	Drange	soil Depth	FRE	average
OM	0.1433	0.1433	0.1429	0.1429	0.1429	0.1429	0.1426	0.1429	0.1429	0.1429	0.1429
EC	0.1433	0.1433	0.1429	0.1429	0.1429	0.1429	0.1426	0.1429	0.1429	0.1429	0.1429
CaCO3	0.1017	0.1017	0.1020	0.1020	0.1018	0.1020	0.1019	0.1018	0.1020	0.1020	0.1019
CaSo4	0.1017	0.1017	0.1020	0.1020	0.1018	0.1020	0.1019	0.1018	0.1020	0.1020	0.1019
ESP	0.0616	0.0616	0.0612	0.0612	0.0614	0.0612	0.0611	0.0614	0.0612	0.0612	0.0613
SLOPE	0.1017	0.1017	0.1020	0.1020	0.1018	0.1020	0.1019	0.1018	0.1020	0.1020	0.1019
Texture	0.1834	0.1834	0.1837	0.1837	0.1840	0.1837	0.1852	0.1840	0.1837	0.1837	0.1838
Drange	0.0616	0.0616	0.0612	0.0612	0.0614	0.0612	0.0611	0.0614	0.0612	0.0612	0.0613
soil Depth	0.0201	0.0201	0.0204	0.0204	0.0202	0.0204	0.0204	0.0202	0.0204	0.0204	0.0203
R.Freg	0.0817	0.0817	0.0816	0.0816	0.0816	0.0816	0.0815	0.0816	0.0816	0.0816	0.0816

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} = \begin{bmatrix} b_{11} & b_{12} & b_{1n} \\ b_{21} & b_{22} & b_{2n} \\ b_{n1} & b_{n2} & b_{nn} \end{bmatrix} \dots (4)$$

number of criteria considered n to create the weighted matrix of priority criteria Table 6:

Finally, the total column sum of the standardized matrix was divided by the total

**Table 6. Multiplying the value of the average traits by the value of each criterion**

	OM	EC	CaCO3	CaSo4	ESP	SLOPE	Texture	Drainage	soil Depth	R.Freg
Average	0.14293	0.14293	0.101918	0.101918	0.061314	0.101918	0.183841	0.061314	0.020302	0.081616
OM	1	1	1.4	1.4	2.33	1.4	0.77	2.33	7	1.75
EC	1	1	1.4	1.4	2.33	1.4	0.77	2.33	7	1.75
CaCO3	0.71	0.71	1	1	1.66	1	0.55	1.66	5	1.25
CaSo4	0.71	0.71	1	1	1.66	1	0.55	1.66	5	1.25
ESP	0.43	0.43	0.6	0.6	1	0.6	0.33	1	3	0.75
SLOPE	0.71	0.71	1	1	1.66	1	0.55	1.66	5	1.25
Texture	1.28	1.28	1.8	1.8	3	1.8	1	3	9	2.25
Drange	0.43	0.43	0.6	0.6	1	0.6	0.33	1	3	0.75
soil Depth	0.14	0.14	0.2	0.2	0.33	0.2	0.11	0.33	1	0.25
R.Freg	0.57	0.57	0.8	0.8	1.33	0.8	0.44	1.33	4	1

$$w_{ij} = \frac{\sum_{i=1}^n b_{ij}}{n} = \begin{bmatrix} w_{11} \\ w_{12} \\ w_{1n} \end{bmatrix} \dots (5)$$

correctness of the importance distribution on the studied characters:

$$\begin{bmatrix} a_{11} & a_{12} & a_{1n} \\ a_{21} & a_{22} & a_{2n} \\ a_{n1} & a_{n2} & a_{nn} \end{bmatrix} \times \begin{bmatrix} w_{11} \\ w_{12} \\ w_{1n} \end{bmatrix} = \begin{bmatrix} a_{11}w_{11} & a_{12}w_{12} & a_{1n}w_{1n} \\ a_{21}w_{21} & a_{22}w_{22} & a_{2n}w_{2n} \\ a_{n1}w_{n1} & a_{n2}w_{n2} & a_{nn}w_{nn} \end{bmatrix} = \begin{bmatrix} v_{11} \\ v_{12} \\ v_{1n} \end{bmatrix} \dots (6)$$

The average of each of the studied characters is then extracted to indicate the weight of each attribute as in Table (7). The original stability value was obtained by multiplying the binary matrix by the weight vectors to indicate the

**Table 7. Extracting the sum of the criteria weights as a final weight for each attribute using the AHP method**

	OM	EC	CaCO3	CaSo4	ESP	SLOPE	Texture	Drainage	soil Depth	R.Freg	sum
OM	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	1.43
EC	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	1.43
CaCO3	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.02
CaSo4	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.02
ESP	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.61
SLOPE	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.02
Texture	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.83
Drainage	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.61
soil Depth	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.20
R.Freg	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.81

Furthermore, the main eigenvector ( $\lambda_{max}$ ) was calculated by averaging the elements of the persistence vector Table (8).

**Table 8. Calculate the maximum eigenvalue from the mean and weights of the criteria.**

Parameter	Pairwise	weighted sum value	Average	Max
OM	7	1.43	0.15	9.507568
EC	7	1.43	0.15	9.507568
CaCO3	5	1.02	0.1	10.16917
CaSo4	5	1.02	0.1	10.16917
ESP	3	0.61	0.06	10.19641
SLOPE	5	1.02	0.1	10.16917
Texture	9	1.83	0.18	10.19074
Drainage	3	0.61	0.06	10.19641
soil Depth	1	0.20	0.02	10.12832
R.Freg	4	0.81	0.08	10.17939
Average				10.04139

$$\lambda_{max} = \sum_{i=1}^n avij = 10.04139...(8)$$

The eigenvalues were calculated by averaging the rows of each matrix, these values were also mentioned as relative weights in the AHP method, while performing pairwise comparisons of the criteria may be followed by a certain level of variance to address this issue, the consistency ratio (CR) was used to prevent bias by weighting the criteria as a solution, the eigenvectors and the largest eigenvalue of the respective matrix were calculated and the consistency index (CI) was checked using the following equation:

$$CI = \frac{\lambda_{max}-n}{n-1} = 0.004599...(7)$$

**Table 9. Stochastic stability index values**

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

$$CR = \frac{CI}{RI} = 0.003087...(9)$$

In our study, the value was 0.003087 CR=, indicating that the land characteristic comparisons were highly stable and that the relative weights were appropriately chosen in the fit assessment model. In the final stage, the values are combined with the weights to obtain the final equation, according to the following equation: 11.

## RESULTS AND DISCUSSION

**Evaluation of the suitability of soil qualities for wheat cultivation:** The results in Table (10) show the evaluation of the parameters for wheat crop cultivation in the study area as follows:

- **Salinity status:** The values were between 0.76 - 17.81 dS m<sup>-1</sup>, comparing these values with the requirements of the crop confirms the existence of simple to moderate determinants

$\lambda_{max}$  represents the maximum eigenvalue of the pairwise comparison matrix and n is the number of criteria in each Pairwise Comparison Matrix (PWCM), and after obtaining the values of the stability index, they are compared with the values of the random index (RI) according to Table 9 to determine the stability ratio that must achieve the following criterion: 0.01CR ≤ 0.01, if not achieved, the results of the comparisons are considered unacceptable and the importance of the weights must be rearranged (Mahdi and Salah 2019; Kahella, and Suliman, 2021.) and the CR is calculated using the following equation As in Table (9).

for the cultivation of the crop based on Sys and according to the requirements received, the values of salinity suitability estimates were between 33.21 - 99.05.

- **Exchangeable sodium percentage ESP:** The values were between 2.83-11.58% and the suitability values for wheat crop were between 96.50-99.05, for all soil locations in the study area.

- **Carbonate mineral content:** The values ranged between 18.5-28.9% and based on Sys that the carbonate mineral content factor is a minor determinant of crop growth, the estimated values ranged between 86.1-95.44 in the study area soil sites.

- **Gypsum content:** The gypsum content did not exceed 2% and the gypsum content factor was given an estimate of 97.89-99.97 for all soil sites in the study area.

- **Organic matter content:** The suitability values ranged from 41.55-63.46 for the wheat crop and for all study sites.
- **Soil texture:** Soil texture was a limiting factor in some locations for the wheat crop and the estimate of texture factor ranged from 50-97.5 for the wheat crop and for all soils of the study area.
- **Soil depth:** It is considered very suitable for growing wheat crop and was given an estimate of 100 and did not constitute a determining factor for suitability and because the sedimentary soils are all deep.

- **Slope:** According to the tables of land characteristic requirements approved by Sys, the slope was estimated at 97.5 and did not constitute a limiting factor for the wheat crop in the study area.
- **Drainage:** The degree of drainage was good to moderate drainage in the soils of the study area and an estimate of this factor was given as 97.5 for fine textured soils for wheat yield.
- **Stone or the presence of stones and boulders:** Weights ranged from 76.25-100 for the wheat crop and for all study soil sites.

**Table 10. Evaluation weight for wheat crop cultivation in the study area according to Sys et al., (1993)**

	EC	ESP	Tex.	Depth	Gyps	CaCo3	O.M	Slope	Fragm	Drainage	Suit.	Class
P1D1	97.11	96.50	50.0	100	97.89	89.0	49.31	97.5	76.3	97.5	14.59	N2
P2D1	98.93	99.06	72.5	100	99.86	90.0	57.31	97.5	100	97.5	34.78	N1
P3D1	99.05	98.62	50.0	100	99.91	95.4	63.46	97.5	100	97.5	28.10	N1
P4D1	97.91	98.75	97.5	100	99.92	94.7	58.80	97.5	100	97.5	49.87	S3
P5D1	95.05	96.14	97.5	100	98.20	86.1	61.63	97.5	100	97.5	44.14	S3
P6D1	33.21	98.71	97.5	100	99.90	86.5	44.20	97.5	100	97.5	11.61	N2
P7D1	88.13	98.35	97.5	100	99.87	91.0	62.46	97.5	100	97.5	45.60	S3
P8D1	95.85	98.71	50.0	100	98.88	89.0	41.55	97.5	92.5	97.5	15.21	N2
P9D1	91.38	99.06	90.0	100	99.93	91.5	48.72	97.5	100	97.5	34.50	N1
P10D1	97.13	99.06	90.0	100	99.98	91.0	47.14	97.5	100	97.5	35.30	N1

#### Assessing the suitability of soil properties for wheat cultivation using the AHP method:

In the final stage, the values are combined with the weights to get the final equation, according to the following equation:

$$LS = \sum_{i=1}^n Wi Xi \dots (10)$$

Where LS refers to the final suitability, Wi to the weights of the criteria and Xi to the sub-criteria scores according to Sys et.al. (Vargahan, et al., 2011) so the final equation 8 that we reached for the land suitability statement will be in the following final form:

$$L.S = \text{Texture} * 0.18 + \text{ECe} * 0.15 + \text{O.M} * 0.15 + \text{CaCO}_3 * 0.1 + \text{CaSO}_4 * 0.1 + \text{Slope} * 0.1 + \text{ESP} * 0.06 + \text{Drainage} * 0.06 + \text{fregum} * 0.08 + \text{Soil Depth} * 0.02 \dots (11)$$

The results in Table (11) indicate the general properties of the study area, and AHP was adopted to indicate the suitability of the land for wheat crop productivity as follows:

#### Soil salinity:

It was given an importance of 7 with a weight of 15% and is considered a medium determining factor for productivity, as its values ranged between 0.76 - 17.81 dS m<sup>-1</sup> and had a weight between 33.21 - 99.05 for the

crop when using Sys, and in these varying proportions is considered a medium determining factor, and when using the AHP method and thus its values ranged between 4.981% - 14.857% for the wheat crop.

**ESP ratio:** It was given an importance of 7 with a weight of 6% and is considered a simple factor, as its value ranged between 2.83 - 11.58% and was with a weight of 96.50 - 99.05 at Sys for the crop, the highest weight value it reaches when using AHP is 5.943%, so we note that its value ranged between 5.768% - 5.943% for all sites.

#### Calcium carbonate:

It was given a weight of 9/5 with a weight of 1% and is considered a minor factor, as it ranged between 18.5-28.9% and had a weight of 86.1-95.44 at Sys. We note that its value is between 8.61%-9.544% for all sites.

#### Gypsum:

Given a significance of 5/9 with a weight of 1%, all soil units showed high suitability ranging from 9.789%-9.997% due to the low gypsum content of the soil in the study area due to the high levels of calcium and the inverse relationship between them.

**Organic matter:**

Given a weight of 7 and a weight of 15%, its weight values using AHP were between 6.232 - 9.519 for wheat crop, which is a moderately determining factor and this is consistent with (Hamadi, 2018)

**Soil texture:**

It was given a weight of 9/9 with a weight of 18%, and this value changes according to the class of soil texture based on the weights obtained from the table of wheat crop requirements according to the Sys method, and the values ranged between 9 - 17.55% according to AHP for all sites of the study area (Al-Jubouri, and Wheib, 2020) Because soil texture has a significant impact on land suitability and productivity

**Soil depth:**

The characteristic of soil depth was given a weight of 1/9 with a weight of 2% for the

wheat crop, although it was given a weight of 100 by Sys. It is very suitable for wheat cultivation and did not affect suitability. (Kahella and Suliman, 2021)

**Slope:**

AHP was given a weight of 5/9 with a weight of 1% and a weight of 97.5 with Sys, resulting in a final score of 9.75%.

**Drainage score:**

It was given an importance of 3/9 with a weight of 6% and varies according to the type of drainage for each soil unit, as it was given an amount of 5.85% for all pisions if its weight was 97.5 at Sys, as the drainage was good to moderate.

**Stone or the presence of stones and rocks:** It was given a weight of 4/9 with a weight of 8% and its weights ranged from 76.25-100 at Sys, while when using the AHP method it was 6.1%-8%.

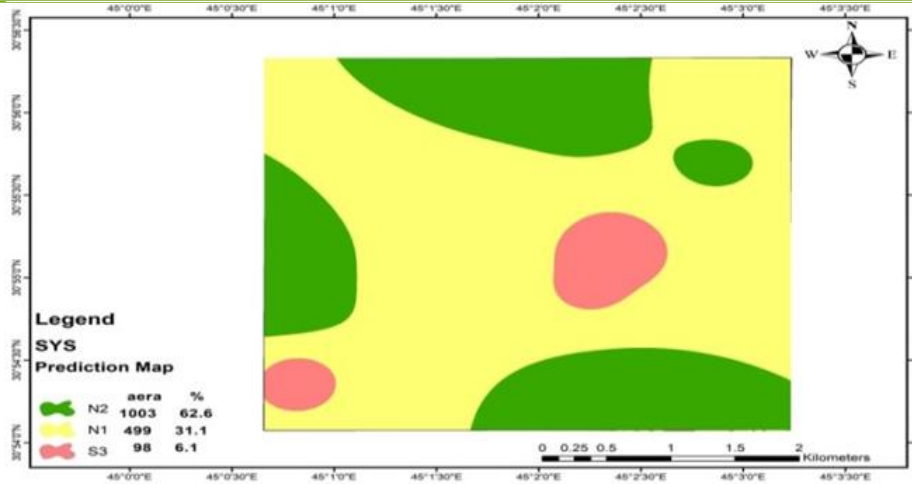
**Table 11. Evaluation of the suitability of soil characteristics for wheat cultivation using the AHP method for the study area**

	EC	ESP	TEX	Depth	Gyps	CaCo3	O.M	Slope	Fragm	Drainage	Suit.	Class
P1	14.57	5.79	9.00	2	9.79	8.90	7.40	9.75	6.1	5.85	79.14	S2
P2	14.84	5.94	13.05	2	9.99	9.00	8.60	9.75	8	5.85	87.01	S1
P3	14.86	5.92	9.00	2	9.99	9.54	9.52	9.75	8	5.85	84.43	S1
P4	14.69	5.92	17.55	2	9.99	9.47	8.82	9.75	8	5.85	92.04	S1
P5	14.26	5.77	17.55	2	9.82	8.61	9.24	9.75	8	5.85	90.85	S1
P6	4.98	5.92	17.55	2	9.99	8.65	6.63	9.75	8	5.85	79.33	S2
P7	13.22	5.90	17.55	2	9.99	9.10	9.37	9.75	8	5.85	90.73	S1
P8	14.38	5.92	9.00	2	9.89	8.90	6.23	9.75	7.4	5.85	79.32	S2
P9	13.71	5.94	16.20	2	9.99	9.15	7.31	9.75	8	5.85	87.90	S1
P10	14.57	5.94	16.20	2	10.00	9.10	7.07	9.75	8	5.85	88.48	S1

**Classification of Land suitability for wheat production according to Sys *et al.*, (1993):**

The final results of the evaluation of the predominant soil units in the study area shown in Figure (2) indicated the existence of variability and diversity in the varieties of Land suitability for wheat cultivation. It is noted that about 6.1% of the total area of the study area are classified as S3. suitability class with an area of 98 hectares, while about 31.1% of the total area of the study area are classified within the N1 limited suitability class for wheat cultivation with an area of 499 hectares, while the remaining 62.6% is considered N2

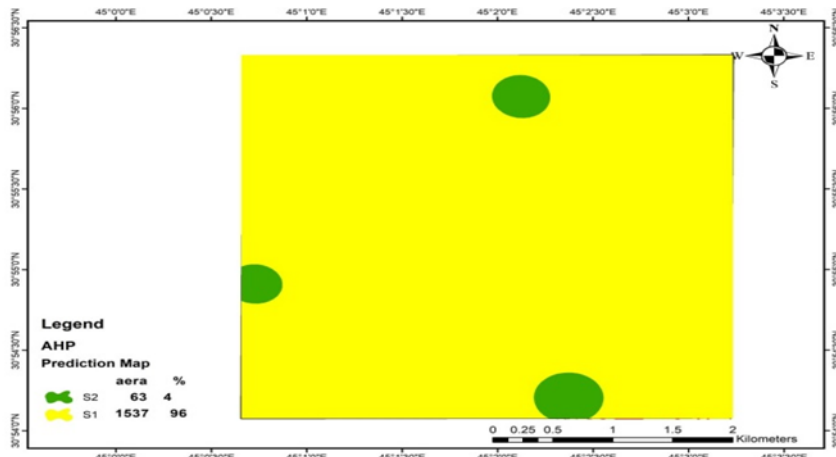
unsuitable for wheat cultivation, which occupies an area of 1003 hectares due to some constraints.



**Figure 2. Distribution map of Land suitability Classed for wheat cultivation according to Sys *et al.*, 1993 for the study area**

**Classification of Land suitability for wheat production according to the Analytic Hierarchy Processes (AHP):** The final results of the evaluation of the predominant soil units in Al-Salhoubia area, shown in Figure (3), indicated the existence of two classes and diversity in the varieties of Land suitability for wheat cultivation. It is noted that about 4% of

the total area of the study area. are classified within the medium suitability class S2 due to the presence of some determinants in it, with an area of 63 hectares, while about 96% of the total area of the study area are classified as within the very suitable class S1 for production wheat crop, with an area of 1537 hectares.



**Figure 3. Distribution map of Land suitability classes for wheat cultivation according to AHP for the study area**

## CONCLUSION

The study evaluated land suitability for wheat cultivation in the Al-Muthanna desert using the AHP model compared with the Sys method based on soil properties. The Sys method indicated that most lands were limited or unsuitable due to constraints such as salinity, gypsum, and other soil characteristics.

In contrast, the AHP model showed that most of the area is highly suitable when the relative importance of soil factors is considered.

## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

## DECLARATION OF FUND

The authors declare that they have not received a fund.

## AUTHOR/S DECLARATION

-We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are

included with the manuscript.-Author/s signature on Ethical Approval Statement.

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## ملاءمة بعض الترب الصحراوية في محافظة المثنى لإنتاجية محصول الحنطة باستعمال طريقتي

### AHP والتحليل الهرمي التسلسلي Sys

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#### المستخلص

تهدف هذه الدراسة إلى تقديم منهج متكامل لعملية تحليل مدى ملاءمة الأراضي الزراعية لإنتاج محصول الحنطة. أجريت هذه الدراسة في صحراء محافظة المثنى الواقعة بين خطي طول  $44^{\circ}50'00$  و  $45^{\circ}15'00$  شرقاً، ودائرتي عرض  $30^{\circ}45'$  و  $31^{\circ}45'00$  شمالاً وبمساحة تبلغ 1600 هكتاراً باستخدام نموذج عملية التسلسل الهرمي التحليلي (AHP) ومقارنتها مع طريقة Sys1993، حيث تم اختيار عشرة معايير للتربة (نسجة التربة، عمق التربة، الانحدار، نسبة كربونات الكالسيوم، نسبة كبريتات الكالسيوم، EC, ESP، درجة الصرف الطبيعي، المادة العضوية، الحجرية) وأظهرت نتائج الدراسة باستخدام الطريقة Sys ان حوالي 6.1% من المساحة الكلية لمنطقة الدراسة تقع ضمن صنف الملائمة S3 وبمساحة 98 هكتاراً في حين ان حوالي 31.1% من المساحة الكلية لمنطقة الدراسة تقع ضمن الأصناف غير الملائمة بدرجة محدودة N1 وبمساحة 499 هكتاراً، في حين تعد بقية مساحة الأرض 62.6% غير ملائمة N2 والتي تشغل مساحة 1003 هكتاراً وذلك بسبب وجود بعض المعوقات فيها. وفقاً لطريقة التسلسل الهرمي التحليلي، وجد أن حوالي 4% من المساحة الكلية لمنطقة الدراسة تقع ضمن صنف متوسطة الملائمة S2 لوجود بعض المحددات فيها وبمساحة 63 هكتار في حين ان حوالي 96% من المساحة الكلية لمنطقة الدراسة تقع ضمن صنف الملائمة جدا S1 لزراعة محصول الحنطة وبمساحة 1537 هكتاراً.

الكلمات المفتاحية: التحليل الهرمي التسلسلي، ملائمة الاراضي.