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Assessment of soil fertility using geographic information systems and fertility indicators: a case study for the Bani Walid area

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Abstract: This research presents an assessment of soil fertility by (GIS) and three main quality indices: The Nutrients index (NI), Soil Fertility Index (%), and soil quality (SQ) Soil samples were collected from the study area, GIS application and fertility indicators were found to contain the following: pH ranges from (7.00 to 7.50) is mildly/strongly alkaline the EC was characterized as non-saline- strong (range from 0.15 - 22.00) and moderately calcareous, calcareous soil (the CaCO3 range from 16.30% to 41.00%.) The soil had a low soil OM content which did not exceed, 55.28%.the OM ranges from (0.33 % to 1.61%). CEC ranged from (4.35-12.70). ESP (%) ranged from (2.43 to 25.30). Soil most are non-sodic (96.96 %.), and the soil bulk density (BD) ranged from 1.13 to 1.56. Texture sandy loam >loam> loams sandy>clay loam, respectively. Nutrients cover about 50% very low .low 23%, low levels are 25%, acceptable levels are 23%, high values are 0.99% and medium 0.0061%, and very poor and poor levels are 1%.by quality indices for three zones: NI gives high for K, P and low for N, Cu, Zn, Fe, and Mn respectively. SF (%) is Excellent for K(C1) and Nonagricultural for P, N, Cu, Zn, Fe and Mn (C6) respectively. (SQ): (S3), > (S2), > (S1). Respectively.

Keywords: GIS; Nutrients; Soil; Index And Fertility.

تقييم خصوبة التربة باستخدام نظم المعلومات الجغرافية ومؤشرات الخصوبة: دراسة حالة لمنطقة بني وليد

المستخلص: يهدف هذا البحث تقييم خصوبة التربة في منطقة الدراسة والتي تعتمد على دراسة استخدام نظم المعلومات الجغرافية ومؤشرات الخصوبة وهي: مؤشر المغذيات (NI)، ومؤشر خصوبة التربة (٪)، ومؤشر جودة التربة (SQ). تم جمع عينات التربة من منطقة الدراسة، وتطبيق GIS، ومؤشرات الخصوبة التي تبين أنها تحتوي على: الرقم الهيدروجيني للتربة يتراوح من (7 إلى 7.50) وهي قلوية بشكل معتدل أو قوية. و EC بأنها غير مالحة –قوية (تتراوح من 0.15 إلى 22.00) و كانت كربونات الكالسيوم في التربة كلسية متوسطة الى جيرية حيث تتراوح من(16.30٪ إلى 41.00٪.) بينما كان محتوى المادة العضوية منخفض فيها لم يتجاوز 55.28٪. حيث تراوحت نسبة المادة العضوية من (0.33% إلى 1.61%). وتراوحت نسبة ESP (من4.35 الى 12.70). (%) وكذلك من (2.43 إلى 25.30). حيث نلاحظ أن معظم التربة غير صودية بنسبة (96.96%)، وكذلك كانت الكثافة الظاهرية للتربة من 1.13 إلى 1.56. القوام للتربة: الرملي طمي> طميي رملي > طمي > طمي طيني، على التوالي. وتغطي العناصر الغذائية الكبرى والصغرى بشكل عام حوالي 50% منخفضة جداً، ومنخفضة 23%، ومستويات متوسطة 25%، مقبولة 23%، مرتفعة 0.99% , فقيرة جدا 0.0061%، فقيرة 1%. حسب مؤشرات الجودة لثلاث مناطق: NI يعطي نسبة عالية من K و P ومنخفضة بالنسبة لـ N و Cu و Zn و Fe و Mn على التوالي. يعتبر SF (%) ممتازًا بالنسبة إلى البوتاسيوم (C1) وغير الزراعي بالنسبة إلى P و N و Cu و Zn و Fe و(C6) Mn على التوالي. QS: Q3<Q<2<Q1 على التوالي.

الكلمات المفتاحية: نظم معلومات الجغرافية، المغذيات، التربة، مؤشر الخصوبة.

INTRODUCTION

The fundamentals of soil fertility are predicated on an understanding of a soil's chemical and physical characteristics and how this affects plant development. Once these characteristics are identified, soil can be altered by physical methods and the addition of materials that will change the soil's natural composition, Major element and micronutrient deficiencies have been linked to specific soil properties. (N, P, K Fe, Mn, Cu, Zn) . The nutrients that plants need can be arranged from the most mobile to the least mobile within the plant based on how mobile they are: • Very mobile: Mg, N, P, and K • Slightly mobile: S • Immobile: Cu, Fe, Mo, and Zn • Very immobile: B and Ca. The pH of soil water varies from 5.5 to 6.5; strongly weathered soils are closer to pH 5.5 while less weathered soils are closer to pH 6.5. (Jones Jr, 2012) quality (SQ) refers to the ecosystem's and soil's capacity to provide plants with the nutrients they require at every stage of growth to maintain crop yield. (Mukherjee & Lal, 2015). Index of Fertility (FI) Numerous applications in the fields of study that support the long-term viability of soil management depend on the understanding of soil fertility (Mohamed et al., 2020).

Libyan soils are typically shallow, and sandy, with low organic matter content and water-holding capacity.(Laytimi & Area, 2002). Physical indicators that affect soil quality include bulk density, root depth, and soil texture. Chemical indicators that affect soil quality include cation exchange capacity (CEC), electric conductivity (EC), and pH these indicators and soil quality have highly significant correlations. (Istijono & Harianti, 2019; Moore et al., 2016). By allocating data to soil maps and using the maps' multicriteria for decision analysis, one may create a themed map that prioritizes soil conservation and management using GIS-based multicriteria decision analysis techniques. (Varade et al., 2017). Aimed at evaluating the fertility status of soils in the study area using fertility ratings and nutrient index to determine the variability existing among soil physicochemical properties.

The main objective of this research was to assess the soil of the study areas by this paper applies GIS and fertility index, for agricultural investment to help decision-makers and regional governments find the best solutions for improving soil quality and address the issue of food security, which is one of the most significances concerns for sustainable development.

MATERIALS AND METHODS

Study area

Geographically, the study area is located between 448200 to 451800 E and latitudes 3492700 to 3439600 N East Longitude and the geographical extent of the Bani Waleed region in the northwest of Libya. The studied area is known as Wadi Al-Qalala'a Fig (1). It has an area of 740.55ha, with a medium to low available water content Due to the dry climate.

Methodology

The study was elaborated through four stages. The first stage was consecrated to build up the spatial database by processing topographic maps; (a) collection, digitizing, and mosaicking of the topographic maps (b) mosaicking clipping the topographic maps excerpt the studied area), by using the software of geographic information system (ArcGIS 10.3). The second stage was consecrated to the fieldwork to collect the sample's soil at depth (0-60 cm). Laboratory work represented the third included the chemical characterization of soil samples. Fig (2).

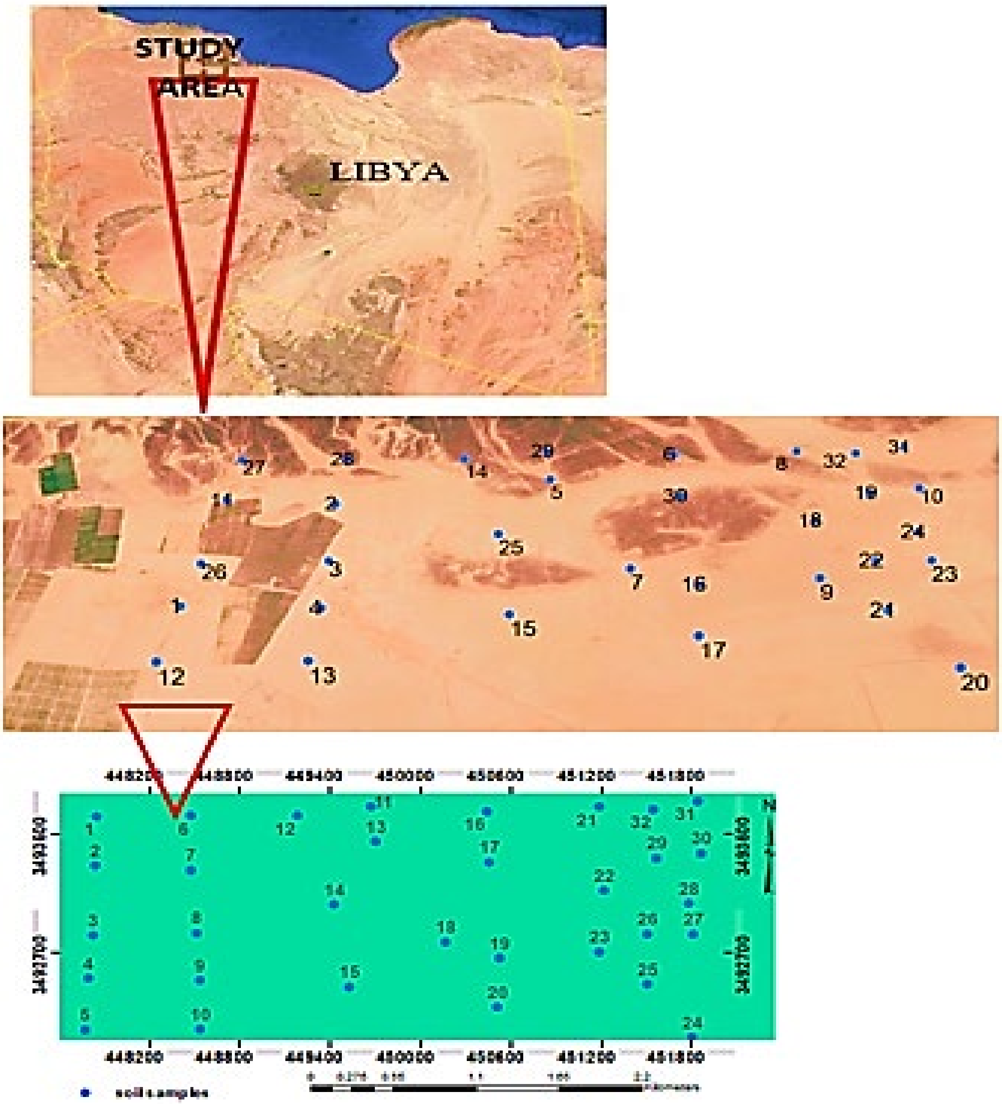

Figure: (1). Location studied of area. By using Google Earth and software (ArcGIS 10.3).

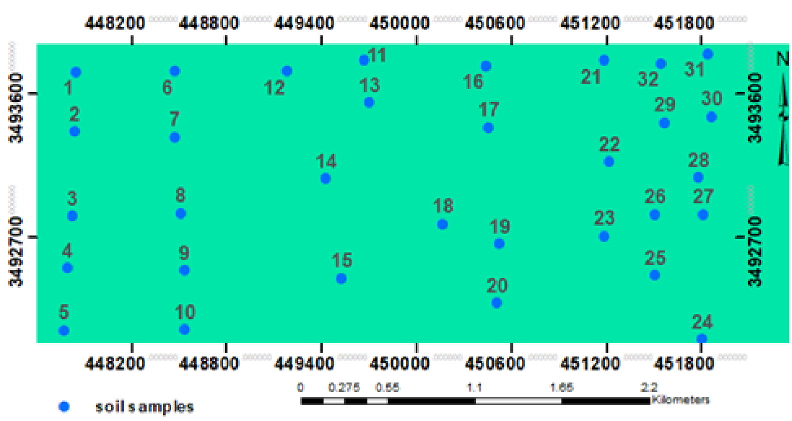

Figure: (2). Studied area and soil sample locations

Analysis of Soil Samples:

Soil Sampling and Analysis

- Sample Collection: Thirty-two soil samples were collected from the root zone (0-60 cm depth) in the studied area.

- Sample Preparation: The samples were air-dried and crushed, passing through a 2 mm sieve for subsequent analyses.

- Sampling Design: A random nested soil sampling design was employed, covering the entire area (see Fig. 2).

Soil Physical Analysis

- Texture: Sieves and the hydrometer method were used to determine soil texture (Kettler et al., 2001).

- **Chemical Analysis**

  - Salinity: Measured in the soil paste extract.

  - pH: Determined in a 1:2.5 soil suspension using an EC meter and pH measurement (Page et al., 1982).

  - Sodium Adsorption Ratio (SAR): Calculated based on soluble concentrations of Ca, Mg, and Na.

  - Organic Matter Content (OM%): Assessed using the Walkley & Black method (Page et al., 1982).

  - Calcium Carbonate ($CaCO_3$%): Determined via the pressure calcimeter method (Page et al., 1982).

Available Nutrients Assessment

- Nutrients: The content of available nutrients (K, P, B, Fe, Zn, Mn, Cu) was extracted using the method by Soltanpour (Soltanpour, 1991).

- Potassium: Measured using a flame photometer (Page et al., 1982).

- Micronutrients: Assessed by atomic absorption.

Soil fertility evaluation

- Nutrient index (NI) Using these fertility classes **Table :(2)**, the Nutrient Index was calculated using the following equation (1).

  (Nutrient Index (NI) =$((NL * 1 + NM * 2 + NH * 3))/NT$.

- Where, NL, NM, and NH are several samples falling in low, medium, and high classes of nutrient status, respectively and NT is the total number of samples analyzed for a given area.

- Soil Fertility Index (%) based on the samples in each of the six classes according to Table (3).

Table:(1). Rating chart for analyzed soil nutrient values, Physical, and Chemical Characterization

Class	Rating	Class	Rating
EC(dS/m)*		Available Potassium (K) **	(mgkg-1)
Nonsaline	< 2	LOW	<200
Very slightly saline	2 to < 4	Medium	200 - 400
Slightly saline	4 to < 8	High	>400
Moderately saline	8 to < 16	Extraction Method DTPA	
Strongly saline	≥ 16	Iron (Fe) ***	(PPM)
ESP%*		LOW	<2.5
Non- Sodic	<15	Adequate	2.5 – 5.0
Sodic	>15	High	>5.0
CaCO3 %*	CaCO3 %	Manganese (Mn) ***	(PPM)
Non-Calcareous	<15	LOW	<0.6
Moderately Calcareous	15-20	Adequate	
Calcareous	>20	High	>2.0
OM% *		Zinc (Zn) ***	(PPM)
<1	very low	LOW	<1.0
1–2.5	low	Adequate	1 – 1.5
2.5–5.0	medium	High	>1.5
5.0–10.0	high	Copper (Cu) ***	(PPM)
>10.0	very high	LOW	<0.6
PH *		Adequate	0.60 – 2.0
<5.5	strongly acidic	High	>2.0
5.5–6.2	moderately acidic	Extraction Method Hot water	
6.2–7.0	neutral	Boron(B) ***	(PPM)
7.0–7.8	moderately alkaline	LOW	<0.5
>7.8	strongly alkaline	Adequate	0.5 – 2.0
Available Nitrogen (N)**	(mgkg-1)	High	>2.0
LOW	<40		
Medium	40 - 80		
High	>80		
Available Phosphorus (P)**	(mgkg-1)		
LOW	<10		
Medium	10 - 15		
High	>15		

*USDA (2017), (** Hamissa, M. et al 1993) and (*** Calabi-Floody, M .et al 2017).

Table :(2). Nutrient Index with Range and Remarks

Fertility level	Range of soil nutrient	Nutrient indexes	Fertility level
Low	Below 1.67	I	Low
Medium	1.67 – 2.33	II	Medium
High	Above 2.33	III	High

Table :(3).. Fertility classes according to (Storie, 1933 and 1944).

Fertility Class	Fertility Index%	Description
C1	> 80	Excellent
C2	< 80 - > 60	Good
C3	< 60 - > 40	Fair
C4	< 40 - > 20	Poor
C5	< 20 - >10	Very poor
C6	< 10	Nonagricultural

The used Soil quality (SQ) classes into there are shown in Table (4)

Table :(4). Quantitative and qualitative classifications of considered indicators.

Indicators	Range	Class
	< 1.13	High quality S1
Soil quality	1.13–1.46	S2 (Moderate quality)
	> 1.46	S3 (Low quality)

The fertility index was described according to Equation (2): (Kosmas, C. et al 1999)

$FI = (FN \times FP \times FK \times F\,Cu \times FZn \times FFe \times FMn)^{1/7}$

where FI = fertility index, FN, FP, FK, FCu, FZn, FFe, and FMn = available nitrogen, phosphorus, potassium, copper, zinc, iron, and manganese respectively.

RESULTS

Table :(5). Physical and Chemical Characteristics of soil samples

Sample No	pH	EC dS/m	Soluble Ions(meq/) l Ca+2	Mg+2	Na+2	CaCO3 (%)	OM (%)	CEC	ESP%	BD	Texture
1	7.40	16.00	55	32.2	77.7	29.50	0.87	4.35	13.56	1.32	SL
2	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
3	7.30	1.92	10	4.8	3.1	16.30	0.50	6.09	6.00	1.55	SL
4	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
5	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
6	7.40	16.00	55	32.2	77.7	29.50	0.87	4.35	13.56	1.32	SL
7	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
8	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
9	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
10	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
11	7.40	16.00	55	32.2	77.7	29.50	0.87	4.35	13.56	1.32	SL
12	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
13	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
14	7.00	22.00	75.8	43.6	119.5	28.00	0.50	4.35	25.30	1.51	LS
15	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
16	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
17	7.40	16.00	55	32.2	77.7	29.50	0.87	4.35	13.56	1.32	SL
18	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
19	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
20	7.40	0.15	1.8	1.4	4.3	17.50	0.33	10.43	3.45	1.56	SL
21	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
22	7.10	7.00	31	28	24.4	25.30	1.00	12.70	12.00	1.54	CL
23	7.00	1.60	10	4.3	6.8	41.00	1.61	12.00	7.88	1.13	L
24	7.50	2.00	7.2	5.2	6.8	31.50	1.24	11.50	2.43	1.25	L
25	7.50	2.00	7.2	5.2	6.8	31.50	1.24	11.50	2.43	1.25	L
26	7.50	2.00	7.2	5.2	6.8	31.50	1.24	11.50	2.43	1.25	L
27	7.50	2.00	7.2	5.2	6.8	31.50	1.24	11.50	2.43	1.25	L
28	7.50	2.00	7.2	5.2	6.8	31.50	1.24	11.50	2.43	1.25	L
29	7.10	7.00	31	28	24.4	25.30	1.00	12.70	12.00	1.54	CL
30	7.00	1.60	10	4.3	6.3	41.00	1.61	12.00	7.88	1.13	L
31	7.40	16.00	55	32.2	77.7	29.50	0.87	4.35	13.56	1.32	SL
32	7.40	16.00	55	32.2	77.7	29.50	0.87	4.35	13.56	1.32	SL

As displayed in Tables 5 and 6, the Soil pH in the soils studied was (ranging from 7.00 to 7.50, with an average of 7.26), let’s consider the hydrogen ion concentration (H+). This adjustment reveals that the soil settings are mild to strongly alkaline (Brady & Weil, 2002). There is a need to reduce soil alkaline to improve soil fertility for sustainable soil fertility management.

As displayed in Tables 5 and 6, the Soil electrical conductivity (EC) was nonsaline to highly salinity soils in the soils studied and ranged from 0.15 to 22.00 dS/m, with an average of 5.03 dS/m. Figure 3 (EC) shows the spatial distribution of EC. The study area was divided into Four categories of EC: Non-Saline, Very Slightly Saline, Moderately Saline, and Strongly Saline: 149.470ha, 20.18%, 264.19ha, 35.68%, 162.36ha, 21.92%, 164.52ha, and 22.22%, respectively. As show Table (1). (Shokr et al., 2021).

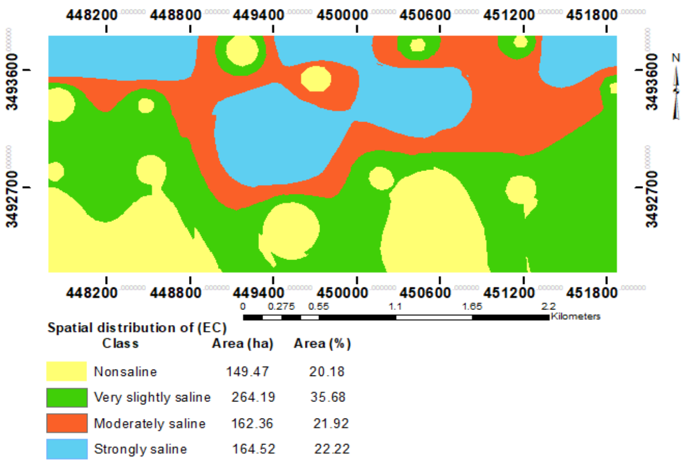

Figure: (3). spatial distribution of the EC(dS/m) .

"The results displayed in Tables 5 and 6 reveal that the CaCO3 content ranges from 16.30% to 41.00%, with an average of 30.06%. These findings suggest soils with a moderate to high calcium content. Within the study area, two predominant classes: 'Moderately Calcareous' and 'Calcareous.' The spatial distribution of CaCO3 soil samples, as depicted in Figure 4, further illustrates this pattern:

- Moderately Calcareous: Covers 30.21 hectares (approximately 4.08% of the area).
- Calcareous: Dominates a substantial portion, spanning 710.19 hectares (about 95.92%).

It's worth noting that soils in the Mediterranean region often form in situ, and their characteristics persistently reflect the underlying parent material from which they originate." (Bockheim et al., 2005).

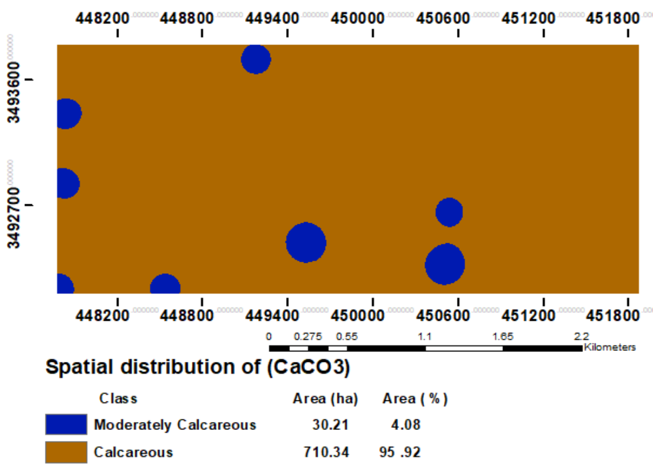

Figure: (4). spatial distribution of the CaCO3 (%).

Displayed in Tables 5 and 6, the organic matter content was low in the soils studied and ranged from 0.33% to 1.61%, with an average of 1.03. that indicated that the organic matter content ranged from less than 2% (very low) to (low) in the soils AS shown (Table 1). Figure 5 (OM) showed the spatial distribution of OM. The study area was divided into two categories of OM: very low and low 331.19 ha, 44.72%, 409.36 ha, and 55.28%, respectively. Hence, it is recommended to use organic fertilizers (Bot & Benites, 2005).

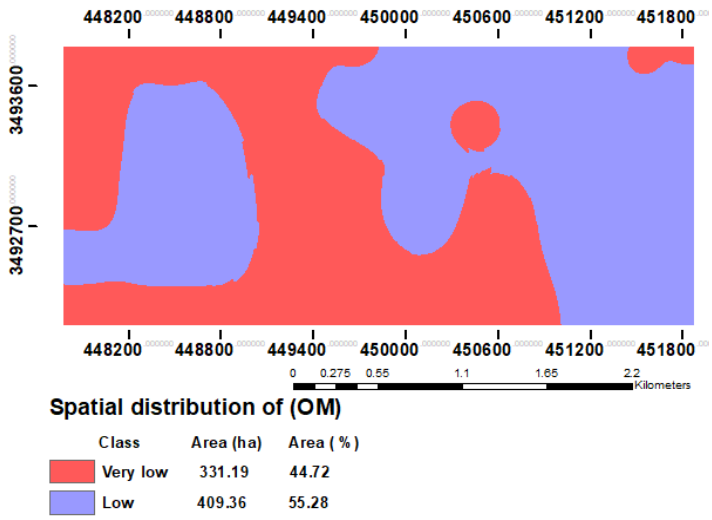

Figure: (5). spatial distribution of the OM (%).

The results of CEC ranged from 4.35-12.70 CEC (meq/100 g) with an average value of CEC (meq/100 g) is 9.76. The CECs of the clay minerals in the soil of study areas Kaolinite1:1. Figure(6) (CEC) shows the spatial distribution of CEC. The study area was divided into two categories (below 5, between 5 and 13) 12.271ha, 1.66%, 728.28ha, and 98.43%, respectively. Low CEC soils are not as resilient and are unable to accumulate nutrient stores The CEC of many sandy soils is less than 4 $cmol_c/kg$. The entire capacity for storing nutrients is determined by the kind, amount, and content of clay. For most crops, values greater than 10 $cmol_c/kg$ are deemed adequate (Nachtergaele et al., 2023).

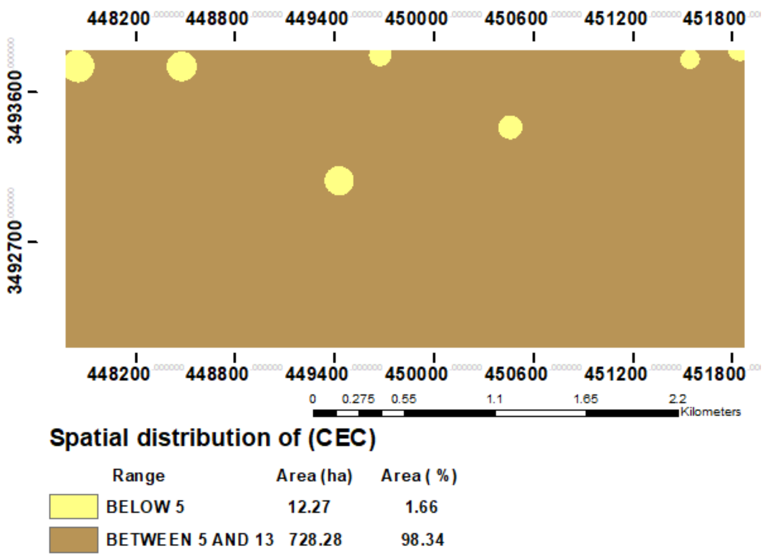

Figure: (6). spatial distribution of the CEC (meq/100 g)

As displayed in Tables 5 and 6, the ESP (%) in soils studied Was ranged from 2.43 to 25.30 ESP (%), with an average of 7.87. Figure 7 ESP (%) shows the spatial distribution of ESP (%). The study area was divided into two categories of ESP (%): Non-Sodic and Sodic 781.03 ha, 96.96%, 22.51 ha, and 3.04% respectively.

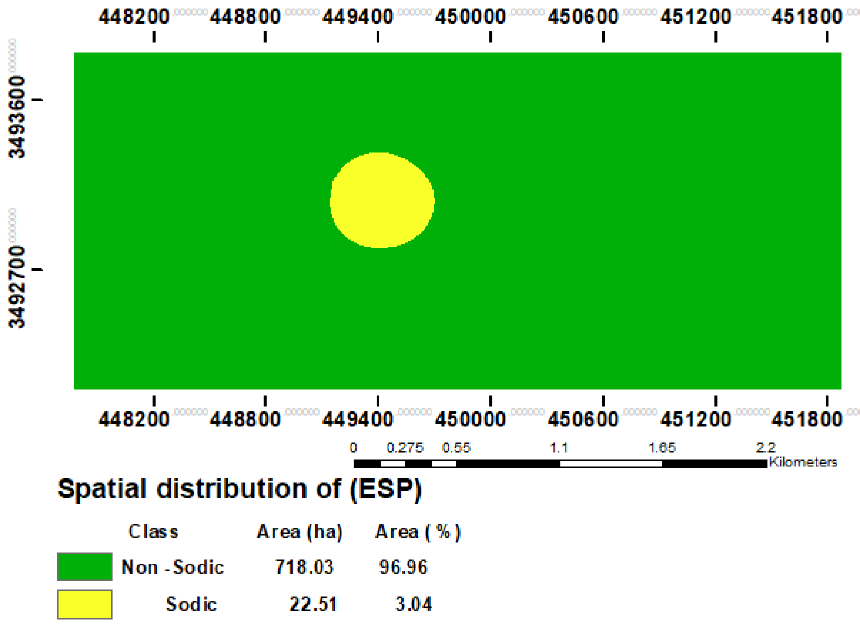

Figure: (7). spatial distribution of the SEP (%)

As displayed in Tables 5 and 6, the soil bulk density (BD, $Mg{\cdot}cm^{-3}$) in soils studied ranged from 1.13 to 1.56 (BD, $Mg{\cdot}cm^{-3}$) with an average of 1.33. Displayed the soil studied area Textural Class in Table 5b has four categories Sandy loam(sample 1,2,3,5,6,10,11,12,15,17,19,20,31 and 32) loam (samples4,7,8,9,13,16,18,21,23, 24,25,26,27,28, and 30) loam Sandy(sample 14) and Clay Loam (samples 22 and 29) One significant physical factor affecting soil sustainability is soil texture. It has an impact on microbial activity, tillage, irrigation techniques, soil aeration, nutrient absorption, in-filtration and retention of water, and more (Gupta, 2007).

Table (6). Statistics of some soil properties

Statistic	soil properties						
	PH	EC	CaCO3	OM	CEC	ESP	BD
Meta	7.26	5.03	30.06	1.03	9.76	7.87	1.33
Med	7.40	1.60	29.50	1.00	11.50	7.88	1.32
Std	0.21	6.62	9.07	0.50	3.13	5.14	0.18
Ran	0.50	21.85	24.70	1.28	8.35	22.87	0.43
Min	7.00	0.15	16.30	0.33	4.35	2.43	1.13
Max	7.50	22.00	41.00	1.61	12.70	25.30	1.56

Soil fertility evaluation the current study used a geographic information system (GIS) to carry out a spatial model for the assessment of soil quality. The four main quality indices used in the study were the nutrient index (NI), fertility index (FI), chemical index (CI), and soil quality (SQ).

Table (7). Distribution of Soil Nutrient Macro and Micro Nutrients

SAM.:No	Micronutrient contents (ppm and N %)			Macronutrient contents(ppm)			
	K	P	N	Cu	Zn	Fe	Mn
1	420.00	9.14	0.03	0.36	1.02	1.02	0.78
2	460.00	2.46	0.02	0.26	0.54	0.76	1.70
3	700.00	3.69	0.05	0.46	0.38	1.56	0.86
4	520.00	6.33	0.06	0.22	0.40	0.54	1.38
5	460.00	2.46	0.02	0.26	0.54	0.76	1.70
6	420.00	9.14	0.03	0.36	1.02	1.02	0.78
7	520.00	6.33	0.06	0.22	0.40	0.54	1.38
8	520.00	6.33	0.06	0.22	0.40	0.54	1.38
9	520.00	6.33	0.06	0.22	0.40	0.54	1.38
10	460.00	2.46	0.02	0.26	0.54	0.76	1.70
11	420.00	9.14	0.03	0.36	1.02	1.02	0.78
12	460.00	2.46	0.02	0.26	0.54	0.76	1.70
13	520.00	6.33	0.06	0.22	0.40	0.54	1.38
14	380.00	1.06	0.01	0.30	0.92	1.76	0.78
15	460.00	2.46	0.02	0.26	0.54	0.76	1.70
16	520.00	6.33	0.06	0.22	0.40	0.54	1.38
17	420.00	9.14	0.03	0.36	1.02	1.02	0.78
18	520.00	6.33	0.06	0.22	0.40	0.54	1.38
19	460.00	2.46	0.02	0.26	0.54	0.76	1.70
20	460.00	2.46	0.02	0.26	0.54	0.76	1.70
21	520.00	6.33	0.06	0.22	0.40	0.54	1.38
22	700.00	8.09	0.03	0.66	0.36	3.40	1.28
23	520.00	6.33	0.06	0.22	0.40	0.54	1.38
24	750.00	1.76	0.04	0.34	1.26	1.66	1.38
25	750.00	1.76	0.04	0.34	1.26	1.66	1.38
26	750.00	1.76	0.04	0.34	1.26	1.66	1.38
27	750.00	1.76	0.04	0.34	1.26	1.66	1.38
28	750.00	1.76	0.04	0.34	1.26	1.66	1.38
29	700.00	8.09	0.03	0.66	0.36	3.40	1.28
30	520.00	6.33	0.06	0.22	0.40	0.54	1.38
31	420.00	9.14	0.03	0.36	1.02	1.02	0.78
32	420.00	9.14	0.03	0.36	1.02	1.02	0.78
Summary of the Statistics for macro- and micronutrients							
	K	P	N	Cu	Zn	Fe	Mn
aver	530.94	5.16	0.04	0.31	0.69	1.10	1.30
MAX	750	9.14	0.06	0.66	1.26	3.4	1.7
MIN	740	1.6	0.01	0.22	0.36	0.54	0.78

Spatial Distribution of Soil Macro and Micro Nutrients:

As displayed in Table 7, the soil potassium (K) in the soils studied ranged from 740 to 750 (K) with an average of 530.94. Figure 8 (K) shows the spatial distribution of K. The study area was divided into two categories K medium at 4.53 ha (0.16%) and high at 736.02 ha (99.39%) As shown in Table (1). the types and concentrations of cation, the anion concentration, and the characteristics of the soil action-exchange materials all affect how potassium is distributed across negatively charged sites on the soil and in the soil solution. (Kilmer et al., 1968).

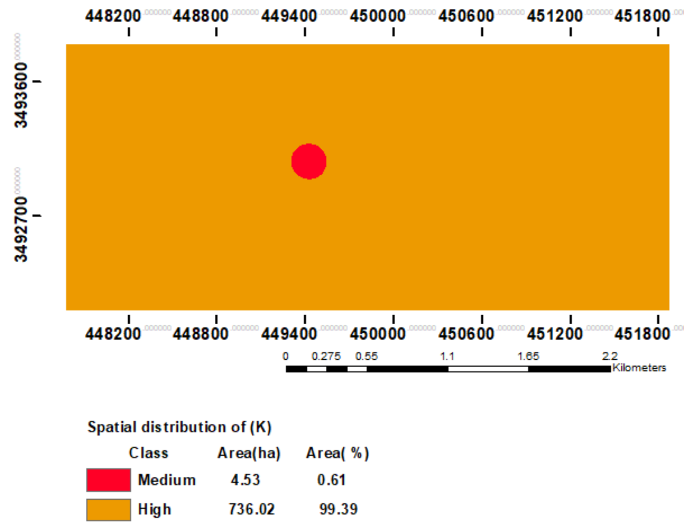

Figure: (8). spatial distribution of the (K ppm).

As displayed in Table 7, the soil phosphorus (P) in the soils studied ranged from 1.6 to 9.14 (P) with an average of 530.94. Figure 9 (P) shows the spatial distribution of P. The study area was divided into two categories of P: very low at 378.56 ha 51.12 % and low at 361.99 ha,48.88% As shown in Table (1). It is critical to implement cutting-edge technologies that improve P utilization efficiency and management concerns around low P. Using microbes for P solubilization (Hu et al., 2023; Liu et al., 2023), partially activated P (Fang et al., 2022), slow/controlled release P fertilizers (Fertahi et al., 2020; Teixeira et al., 2016), using nanotechnology (Basavegowda & Baek, 2021), and creating foliar fertilizers (McBeath et al., 2020) are some of these creative approaches.

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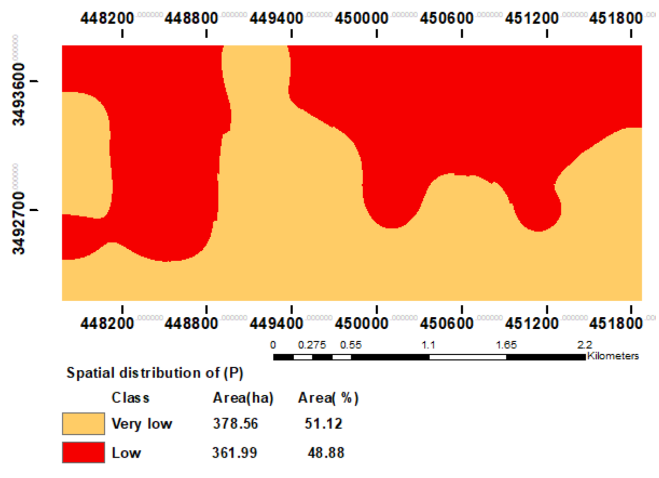

Figure: (9). spatial distribution of the (P ppm).

As displayed in Table 7, the soil nitrogen (N) in the soils studied ranged from 0.01 to 0.06 (N) with an average of 0.04. Figure 10 (N) shows the spatial distribution of N. The study area was divided into two categories of N: trace-very poor at 320.04 ha.43.22% and slightly at 420.51 ha. 56.78%. As shown in Table (1). Appropriate irrigation timing and nitrogen fertilizer dosage are efficient ways to lower nitrogen leaching, enhance nitrogen utilization, and raise yields (He et al., 2023).

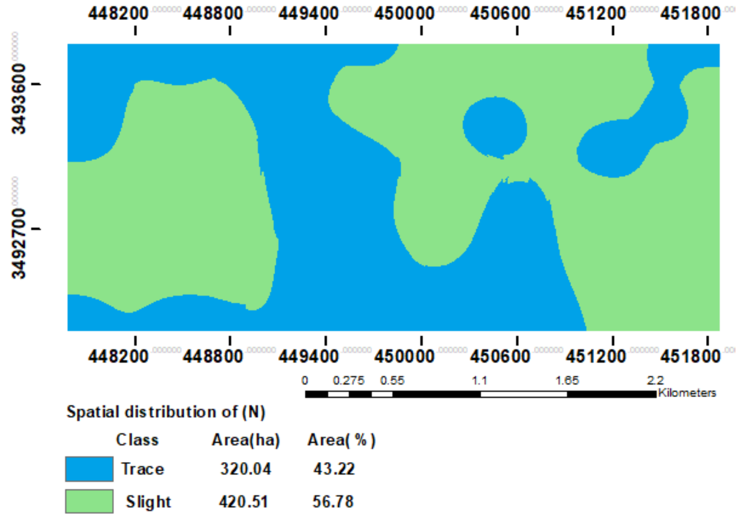

Figure: (10). Spatial distribution of the (N %).

As displayed in Table 7, the soil copper (Cu) in the soils studied ranged from 0.22 to 0.66 (Cu) with an average of 0.31. Figure 11 (Cu) shows the spatial distribution of Cu. The study area was divided into two categories of Cu: very low for 673.87 ha (91.00%) and low for 66.86 ha (9.00%), As shown in Table (1). Treatments for copper deficiencies often involve the following: • Applying acid fertilizers to calcareous soils; • Liming acidic soils to raise pH levels; • Foliar fertilization.

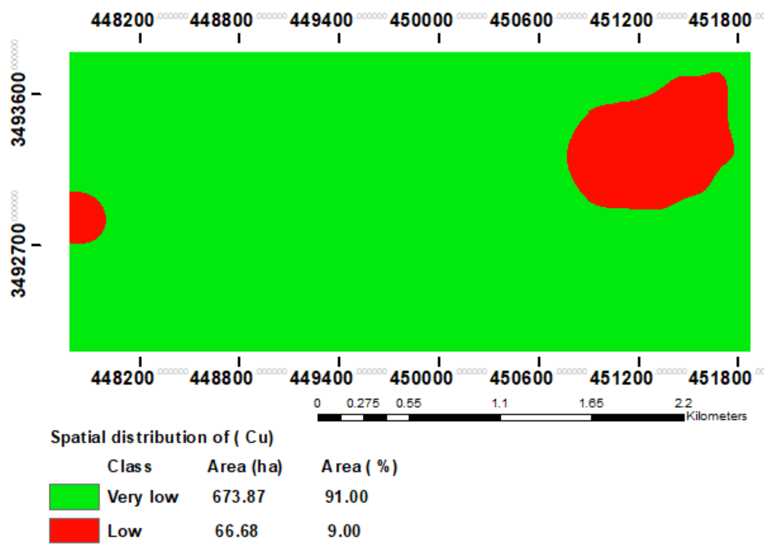

Figure: (11). Spatial distribution of the (Cu ppm).

As displayed in Table 7, the soil zinc (Zn) in the soils studied ranged from 0.36 to 1.26 (Zn) with an average of 0.69. Figure 12 (Zn) shows the spatial distribution of Zn. The study area was divided into two categories of Zn: low for 684.25 ha (92.40%) and adequate for 56.30 ha (7.60%). As shown in Table (1) The types of soils affected by Zn deficiency include all soils with low Zn availability, such as high pH calcareous soils, intensively cropped soils, and sandy soils (Kochian, 1993).

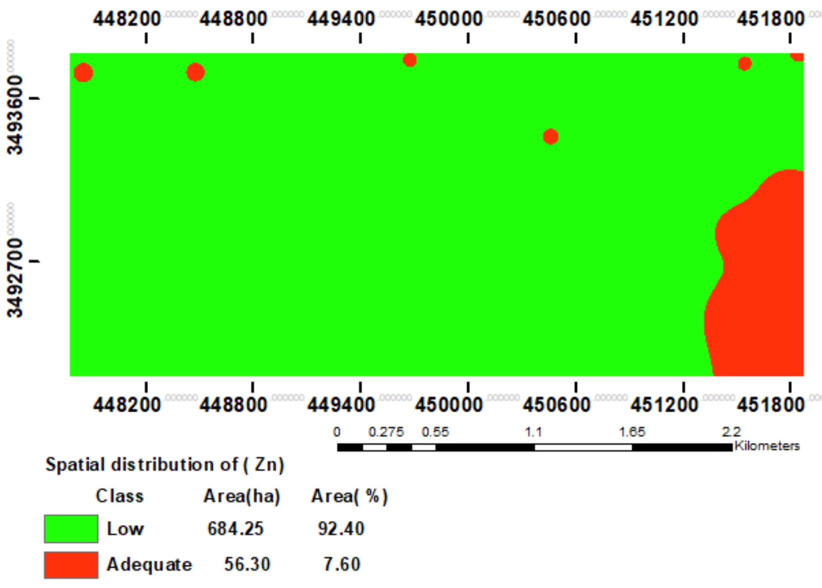

Figure: (12). Spatial distribution of the (Zn ppm).

As displayed in Table 7, the soil iron (Fe) in the soils studied ranged from 0.54 to 3.4 (Fe) with an average of 1.10. Figure 13 (Fe) shows the spatial distribution of Fe. The study area was divided into two categories of Fe: below for 726.14 ha (98.05%) and adequate for 14.41 ha (1.95%), As shown in Table (1). the usage of Fe fertilizers in the soil works in lowering the pH of the soil in the rhizospheric region by the use of sulfur or additional acidifying agents (Sánchez-Rodríguez et al., 2013).

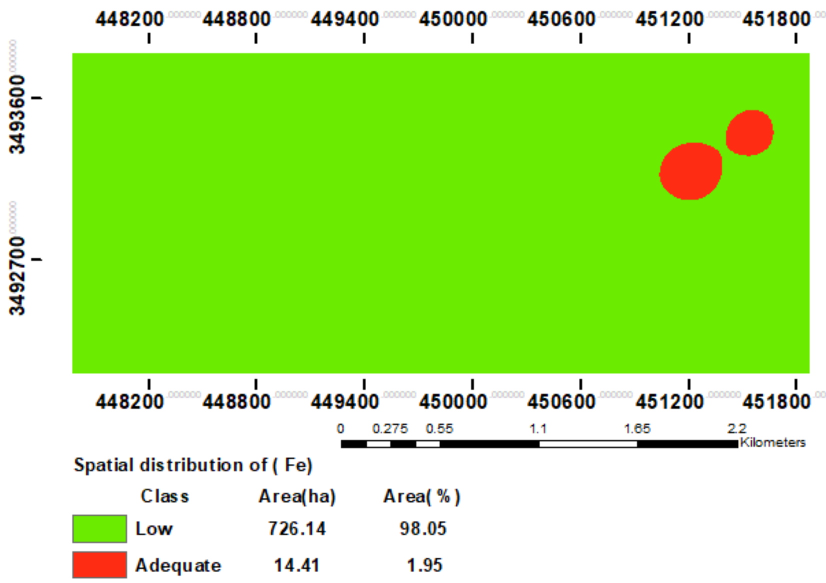

Figure: (13). Spatial distribution of the (Fe ppm).

As displayed in Table 7, the soil Manganese (Mn) in soils studied ranged from 0.78 to 1.7 (Mn) with an average of 1.30. Figure 14 (Mn) shows the spatial distribution of Mn. The study area was divided into three categories of Mn: be very low for 51.08 ha (6.90%) and low for 235.11 ha (31.75%) adequate for 454.36 ha 61.35%. As shown in Table (1). Because soluble Mn2+ is quickly converted to plant-unavailable Mn oxides, fertilization with Mn salts at the soil surface is frequently ineffective. The soil pH Must be corrected, (Rashed et al., 2019). it is advised to use environmentally friendly sources, such as organic products like compost, animal manure, and microbial fertilizers, which can improve plant growth and increase soil fertility (Ijaz et al., 2021; Marschner et al., 2003; Meek et al., 1968).

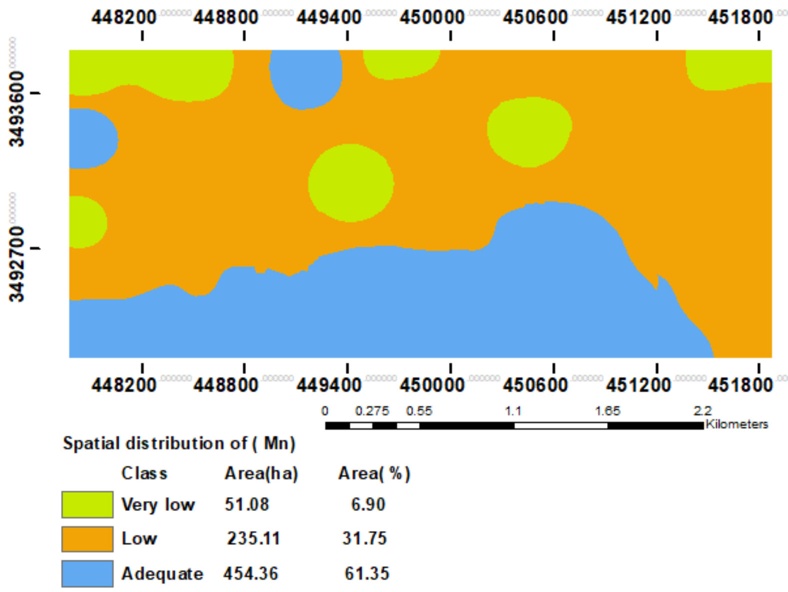

Figure: (14). Spatial distribution of the (Mn ppm).

Index of Soil Fertility

The nutrient index (NI): value was determined to evaluate the research area's macro- and micronutrients' overall nutritional status. By Equation (1), Table (2), and Figure (15).

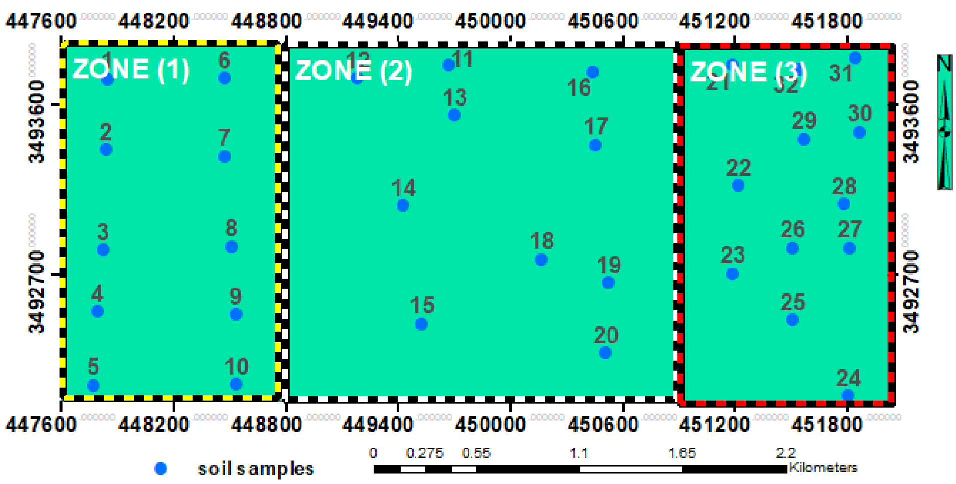

Figure: (15). Spatial distribution of the zones in the area study.

Three zones were used to examine macro- and micronutrients: zone (1) samples from 1 to 10, zone (2) samples from 11 to 20, and zone (3) samples from 21 to 32. Displayed in Figure (14).

Table (8-a). Summary of the Statistics for macro- and micronutrients: zone (1) samples.

	Macro- and micronutrients (ppm but N%)						
Stat	K	p	N	Cu	Zn	Fe	Mn
Mean	500.00	5.47	.041	.28	.56	.80	1.30
Med	490.00	6.33	.040	.26	.47	.76	1.38
Std.	81.10	2.59	.019	.08	.25	.32	0.37
Ran	280.00	6.68	.04	.24	.64	1.02	.92
Min	420.00	2.46	.02	.22	.38	.54	.78
Max	700.00	9.14	.06	.46	1.02	1.56	1.70

Table (8-b). Summary of the Statistics for macro- and micronutrients: zone (2) samples.

	Macro- and micronutrients (ppm but N%)						
Stat	K	p	N	Cu	Zn	Fe	Mn
Mean	462.00	4.82	0.03	0.27	0.63	0.85	1.33
Med	460.00	4.40	0.03	0.26	0.54	0.76	1.38
Std.	47.56	2.99	0.02	0.05	0.25	0.37	0.40
Ran	140.00	8.08	.05	.14	.62	1.22	.92
Min	380.00	1.06	.01	.22	.40	.54	.78
Max	520.00	9.14	.06	.36	1.02	1.76	1.70

Table (8-c). Summary of the Statistics for macro- and micronutrients: zone (3) samples.

	Macro- and micronutrients (ppm) (N %)						
Stat	K	p	N	Cu	Zn	Fe	Mn
Mean	629.17	5.19	0.04	0.37	0.86	1.56	1.26
Med	700	6.33	0.04	0.34	1.02	1.66	1.38
Std.	136.94	3.17	0.01	0.15	0.42	0.98	0.23
Ran	330	7.38	0.03	0.44	0.9	2.86	0.6
Min	420	1.76	0.03	0.22	0.36	0.54	0.78
Max	750	9.14	0.06	0.66	1.26	3.4	1.38.

Equation (1) was used to calculate the nutrient index values of the soil nutrients shown in Table 7. Nutrient Index categories I, II, and III were then assigned to these nutrient index values (Table 2). Using tables (8-a-b-c), the fertility status of the three soil zones for macro- and micronutrients was assessed for the study area. Table 9 provides the calculated values and corresponding nutrient index categories.

Table:(9). Nutrient Index of macro- and micronutrients

Nutrients	soil types	NI	Fertility status	soil types	NI	Fertility status	soil types	NI	Fertility status
K+	ZONE (1)	III	High	ZONE (2)	III	High	ZONE (3)	III	High
P		III	High		III	High		III	High
N		I	Low		I	Low		I	Low
Cu		I	Low		I	Low		I	Low
Zn		I	Low		I	Low		I	Low
Fe		I	Low		I	Low		I	Low
Mn		I	Low		I	Low		I	Low

The provided information was found in Table (9) for each of the three zone uses, phosphorus and potassium achieved a high value. The potassium values obtained from this investigation show that the three-zone soils contain an adequate amount of available potassium and potassium. While the low is not sufficient nitrogen, copper, zinc, iron, and Manganese fertility status was reported in Table 9 (Abah et al., 2015; Verma et al., 2005). Fertility Index (%): was utilized to determine the soil fertility index values using Table (3), Table (10) displays the soil fertility values that were discovered during this investigation.

Table :(10). Fertility classes (FS) in the studied area.

Zone study area	Nutrients	Fertility Class	Fertility Index%	Description
Zone(1)	K^+	C1	98.39	Excellent
	P	C6	1.08	
	N	C6	0.01	
	Cu	C6	0.01	Nonagricultural
	Zn	C6	0.11	
	Fe	C6	0.16	
	Mn	C6	0.26	
Zone(2)	K^+	C1	98.31	Excellent
	P	C6	1.03	
	N	C6	0.01	
	Cu	C6	0.06	Nonagricultural
	Zn	C6	0.13	
	Fe	C6	0.18	
	Mn	C6	0.28	
Zone(3)	K^+	C1	98.55	Excellent
	P	C6	0.81	
	N	C6	0.01	
	Cu	C6	0.06	Nonagricultural
	Zn	C6	0.13	
	Fe	C6	0.24	
	Mn	C6	0.20	

Table 10 data illustrates how the studied area index's fertility index and fertility class fit into two classes: Excellent (C1) and Nonagricultural (C6).

Soil quality (SQ): Equation (2) and Table (7) were used in the study area's SQ calculation.

Table:(11). Soil quality (SQ) in the studied area

SAMPLE No	FI	Class	SAMPLE No	FI	Class
1	1.65	S3	17	1.22	S2
2	1.22	S2	18	1.44	S2
3	1.63	S3	19	1.65	S3
4	1.44	S2	20	1.44	S2
5	1.22	S2	21	1.22	S2
6	1.65	S3	22	1.22	S2
7	1.44	S2	23	1.44	S2
8	1.44	S2	24	2.09	S3
9	1.44	S2	25	1.44	S2
10	1.22	S2	26	1.76	S3
11	1.65	S3	27	1.76	S3
12	1.22	S2	28	1.76	S3
13	1.44	S2	29	1.76	S3
14	1.06	S1	30	1.76	S3
15	1.65	S3	31	2.09	S3
16	1.22	S2	32	1.44	S2

The findings showed that the three classes of soil quality (SQ) in the study area were low quality (S3), moderate quality (S2), and high quality (S1). The quality of the soil samples was found to be high (3.125%), moderate (3.25%), and low (40.625%), respectively. And the FI ranges from 1.22 to 2.02. according to table (11)**.**

Table (12). Pearson's correlation coefficient between soil Physical, Chemical macro-, and micronutrients in the study area.

Parameter	K	P	N	Cu	Zn	Fe	Mn
PH	0.155	-0.411**	-0.643**	0.222	0.726**	0.177	-.016
EC	-0.411**	0.532**	-0.364*	0.366*	0.451**	0.238	-0.877**
CaCO3	0.098	0.408*	0.856**	-0.344*	-0.089	-0.274	-0.183
OM	0.320*	0.348*	0.913**	-0.225	-0.114	-0.145	-0.080
ECE	-0.519**	-0.362*	0.463**	-0.189	-0.451**	0.022	0.806**
ESP	-0.470**	0.586**	-0.130	0.274	0.041	0.189	-0.782**
DB	-0.138	-0.344-*	-0.867-**	0.429**	-0.040-	0.381*	0.159

**. Correlation is significant at 0.01.
*. Correlation is significant at the 0.05.

Table (12). A statistical analysis was performed to find out possible correlations between (K, P, N, Cu, Fe, Zn, and Mn). Contents and the studied soil properties (PH, EC, CaCO3, OM, ECE, ESP, and DB). There is a low significant positive correlation (r = 0.155, 0.098, and 0.320) between the available K and parameters of PH, CaCO3, and OM. There exists a negative correlation (r = -0.411, -0.519, -0.470, and -0.138) among k and (EC, ECE, ESP, and DB) parameters, indicating they a medium, high, and low. There was a medium significant negative correlation (r=- 0.411, -0.362, and -0.344) between p with (PH, ECE, and DB) respectively, and an appositive correlation high, medium, and high (r = 0.532, 0.408, 0.348, and 0.586) between p with (EC, CaCO3, OM and ESP) respectively. An appositive correlation of high, high, and medium (r = 0.856, 0.913, and 0.463) was found between p and (CaCO3, OM, and ECE), and a high, medium, low, and high significant negative correlation (r = - 0.643, -0.364, -0.130, and -0.867) was found between p and (PH, EC, ESP, and DB), respectively. There was a medium, low, low, and low significant negative correlation (r=- 0.344, -0.225, -0.130, and -0.189) between Cu with (CaCO3, OM, and CEC) respectively, and an appositive correlation low, medium, low and medium (r = 0.222, 0.366, 0.274 and 0.429) between p with (PH, EC, ESP, and DB) respectively. There was a medium, low, low, medium and low significant negative correlation (r= -0.089-0.114, -0.451, and -0.040) between Zn with (CaCO3, OM, ECE, and DB respectively, and an appositive correlation high, low, and low (r = 0.726, 0.451and 0.041) between Zn with (PH, EC, and ESP) respectively. There was an all-low significant negative correlation (r= -0.274, and -0.145) between Fe with (CaCO3and OM) respectively, and an appositive correlation low, low, and medium (r = 0.177, 0.238, 0.022, 0.189and 0.381) between Fe with (PH, EC, ECE, ESP, and DB) respectively. There was a low, high, low, low, low, and high significant negative correlation (r= -0.016,-0.887,-0.183, -0.080, and,-0.782) between Mn with (PH, EC, CaCO3, OM, and ESP) respectively, and an appositive correlation low, low, and medium (r = 0.806, and 0.159) between Mn with (ECE, and DB) respectively.

DISCUSSION

The study has led to the use of GIS for quantitative assessment of asses the validity of the different indices of the determination of Soil Fertility. The results indicated that the soil Fertility (SF) of the study area was classified according to Referring of Physical and Chemical Characteristics of soil and Soil Nutrient Macro and Micro Nutrient concentration to the standard guidelines According to Tables (5 and 6). our noting that This pH range is not suitable for the uptake of most nutrients as the optimum range for plant absorption varies from 6.5 to 7.5 and (Figure 3) shows the soil EC was Strongly Saline>Very Slightly Saline> Non-Saline> Moderately Saline respectively. (Figure 4) show that the soil $CaCO_3$ was high calcareous> moderately calcareous. This could be the cause of the high CaCO3 levels to the build-up of Ca^{++} ions in highly salinized soil. (Figure 5) show most soil samples had low OM contents which did not exceed 55.28%. (Figure 6) show Most of the soil had between 5 and 13 ECE contents which did not exceed 98.38%. Noting (figure 7) shows Most soil is Non-Sodic, percentage of 96%.Most soils in the study area are, by nature, alkaline and low in available nutrients. Thus in planning a crop production program, agricultural all types of fertilizers should be applied at the rate required The provided information found macro- and micronutrients in this research for each of the study area uses which were potassium in about(99.39%)high and adequate for about Mn (61.35%), Zn (7.60%) and Fe(1.95%) and low Fe (98.05%), Zn (92.40%), P(48.88%), Mn (31.75%), and Cu(9.00%)and very low Cu (91.00%) and Mn (6.90 %) and very poor N(100%).

CONCLUSION

Using the validity of the various indices for determining soil fertility, while assessing the chemical and physical characteristics of the soil, the findings showed that the study area's soil fertility (SF) was different. Inadequate nutrient levels in the soil, the decline is as follows: of the entire study area, very low values are around 50% and low levels are 25%, acceptable levels are 23%, high values are 0.99%, and medium 0.0061%, and very poor and poor levels are 1%. Fertilizer recommendations are dependent on crop types and are based on the levels of nutrients currently present in the soil. Therefore, nutrients should be added to the soil. Usually require the addition of fertilizer: copper, zinc, phosphorus, and nitrogen.

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Author contributions: The author did all the work related to the manuscript, including designing the research, collecting information, formulating theories and proofs, and preparing the entire paper.

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