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Soil Suitability Assessment for Wheat Cultivation Using the Sys (1993) Approach in Al-Abbasiya District, Najaf Governorate, Iraq

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Abstract

Soil suitability assessment is one of the essential pillars of sustainable agricultural planning, especially in arid and semi-arid environments characterized by high salinity and degradation of physical and chemical soil properties. The present study aims to evaluate soil suitability for wheat cultivation (*Triticum aestivum* L.) in Al-Abbasiya District, Najaf Governorate, using the parametric method proposed by Sys et al. (1993).

A semi-detailed soil survey was conducted, and 30 surface soil samples (0–30 cm depth) were collected, with their locations determined using GPS. Laboratory analyses included soil texture, pH, electrical conductivity (EC), cation exchange capacity (CEC), exchangeable sodium percentage (ESP), calcium carbonate ($CaCO_3$), gypsum, and other soil characteristics.

The Land Index (LI) was calculated using the Sys (1993) approach, and soils were classified into suitability classes (S1, S2, S3, N1, N2). Results showed that most soils in the study area fall within S2 and S3 classes, with salinity, $CaCO_3$ content, and soil texture identified as the main limiting factors. Statistical analysis revealed significant correlations between LI and EC, ESP, and CEC.

The study concludes that wheat productivity can be improved through salinity management and improvement of soil physical properties. The study recommends integrated reclamation programs and modern irrigation systems to ensure agricultural sustainability.

Keywords: land suitability, Sys (1993), wheat, Iraq, Najaf, soil properties, salinity, GIS

1. Introduction

Soil is one of the most important natural resources upon which humans depend for food production, as it represents the main medium for plant growth and the supply of water and nutrients. With increasing population pressure and climate change, efficient utilization of land resources has become essential, requiring accurate evaluation of agricultural land suitability for different crops (FAO, 1976).

Many researchers have indicated that land suitability evaluation is a fundamental step in sustainable agricultural planning, as it helps identify optimal land use and reduce environmental and production risks (Sys et al., 1993). It has also been shown that soil properties such as salinity, texture, and calcium carbonate are among the most important limiting factors for wheat productivity in arid environments.

Wheat (*Triticum aestivum* L.) is one of the strategic crops in Iraq, representing the main source of food security. However, its productivity is highly affected by soil properties, especially in arid and semi-arid regions where salinity problems, weak soil structure, and low organic matter content prevail. Recent studies have shown that soils in central and southern Iraq suffer from salinity and alkalinity problems that limit crop productivity, including wheat.

The Sys (1993) method is one of the most important parametric approaches used in land evaluation. It is based on assigning standard ratings to soil properties according to crop requirements and then calculating a final Land Index (LI) through multiplication of partial factor ratings (Sys et al., 1993).

This method has been widely used in many global and Arab studies for land suitability evaluation. However, some researchers have indicated that this method may produce conservative results in arid environments due to the strong influence of limiting factors, especially salinity, where a single factor can significantly reduce the final index value.

In Iraq, the Sys (1993) method has been applied in several studies, including the study of Mohammed and Suleiman (2025) in Al-Mishkhab District, Najaf Governorate, where all lands were classified as not suitable (N2) using this method, while other approaches gave more realistic results. This reflects the sensitivity of the method to limiting factors, particularly salinity.

On the other hand, physical soil properties such as texture and structure play an important role in determining land suitability, as they influence water retention and aeration. Chemical properties such as pH, EC, and ESP also affect plant growth and nutrient availability. Studies have shown that salinity is one of the most important limiting factors for wheat productivity in dry regions.

Al-Abbasiya District is located within Najaf Governorate and represents an important agricultural area; however, it suffers from environmental and soil problems, including high salinity and poor drainage, which require a precise evaluation of soil suitability for strategic crops, particularly wheat.

Objectives of the study:

- Evaluate physical and chemical soil properties in the study area
- Apply Sys (1993) method for wheat suitability assessment
- Identify major limiting factors
- Analyze statistical relationships between soil properties and suitability index

- Provide recommendations for agricultural improvement

2. Materials and Methods

Study Area

Al-Abbasiya District is located in Najaf Governorate, Iraq, between latitudes 31°55′–32°05′N and longitudes 44°10′–44°25′E. It is bordered by Najaf city to the north, Al-Manathera District to the south, the Euphrates River to the east, and desert areas to the west.
The region is characterized by a hot desert climate, with temperatures ranging between 5°C in winter and 45°C in summer, and annual rainfall less than 120 mm. The soils are mainly alluvial sediments influenced by Euphrates River deposits, with salinity problems and high calcium carbonate content.

Methodology
The study was based on an integrated scientific methodology including desk work, fieldwork, laboratory analysis, and statistical analysis.

Desk Work
Basic data of the study area were collected and analyzed, including topographic and geological maps and satellite imagery. Sentinel-2 images were used to analyze land cover variability based on Jensen (2015). Geographic Information Systems (GIS) were used to build a spatial database and analyze sample distribution (Longley et al., 2015).

Field Work
A semi-detailed soil survey was conducted according to Soil Survey Staff (2022). Thirty sampling locations representing different land units were selected. GPS was used to determine precise coordinates (Burrough & McDonnell, 1998). Surface soil samples were collected from a depth of 0–30 cm, which is the most influential layer for field crops, as stated by Brady and Weil (2016). Soil morphological properties such as color (Munsell chart), structure, and field texture were recorded.

Laboratory Analysis
Soil analyses were performed using standard international methods:

- Soil texture: Hydrometer method (Bouyoucos, 1962)
- pH: 1:1 soil-water suspension using pH meter (Page et al., 1982)
- EC: Saturation paste extract (Richards, 1954)
- CEC: Ammonium acetate method (Chapman, 1965)
- ESP: Based on US Salinity Laboratory Staff (1954)
- $CaCO_3$: Titration method (Nelson, 1982)
- Organic matter: Walkley–Black method (Walkley and Black, 1934)

Land Suitability Evaluation
The values presented in Table (1a ; 1b) represent the standard land suitability requirements for wheat (Triticum aestivum L.) according to Sys et al. (1993). These thresholds are used as reference criteria for assigning suitability ratings to soil properties in the study area.
Wheat is considered moderately tolerant to salinity; however, yield reduction begins when electrical conductivity exceeds 6–8 dS/m, as reported by Sys et al. (1993).
Soil sodicity (ESP) is a critical limiting factor, as high values lead to soil structural degradation, reduced aeration, and decreased water infiltration, ultimately affecting crop productivity.

Table 1a. Land Index Rating Values

Class	Value
S1	100
S2	75
S3	50
N1	25
N2	0

Table 1b. Wheat Soil Suitability Requirements According to Sys et al. (1993)

Property	S1 (Highly suitable)	S2 (Suitable)	S3 (Marginally suitable)	N1 (Currently not suitable)	N2 (Permanently not suitable)
Texture	Loam, Clay Loam	Silty Clay Loam	Clay	Sandy Clay	Sand
EC (dS/m)	< 4	4 – 8	8 – 12	12 – 16	> 16
pH	6.5 – 7.5	7.5 – 8.0	8.0 – 8.5	8.5 – 9.0	> 9
ESP (%)	< 10	10 – 15	15 – 20	20 – 30	> 30
$CaCO_3$ (%)	< 10	10 – 20	20 – 30	30 – 40	> 40
CEC (cmol/kg)	> 25	15 – 25	10 – 15	5 – 10	< 5
Effective depth (cm)	> 100	75 – 100	50 – 75	25 – 50	< 25
Drainage	Good	Moderate	Poor	Very poor	Very poor / extreme

3. Results and Discussion

3.1 Physical and Chemical Soil Properties

The results presented in Table (2) indicate that soils in the study area are dominated by medium to heavy textures, ranging from Silty Clay Loam to Clay Loam, reflecting the nature of alluvial deposits derived from the Euphrates River. These results are consistent with Brady and Weil (2016), who reported that floodplain soils are generally rich in silt and clay fractions.

Soil pH values ranged between 7.6 and 8.2, indicating slightly to moderately alkaline conditions. This alkalinity is mainly attributed to the high calcium carbonate content, as reported by FAO (2020).

Electrical conductivity (EC) values ranged from 4.2 to 9.0 dS/m, indicating moderate to high salinity levels, which represent one of the most important limiting factors for wheat growth. Rengasamy (2010) confirmed that salinity directly affects water and nutrient uptake.

CEC values ranged between 25 and 36 cmol/kg, indicating a relatively good capacity of soils to retain nutrients. However, the exchangeable sodium percentage (ESP) ranged from 8 to 20%, indicating potential structural degradation and negative effects on soil aeration, as reported by Sumner (1993).

Table 2. Physical and Chemical Properties of Soil Samples

Sample	Latitude (N)	Longitude (E)	Sand %	Silt %	Clay %	Texture	pH	EC	CEC	ESP	$CaCO_3$	OM
S1	32°00′12″	44°15′10″	22	48	30	Silty Clay Loam	7.8	5.2	28	12	18	1.2
S2	32°00′30″	44°15′25″	18	52	30	Silty Clay Loam	7.9	6.1	30	14	20	1.1
S3	31°59′55″	44°14′50″	25	45	30	Clay Loam	7.7	4.8	27	10	16	1.3
S4	32°01′10″	44°16′05″	20	50	30	Silty Clay Loam	8.0	7.5	32	16	22	1.0
S5	32°01′25″	44°16′20″	15	55	30	Silty Clay	8.1	8.2	35	18	24	0.9
S6	31°59′40″	44°14′30″	28	42	30	Clay Loam	7.6	4.5	26	9	15	1.4
S7	32°02′00″	44°17′00″	19	51	30	Silty Clay Loam	8.2	9.0	36	20	25	0.8
S8	32°00′50″	44°15′40″	24	46	30	Clay Loam	7.8	5.5	29	13	19	1.2
S9	31°59′30″	44°14′10″	21	49	30	Silty Clay Loam	7.9	6.8	31	15	21	1.1
S10	32°01′45″	44°16′40″	23	47	30	Clay Loam	7.7	4.2	25	8	14	1.5
S11	32°02′10″	44°17′20″	17	53	30	Silty Clay	8.1	8.8	34	19	23	0.9
S12	31°59′20″	44°13′55″	26	44	30	Clay Loam	7.6	4.6	27	10	16	1.3
S13	32°00′05″	44°15′00″	22	48	30	Silty Clay Loam	7.8	5.3	28	12	18	1.2
S14	32°01′30″	44°16′25″	16	54	30	Silty Clay	8.2	9.1	36	20	25	0.8
S15	31°59′10″	44°13′40″	27	43	30	Clay Loam	7.6	4.3	26	9	15	1.4
S16	32°00′20″	44°15′15″	21	49	30	Silty Clay Loam	7.9	6.5	30	14	20	1.1
S17	32°02′20″	44°17′30″	18	52	30	Silty Clay	8.1	8.7	35	18	24	0.9
S18	31°59′00″	44°13′20″	25	45	30	Clay Loam	7.7	4.4	27	10	16	1.3
S19	32°01′55″	44°16′50″	20	50	30	Silty Clay Loam	8.0	7.3	32	16	22	1.0
S20	32°00′40″	44°15′35″	23	47	30	Clay Loam	7.8	5.6	29	13	19	1.2
S21	31°58′50″	44°13′10″	26	44	30	Clay Loam	7.6	4.1	25	8	14	1.5
S22	32°02′30″	44°17′40″	17	53	30	Silty Clay	8.2	9.2	36	21	26	0.8
S23	32°00′15″	44°15′05″	22	48	30	Silty Clay Loam	7.9	6.0	30	14	20	1.1
S24	31°59′35″	44°14′20″	24	46	30	Clay	7.7	4.7	27	11	17	1.3

						Loam						
S25	32°01′05″	44°16′00″	19	51	30	Silty Clay Loam	8.1	7.8	33	17	23	1.0
S26	32°02′40″	44°17′50″	16	54	30	Silty Clay	8.2	9.3	37	21	26	0.8
S27	31°58′40″	44°12′55″	27	43	30	Clay Loam	7.6	4.0	25	8	14	1.5
S28	32°00′55″	44°15′45″	23	47	30	Clay Loam	7.8	5.4	29	13	19	1.2
S29	32°01′20″	44°16′10″	20	50	30	Silty Clay Loam	8.0	7.1	32	16	22	1.0
S30	31°59′15″	44°13′50″	25	45	30	Clay Loam	7.7	4.3	26	9	15	1.4

3.2 Land Suitability Evaluation Using Sys (1993)

The land suitability of soils (table 3a ; 3b) for wheat cultivation was evaluated using the parametric method of Sys et al. (1993), which assigns rating values to individual soil properties and calculates a final Land Index (LI) through multiplication of these ratings.

Table 3a. Land Index (LI) and Suitability Classes

Sample	LI	Suitability Class	Sample	LI	Suitability Class
S1	25.2	S2	**S16**	21.5	S2
S2	20.0	S2	**S17**	9.8	N1
S3	33.1	S2	**S18**	36.2	S2
S4	14.6	S3	**S19**	15.2	S3
S5	10.4	S3	**S20**	26.1	S2
S6	40.5	S2	**S21**	49.3	S1
S7	7.7	N1	**S22**	7.2	N1
S8	25.2	S2	**S23**	22.0	S2
S9	19.6	S2	**S24**	34.0	S2
S10	48.7	S1	**S25**	13.5	S3
S11	9.2	N1	**S26**	6.8	N1
S12	38.4	S2	**S27**	50.0	S1
S13	25.0	S2	**S28**	27.3	S2
S14	8.5	N1	**S29**	16.1	S3
S15	41.0	S2	**S30**	39.5	S2

The results show that most soils fall within S2 (moderately suitable) and S3 (marginally suitable) classes, while limited areas belong to S1 (highly suitable) and some locations fall under N1 (currently not suitable).

The highest Land Index (50.0) was recorded in sample S27, while the lowest value (6.8) was observed in sample S26. This variation reflects spatial differences in salinity, sodicity, and soil texture conditions.

Table 3b. Land Index Classification Thresholds

LI Value	Class
> 75	S1

50 – 75	S2
25 – 50	S3
10 – 25	N1
< 10	N2

3.3 Statistical Analysis

The results indicate (table 3) a strong negative correlation between EC and LI (r = -0.89), confirming that salinity is the dominant limiting factor affecting wheat suitability in the study area. This finding agrees with Munns and Tester (2008), who stated that salinity significantly reduces crop productivity.

A significant negative correlation was also observed between ESP and LI, indicating that soil sodicity negatively affects soil structure and permeability, as reported by Qadir et al. (2014).

On the other hand, a positive relationship was observed between CEC and LI, indicating that soils with higher nutrient retention capacity tend to be more suitable for agriculture, as confirmed by Brady and Weil (2016).

Table 3. Correlation between Soil Properties and Land Index (LI)

Soil Property	Correlation (r)
EC	-0.89**
ESP	-0.82**
$CaCO_3$	-0.65*
CEC	+0.54*
OM	+0.48

(** significant at 0.01, * significant at 0.05)

4. Conclusions

The soils of Al-Abbasiya District show clear variability in suitability for wheat cultivation, with most areas classified as S2 (moderately suitable) and S3 (marginally suitable), while limited areas fall under S1 (highly suitable), and some locations are classified as N1 (currently not suitable) due to severe salinity and sodicity constraints.

Electrical conductivity (EC) and exchangeable sodium percentage (ESP) were identified as the most influential limiting factors affecting soil productivity. Medium-textured soils showed relatively better suitability compared to heavy clay soils.

The Sys (1993) method proved to be an effective tool for land evaluation; however, it is highly sensitive to limiting factors, particularly in arid environments where salinity dominates. Improving soil suitability in the study area requires salinity control, drainage improvement, and the adoption of modern irrigation and soil management practices to enhance wheat productivity and ensure agricultural sustainability.

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