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Application of GIS Techniques and ASLE Program for Soil Fertility Assessment at Samannoud District, Gharbia Governorate, Egypt

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SOIL FERTILITY assessment and soil fertility mapping can provide insights for appropriate strategies to select crops suitable for soils and to build a decision making framework to help farmers and improve land management. This study's primary goal was to assess the soil's level of fertility and land suitability for some strategic crops using ASLE software and GIS techniques in some soils at Samanoud District, Gharbia Governorate, Egypt. For this aim, 17 soil samples were randomly distributed over the study area according to locations using GPS. The studied area covers about 166.2 km^2. In the southern and western regions of the study area, higher clay values were found. The concentrations of N, P and K were evaluated as low or medium based on their availability in the studied area. In the northern regions of the examined area, there was a higher concentration of OM and available P. On the other hand, higher available N levels were seen in the southern regions. Meanwhile, the higher available K values were recorded close to the center of the study region. According to the ASLE program, there are two classes of fertility index data outputs in the area under study: (i) Fair-C3 and (ii) Poor-C4. The soils in the study area were very suitable for growing wheat (S1) and fitted into two classes: very suitable (S1) and suitable (S2) for maize cultivation. In addition, the studied area fitted into three classes including very suitable classes (S1), suitable (S2), and currently unsuitable (N1) for faba bean cultivation. However, the studied area was classified into moderately suitable (S3) and marginally suitable (S4) for rice cultivation. In essence, the appropriate field crops could be categorized according to its suitability as follows: wheat, maize, faba beans, and rice. Such data might help in supporting decision makers for optimum soil management.

Keywords: Assessment of Soil fertility, Fertility index, NPK, land suitability, crops, ASLE, GIS.

Introduction

According to FAO, soil fertility refers to the soil's capacity to supply nutrients to plants in quantities sufficient and balanced for optimum growth (Jin at el., 2011). The fertility of soil and nutrient administration has an important role in modern agriculture, which shows in the management of fertilizers and crop yield (Bagherzadeh et al., 2018). Soil fertility has been expressed as the relationship among reactions of organic matter, nutrient ions, and water. Besides, the nature and quality of mineral ores might control the fertility of the soil (Sushanth et al., 2019). Based on the difference in landform, Khadka et al., (2017) collected 81 soil samples (0-20cm) using a soil sampling auger for evaluation of soil fertility in a study area (Tarahara, Sunsari, Nepal). The soil texture of the study area classified from sandy loam to clay loam according to the soil fertility status. Additionally, organic matter, total nitrogen and available copper were medium in content. However, available phosphorus and available manganese exhibits high status, while available iron was very high. Accordingly, appropriate fertilizer doses can be applied a supplemental requirement.

Regular monitoring of spatial alterations in soil fertility status is very important since the cultivation of different crops depends upon tracking and evaluation of soil fertility and determining soil

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properties (El-Seedy, 2019). ASLE - The computer-based application is a useful tool for assessing soil fertility in arid and semi-arid soils, as shown in Fig.1 (Ismail et al. (1994), Ismail & Morsi, (2001) and Ismail et al., (2001)). Soil evaluation can be used by various models such as LECS (land evaluation for capability), GIS (geographic information system) ALES (agricultural land evaluation system (Ganzorig and Adyasuren, 1995) explain that. According to Sayed et al., (2016), a land evaluation is a description of the soil properties, crop cover, meteorological circumstances, goal of land use, and determination of the best way to use the land. In order to evaluation of soil fertility classes, it is being classified into six classes i.e. C6, C5, C4, C3 , C2 and C1 to express Non-agriculture, Very poor, Poor, Fair, Good, and Excellent soils, respectively. Applying the ASLE program for evaluating soil properties and interactions of land units has been studied by (Sayed et al., 2016). Several models and patterns were applied in this field to determine soil fertility (Bijanzadeh and Mokarram, 2017). The study area's SFI (soil fertility index) was categorized as very low, low, and moderate (Bagherzadeh et al., 2018). ASLE program was adopted in in some soils of Dakahlia Governorate in order to evaluate soil fertility status (Elseedy, 2019a, Elseedy, 2019b). Findings of these studies showed that classes of soil fertility index were classified as two Indicators (Good and Fair) for evaluation of soil fertility (C2 and C3, respectively) at the studied area. In another study, calculation of fertility Index and soil fertility evaluation status was studied by the ASLE program to evaluate and calculate soil fertility and fertility Index (FI) for some soils at North Nile Delta, Egypt, tracing fertility status compared with its evaluation 9 years ago (El-Seedy and Saeed, 2019). ASLE showed alterations in soil fertility classes (Fair-C3, Poor-C4, Very Poor-C5, and Non-Agriculture-C6) compared with the previous evaluation since the results of the previous study only revealed three classes (Fair-C3, Poor-C4, and Very Poor-C5) according to the fertility index. Comparing fertility Index mapping in the two studies shows that some of the researched area's were degraded in soil fertility while others were increased in soil fertility. In another study, Hafif, (2021) found that fertility of soil in the study area - soil texture is sandy loam and sand clay loam - was low to moderate, indicated by low pH, P, K, and total N. While soil organic carbon was low to moderate. Also, he found that Ca, Mg, K, and CEC were low to very low. Utilization of GIS as a technique to estimate the locative patterns of differences for some of the soil characteristics at an extent of standards and the soil properties vary spatially with different sized sampling grids due to soil management and soil formation factors. Spatial variations of soil characters result from distinction in soil formation factors and soil arrangement, which is a great determinant of competence of farm inputs and yield. Therefore, locative distributions enable us to use important techniques in using nutrients and fertilizers arrangement and water in agricultural yield (Sağlam et al., 2011). We can also characterize locative patterns by GIS and predict soil value features at locations that are not sampled by some statistical tools by geostatistics. For evaluating the value of variables in locations that are not sampled, locative fulfillment techniques have been utilized in soil science (El-Sirafy et al., 2011). Utilizing a geographic information system (GIS) and geostatistical methods to assess the land suitability for strategic crops is helpful (Aldabaa, and Yousif 2020). The key to successful soil administration for prospective crop yield is planning the spatial distribution of soil characteristics. It also enables us to improve agricultural exercise, and can boost making decisions and resolution with more precise information we need in improving management of fertility programs (Fig 2; El-Sirafy et al., 2011, Behera et al. 2016, Elnaggar et al., 2016, and Elseedy, 2019). The relationship between soil formation agents and soil administration practices through spatio-temporal standards produces the spatial several of soil characteristics and is locally modified by corrosion and sedimentation processes (Iqbal et al., 2005 and Hu et al., 2019). The spatial distribution and variance of soil characteristics are essential for forecasting the effects of changes in land use on soil characteristics (Moore et al., 1993; Park and Vlek, 2002, Lian et al., 2009, and Jiang et al.'s 2017). Therefore, the loss of soil values at a fine spatial resolution considerably increases the uncertainty of model outputs and turns into a basic restriction for the assessment of land quality and soil use. It has been widely understood to apply digital soil mapping (DSM) to predict the main physiochemical properties like depth of soil, available water content, textural fractions, organic carbon, and pH (McBratney et al. 2003; Minasny et al. 2013; Hengl et al. 2015; Dharumarajan et al. 2020a, 2020b). According to Bakhshandeh et al. (2019) and Zeraatpisheh et al. (2019), it's critical to map the geographical soil nutrients distribution in order to identify deficient regions and develop more effective management plans. In general, interpolation methods like local ordinary kriging, inverse distance weighted, and polynomial interpolation are used to establish the spatial distribution of soil nutrients. In view of this, El-Sayed et al. (2020) evaluated and mapped some soils in Sohag using geostatistical analysis tools in GIS whereas they found that four capability classes - Good, Fair, Poor, and Nonagricultural lands - were present in the study area. The spatial distributions of soil properties and soil management practices help in understanding soil characteristics changes and timely amendment management patterns. Further, the evaluation of soil fertility within farmland is an urgent need to comprehension level of soil fertility and obviating soil degradation (Chen, et al. 2020). A soil fertility index map can supply decision-makers with information like spatial designing for soil management. The establishment of fertility maps depends on basic soil properties that can be modeled for spatial mapping (Hounkpatin, et al 2022). Also, in the same context Dharumarajan et al., (2022) illustrated that mapping of soil nutrient is important for determining regions of fertile status and aiding farmers' agricultural management practices to improve crop yields. They evaluated a mapping of soil for predictions of phosphorus, potassium, sulfur, zinc, boron, copper, manganese, and iron nutrients with other soil properties such as soil pH, EC, and SOC in the study area.

In order to evaluate land suitability in the northern Delta (Zamil et al., 2009) carried out a quantified land appraisal study. They reported that soil suitability assessment for crops is essential for planning sustainable land use.

Numerous studies have noted the benefits of employing ASLE program system. The ASLE-program was employed to test the appropriateness for cultivating many field crops, fruit trees, and vegetables, the best plants for growing in the research area, according to Abd El-Azem (2020), are in the following order: date palm, olive, barley, wheat, cotton, cabbage, rice, maize, watermelon, onion, faba bean, apple, pear, pea, and soybean. According to Sayed and Khalafallah (2021), evaluated and mapped land suitability in some parts of Assiut using ASLE models. They could diagnose the soil limitations in the study area. Results for land suitability according to the ASLE program showed that the study area's soils were highly suitable (S1), suitable (S2), moderately suitable (S3), marginally suitable (S4), and currently and permanently unsuitable (N1 and N2, respectively) for 28 field and vegetable crops and fruits. Mohamed Rashed and et al., (2022) discovered that the suitability of the land for growing the following crops-sugar beet, cotton, wheat, tomato, soy bean, maize, onion, pepper, cabbage, olive, date palm, alfalfa, grape, and fig-was highly suitable (S1), suitable (S2), moderately suitable (S3), marginally suitable (S4), and currently unsuitable-N1. The applied system of land evaluation (ASLE) for arid and semi-arid settings was used to evaluate the suitability of particular crops in these locations. The investigation revealed that the soils in the study region were either extremely suitable (S1), suitable (S2), suitable (S3), marginally suitable (S4), now unsuitable (N1), or permanently unsuited (N2) for nine fields, vegetable crops, fruits, and frog crops. GIS tools capable to evaluate the suitability of Kafr El-Sheikh soils whereas they used ASLE program for evaluation (Abosafia et al., 2022). Their results indicated that the study area was not suitable for citrus and onion, moderately suitable for growing maize, and highly suitable for barley, date palm and wheat. Land suitability varied from one region to another, with some areas being very suitable while others were moderately suitable or marginally suitable (Fadl and Sayed, (2020) and Jalhoum et al. (2022). The major goals of this study were to assess the soil fertility of some soils in Egypt's Samannoud District, Gharbia Governorate and determine whether they were suitable for a few critical crops using the ASLE program and GIS techniques.

Materials And Methods

Studied area

The experimental study was carried out at Samannoud district, Gharbia Governorate, Egypt (western bank of Nile River). This studied location covers an area of about 166.2 km^2. It extends between latitudes of 30°03'46" and 30°00"N, and longitudes of 31°20'03" and 31°08'10" E (fig. 1). We have chosen this location since it has a long-term legacy of using intensive mineral fertilizers. Therefore, the main aim of our study is to investigate the adequate levels of fertility indices in such area in order to contextualize its future fertilization plan.

Soil fertility evaluation

Soil samples (17 rhizospheric layers, 0-30 cm) were collected to evaluate fertility indices in studied area.

Land suitability

In addition to the rhizospheric soil samples, 17 soil profiles were prepared to collect representative soil samples from layers of 30-60 and 60-90 cm. Data generated from the three soil layers (0-30, 30-60 and 60-90) were used to feed ASLE program for land suitability evaluation.

Protocols of soil sampling and analyses

The GPS system was utilized to log the sample sites' coordinates. Samples were air-dried, crushed, and sieved through a 2-mm sieve before being used for the physical and chemical analyses. Protocols of soil analyses are shown in Table 1.

GIS and mapping of soil fertility evaluation

The Applied System for Land Evaluation (ASLE) program, created by (Ismail and Morsi, 2001), was used to evaluate soil fertility and determine the fertility index value as seen in Fig. 2. This model incorporates many physiochemical aspects dealing with evaluating soil status. The results are also shown in straightforward maps that are easy to read and depict the regional variation in soil fertility for the research area. According to Storie (1933 and 1944), classes of soil fertility could be evaluated using the program outputs, as shown in Table 2. ArcGIS 10.5 software was used to interpolate several physical and chemical soil parameters in the study region using geostatistical correlations between the known sites. Data of the selected 17 samples were used to estimate each grid point using the spatial interpolation method (IDW). Field crops like wheat (*Triticum aestivum*), faba beans (*Vicia faba*), maize (*Zea mays*), and rice (*Oryza sativa*) were grown on the studied area.

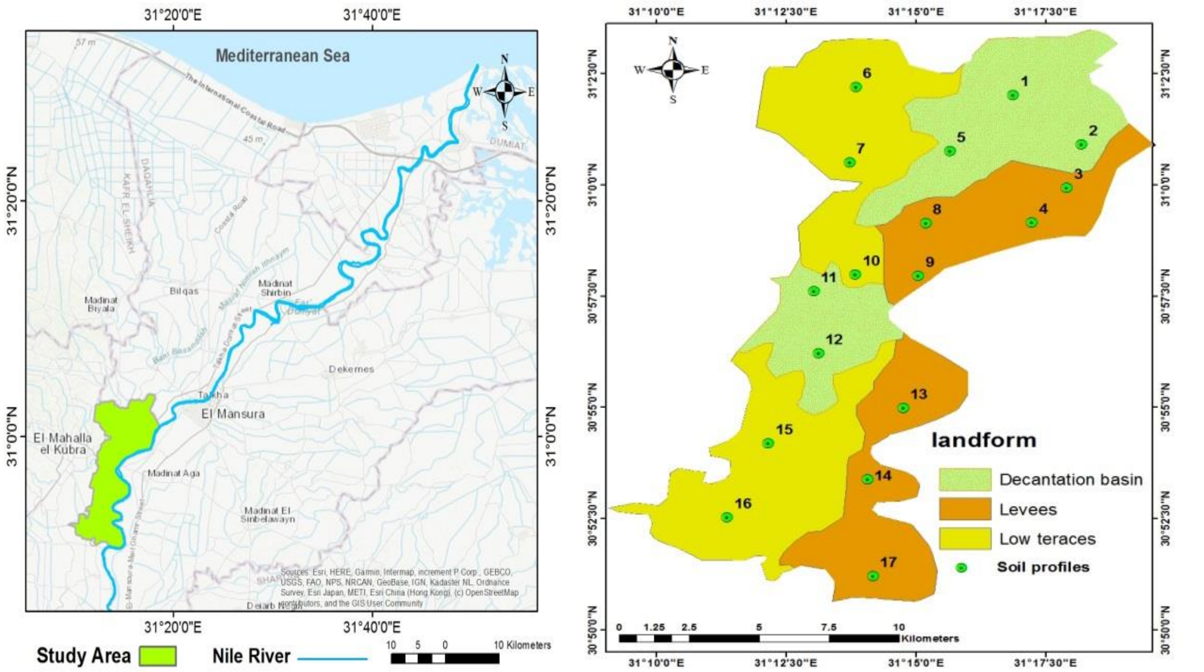

Fig. 1. Locations of the study area and the spatial distribution of soil samples in Samanoud District.

TABLE 1. Soil characteristics and the procedures used for the lab analysis.

Soil property	Methods	Reference
Clay %	Pipette method	(Piper, 1947)
OM-Organic Matter (%)	Method of dichromate oxidation	Walkely & Black's, (1954) Hesse, (1971)
SP-Saturation percentage (%)	Free capillary attraction	Dewis & Freitas, (1970)
BD-Bulk density (kgm^{-3})	Core method	Dewis & Freitas, (1970)
Soil pH (1:2.5)	Using a pH-Meter with a glass electrode	Jackson, (1967)
EC-Electrical conductivity (1:2.5) (dSm^{-1})	EC-Meter	Hesse, (1971)
Exchangeable bases (Ca, Mg, K and Na)	pH 7.0, ammonium acetate 1M	Hesse, (1971)
Available nitrogen	Kjeldahl	Hesse, (1971)
Available phosphorus	Spectrophotometer	Olsen & Sommers, (1982)
Available potassium	Flamephotometer	Hesse, (1971)
CEC ($cmol\ kg^{-1}$)	pH 7.0, ammonium acetate 1M	Hesse, (1971)
ESP (%)	$ESP = \frac{\text{Ex. Na (meq/100 g soil)} * 100}{\text{CEC (meq/100 g soil)}}$	Richards, (1954)

TABLE 2. Classes for land suitability and fertility (Storie, 1933 and 1944).

Fertility Class	Suitability Class	Fertility and Land Suitability Index %
Excellent=C1	Very suitable=S1	> 80
Good=C2	Suitable=S2	< 80 - > 60
Fair=C3	Moderately suitable=S3	< 60 - > 40
Poor=C4	Marginally Suitable=S4	< 40 - > 20
Very poor=C5	Currently unsuitable=N1	< 20 - >10
Non agriculture=C6	Permanently unsuitable=N2	< 10

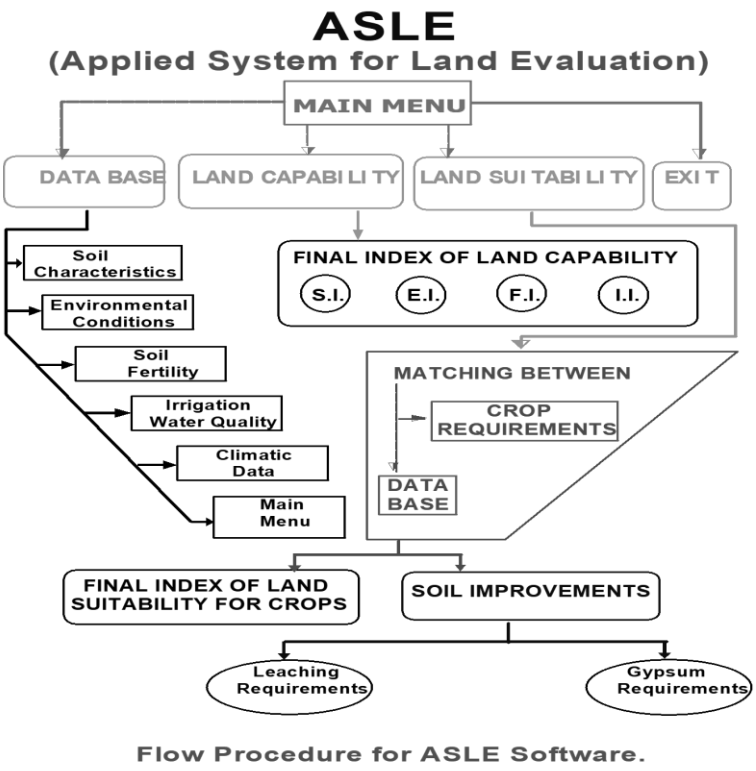

Fig. 2. Flow chart ASLE- program.

Results

Soil physical properties

Table 3 illustrates data of some soil physical properties including clay content, saturation percentage (SP), and soil bulk density (BD). Clay content varied from 26.88 to 47.69% (with an average value of 42.37%). The range of saturation percentages was 48.33 to 84.81%, with an average of 75.32%. The bulk density of the soils varied between 0.91 and 1.11 g cm^{-3}, with an average density of 1.02 g cm^{-3}.

Soil chemical properties

Some of the soil's chemical characteristics are represented by data in Table 3, together with their minimum, maximum, and mean values. These properties include soil pH, EC, exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+), CEC, and ESP. The pH of the soil ranged from 7.97 to 8.60, with an average of 8.30. The range of electrical conductivity was 0.29 to 1.27 dSm^{-1}, with an average value of 0.70 dSm^{-1}, indicating low salinity and low soluble salt concentration. Exchangeable Ca^{2+} ranged from 26.90 to 57.22 cmol kg^{-1}, (average of about 46.17 cmol kg^{-1}) with an average value of 22.03 cmol kg^{-1}. Exchangeable Mg^{2+} ranged between 10.11 and 37.12 cmol kg^{-1}. Between 0.46 and 2.04 $cmolkg^{-1}$, the average exchangeable K^+ concentration was 0.92 $cmolkg^{-1}$. The range of exchangeable Na^+ was 0.06 to 1.48 $cmolkg^{-1}$, with an average of 0.86 $cmolkg^{-1}$. With a mean value of 74.68 $cmolkg^{-1}$, the CEC values ranged from 43.56 to 84.62 $cmolkg^{-1}$. The range of ESP was 0.14 to 1.90% (or around 1.12% on average).

Properties of soil fertility

Data in Table 4 show soil fertility properties, including their minimum, maximum and mean values. These properties such as organic matter (OM), available nitrogen, available phosphorus, available potassium of the studied area. Organic matter (OM) varied from 0.42 to 2.20 % (average about 1.38 %). The range of available N values was 30.73 to 100.25 mg kg^{-1} with an average of 65.10 mg kg^{-1}. Between 2.37 and 13.47 mg kg^{-1}, values of available phosphorus were found with a 5.40 mg kg^{-1} as an average. Between 203.07 and 957.88 mg kg^{-1} of available potassium were found, with a 440.89 mg kg^{-1} average.

Table 3. Soil physiochemical characteristics ranges

Soil samples	Clay %	Soil Texture	SP, %	BD g cm^{-3}	pH (1:2.5)	EC (1:2.5) dS m^{-1}	Exchangeable cations cmol kg^{-1}				CEC, cmolc kg^{-1}	ESP, %
							Ca^{2+}	Mg^{2+}	K^+	Na^+		
1	42.47	Clay	72.68	0.93	8.42	0.50	46.97	20.69	0.58	0.94	79.19	1.19
2	46.38	Clay	80.29	0.98	8.51	1.18	46.76	28.77	1.13	0.95	84.62	1.13
3	43.03	Clay	76.77	1.01	8.50	0.61	54.00	14.78	0.75	1.48	78.01	1.90
4	42.95	Clay	79.61	1.11	8.06	0.94	55.90	16.50	0.84	0.45	73.68	0.61
5	40.23	Sandy Clay	74.32	0.94	8.13	0.73	40.97	23.54	0.60	0.89	73.00	1.21
6	43.95	Clay	78.68	1.01	8.37	0.51	36.18	36.41	0.72	1.11	77.43	1.44
7	47.69	Clay	83.83	1.05	8.60	0.80	50.45	28.70	0.46	0.61	83.23	0.74
8	42.73	Clay	72.17	1.03	8.05	1.16	51.89	16.86	2.04	0.21	77.01	0.27
9	42.77	Clay	79.26	1.06	8.02	0.49	48.49	21.20	1.28	0.27	74.23	0.36
10	35.66	Clay Loam	59.42	0.99	7.97	0.64	39.37	14.97	0.57	0.92	62.83	1.47
11	44.68	Clay	74.98	1.01	8.32	0.65	50.85	22.04	0.58	1.39	81.86	1.70
12	46.27	Clay	78.08	1.08	8.58	1.27	51.69	23.96	0.89	1.24	80.78	1.54
13	26.88	Sandy Clay Loam	48.33	1.07	8.19	0.29	26.90	10.11	1.49	0.06	43.56	0.14
14	43.69	Clay	79.05	1.10	8.47	0.45	57.22	12.73	0.49	1.18	81.62	1.44
15	45.62	Clay	84.81	1.08	8.60	0.44	36.65	37.12	1.05	1.24	77.06	1.61
16	40.64	Silty Clay	75.12	1.03	8.16	0.56	36.69	28.08	1.32	0.47	65.56	0.71
17	44.70	Clay	83.01	0.91	8.16	0.69	53.86	18.02	0.90	1.15	75.93	1.52
minimum	**26.88**		**48.33**	**0.91**	**7.97**	**0.29**	**26.90**	**10.11**	**0.46**	**0.06**	**43.56**	**0.14**
Maximum	**47.69**	**Clay**	**84.81**	**1.11**	**8.6**	**1.27**	**57.22**	**37.12**	**2.04**	**1.48**	**84.62**	**1.90**
Average	**42.37**		**75.32**	**1.02**	**8.3**	**0.7**	**46.17**	**22.03**	**0.92**	**0.86**	**74.68**	**1.12**

Table 4. Soil Fertility characteristics ranges

Soil samples	OM %	Available nutrients (mgkg^{-1})			Soil properties	OM %	Available nutrients (mg kg^{-1})		
		N	P	K			N	P	K
1	1.60	69.58	2.96	258.77	**11**	1.51	61.70	2.62	267.62
2	1.49	91.89	7.74	529.36	**12**	1.12	93.19	2.81	419.23
3	1.07	67.70	2.37	319.91	**13**	0.92	72.67	3.00	721.41
4	2.13	78.75	13.47	492.16	**14**	1.24	73.14	2.81	211.89
5	2.15	61.90	9.71	311.09	**15**	1.02	43.43	3.51	429.36
6	2.20	36.96	9.42	309.62	**16**	1.62	100.25	3.62	681.67
7	1.54	30.73	8.40	203.07	**17**	1.12	49.21	3.07	446.87
8	1.40	84.49	9.37	957.88	**minimum**	**0.42**	**30.73**	**2.37**	**203.07**
9	0.42	48.69	3.23	662.24	**Maximum**	**2.20**	**100.25**	**13.47**	**957.88**
10	0.96	42.37	3.71	272.95	**Average**	**1.38**	**65.10**	**5.40**	**440.89**

ASEL and soil fertility evaluation

Data in Table 5 show the ranges and averages of soil properties indices, fertility index, and fertility class according to the ASEL program. Average of clay index was 92.61 %, which varied from 80.69 to 99.83 %. The average available nitrogen index was 35.35%, which varied from 18.49 to 62.68%. The available phosphorus index ranged between 11.17 and 33.21 % (average about 17.53%). The available potassium index varied from 58.32 and 100.00 % (average about 90.09%). While OM varied from 5.66 and 31.25 % (average about 18.56%). The average exchangeable K index was 61.11%, which varied from 35.84 to 100.00%. Exchangeable Ca^{2+} and Mg^{2+} index were 100.00% for all soils in the studied area.

According to ASLE program, the fertility index (FI) in the studied area ranged between 37.25 (Poor-C4) and 55.73% (Fair-C3), with a 45.20% average (Fair-C3).

ASEL and land suitability

According to the ASLE program, results for land suitability for the chosen field crops (Wheat, Maize, Faba Bean, and Rice) in the investigated soils are shown in Table 6 and Figures 11 and 12. These results show that the soils in the investigated area were very suitable (S1) for wheat (average about 93.71%). While were fit into two classes, which are very suitable (S1) and suitable (S2) for Maize (about 90.82 % on average). Also, were fitted into three very suitable classes (S1), suitable (S2), and currently unsuitable (N1) for Faba Bean (with an average value of 80.84%). While were fit into two classes, which are S3= moderately suitable and S4= marginally suitable for Rice an average of 42.28 %.

Table 5.: Ranges of properties indices and Soil fertility index in the studied area according to ASLE program

Soil samples	Soil properties index (%)									
	Clay	Available nutrients			OM	Exchangeable cations			Fertility index	Fertility Class
		N	P	K		K	Ca	Mg		
1	98.42	62.68	13.05	67.13	27.75	40.84	100	100	49.32	C3 (fair)
2	92.08	27.71	23.59	100	20.83	65.83	100	100	45.23	C3 (fair)
3	99.83	39.76	22.93	100	16.08	63.75	100	100	48.57	C3 (fair)
4	94.33	21.41	20.1	100	27.75	49.59	100	100	44.28	C3 (fair)
5	80.69	46.37	21.79	98.79	27.50	54.59	100	100	49.46	C3 (fair)
6	93.17	34	21.34	83.72	31.25	52.09	100	100	55.73	C3 (fair)
7	90.50	18.49	33.21	66.96	17.50	48.34	100	100	43.92	C3 (fair)
8	95.83	24.21	23.87	100	15.91	100	100	100	48.42	C3 (fair)
9	89.67	33.41	14.92	100	5.66	86.25	100	100	37.25	C4 (poor)
10	98.75	30.97	13.7	92.93	13.50	55.42	100	100	41.9	C3 (fair)
11	95.92	49.43	12.19	63.76	18.92	37.09	100	100	43.07	C3 (fair)
12	90.16	43.45	11.17	100	16.16	83.75	100	100	46.73	C3 (fair)
13	87.25	36.35	12.19	100	11.08	68.33	100	100	41.58	C3 (fair)
14	91.58	30.66	12.4	58.32	13.75	35.84	100	100	37.6	C4 (poor)
15	88.41	43.01	14.09	100	11.58	64.58	100	100	42.1	C3(fair)
16	96.50	31.25	14.97	100	24.42	67.92	100	100	49.76	C3(fair)
17	91.25	27.74	12.45	100	15.91	64.58	100	100	43.56	C3(fair)
minimum	**80.69**	**18.49**	**11.17**	**58.32**	**5.66**	**35.84**	**100.00**	**100.00**	**37.25**	**C4 poor**
Maximum	**99.83**	**62.68**	**33.21**	**100.00**	**31.25**	**100.00**	**100.00**	**100.00**	**55.73**	**C3 Fair**
Average	**92.61**	**35.35**	**17.53**	**90.09**	**18.56**	**61.11**	**100.00**	**100.00**	**45.20**	**C3 Fair**

Discussion

As a result, soil textures in the studied area varied from Sandy Clay Loam to Clay. Also, the most common type of soil texture was Clay in the study area. The regional distribution of clay soil in the examined soils is shown in Figure 3. This figure showed clear changes in soil sample particle size distribution values that represented the study area. In the southern, western and western north regions of the study area, higher clay values were found. It is known that in the Nile Delta region, the clay content of the soil decreases in the northern Delta (The closer we get to the Mediterranean Sea.), on the contrary, the sand content increases **(El-Seedy and Saeed, 2019**; **Saeed, and Bedair, 2021).** Through their physical and chemical characteristics, clay minerals influence soil fertility by regulating nutrient availability and supplies, securing and stabilizing soil organic matter, regulating soil physical properties through the formation of microaggregates, influencing soil acidity, and regulating soil microbial population and activity (Kome et al 2019). The spatial distribution of saturation percentages for the study area is shown in Figure 3. Higher saturation percentage values were discovered in the research area's southern, western and western north regions. The examined soils showed a correlation between saturation percentage values and clay content as shown in Figure 4.

Table 6. Final land suitability results for the selected field crops, in the studied area according to ASLE program.

Soil samples	Wheat Index, %	Class	Maize Index, %	Class	Faba bean Index, %	Class	Rice Index, %	Class
1	93.57	S1	92.9	S1	86.83	S1	43.64	S3
2	94.5	S1	86.19	S1	76.78	S2	39.27	S4
3	93.26	S1	93	S1	86.92	S1	41.46	S3
4	94.18	S1	92.46	S1	86.42	S1	41.87	S3
5	94.03	S1	92.57	S1	86.52	S1	41.8	S3
6	94.35	S1	92.33	S1	86.3	S1	44	S3
7	94.72	S1	86.02	S1	76.64	S2	42.11	S3
8	93.96	S1	92.62	S1	77.12	S2	41.77	S3
9	93.53	S1	92.92	S1	86.85	S1	43.62	S3
10	93.52	S1	92.93	S1	86.86	S1	43.62	S3
11	93.95	S1	92.93	S1	86.58	S1	41.77	S3
12	90.33	S1	76.6	S2	14.17	N1	35.08	S4
13	91.93	S1	91.66	S1	91.66	S1	42.87	S3
14	94.57	S1	92.16	S1	86.13	S1	44.11	S3
15	95.01	S1	91.8	S1	85.8	S1	44.31	S3
16	92.96	S1	92.69	S1	86.64	S1	43.36	S3
17	94.62	S1	92.12	S1	86.1	S1	44.13	S3
Min.	**90.33**	**S1**	**76.6**	**S2**	**14.17**	**N1**	**35.08**	**S4**
Max.	**95.01**	**S1**	**93**	**S1**	**91.66**	**S1**	**44.31**	**S3**
Average	**93.71**	**S1**	**90.82**	**S1**	**80.84**	**S1**	**42.28**	**S3**

S1= Very suitable, S2= Suitable, S3= moderately suitable, S4= marginally suitable, N1= currently unsuitable

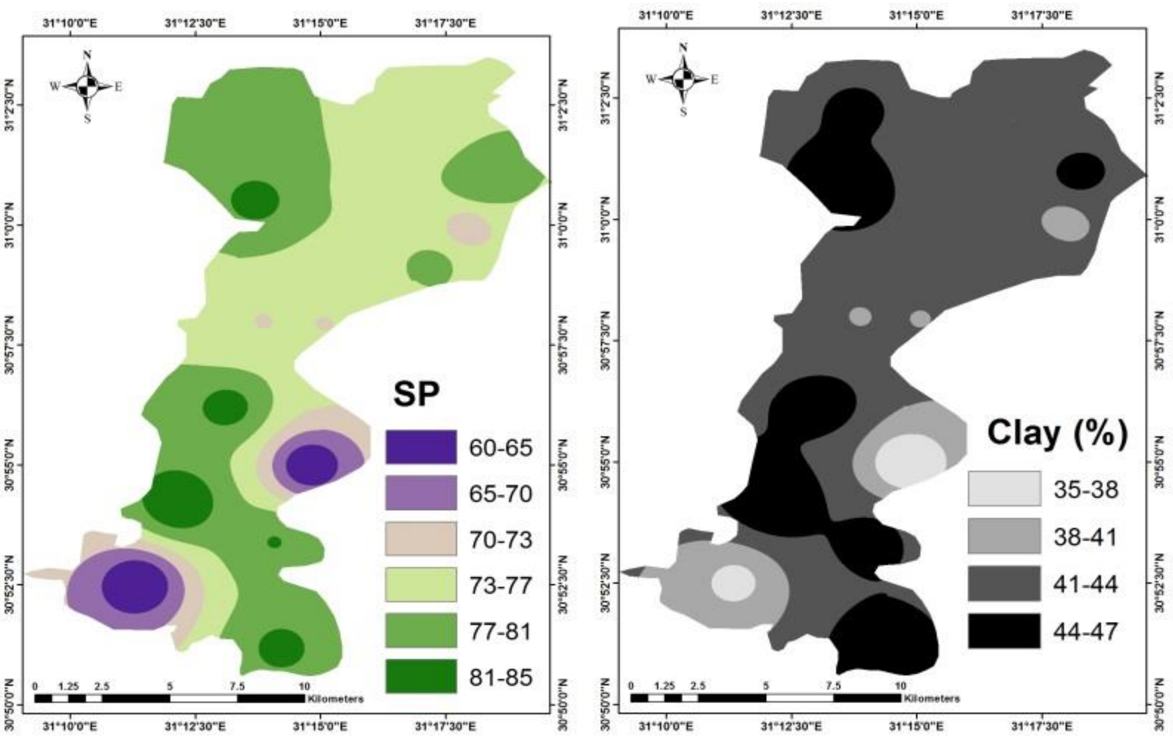

Fig .3. Spatial variability of Clay and Saturation percentage in Samanoud District.

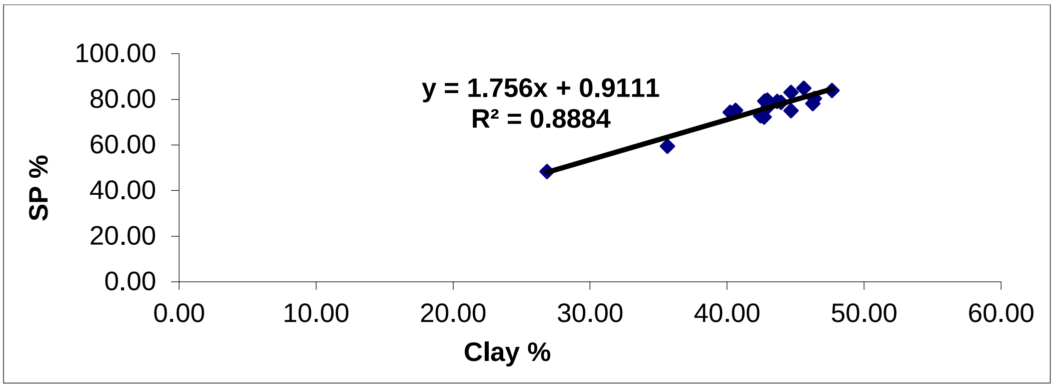

Fig. 4. Linear relationship between Clay % and SP%.

Figure 5 illustrates the spatial distribution of pH and EC in Samanoud region. From the data and according to **Dahnke and Whitney (1988),** these soils are non-saline (0.81 – 1.20 dSm^{-1}), indicating low salinity and low soluble salt concentration **(Nada, et al, 2022)**. The study area is located directly next to the Nile River and is irrigated by Nile water, which is considered high quality water, which affected the decrease in soil salinity. In general, the figure illustrates that the higher values of EC and pH were observed close to the middle parts and the northern parts of the studied area. In terms of soil fertility and long-term production, total exchangeable cations and CEC are significant concepts **(Hodges, 2010).**

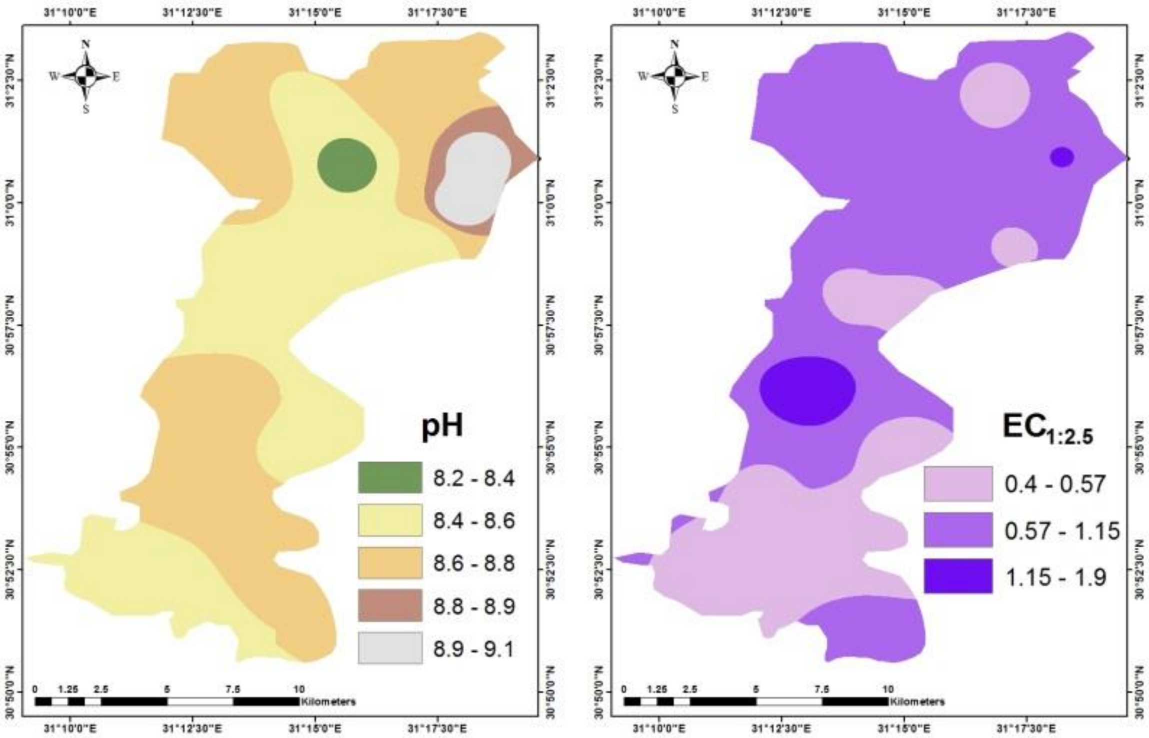

Fig. 5. Spatial variability of pH and EC in Samanoud region.

Figure 6 illustrates the spatial distribution of exchangeable cations, CEC and ESP. In general, the higher values of exchangeable (Ca^{2+}, Mg^{2+} and Na^{+}) and CEC were observed in the southern parts, this could be attributed to the high content of clay in these areas, these results are harmony with **(Nada et al, 2022)**. The increase in soil calcium content may be due to agricultural practices in the region, as farmers add agricultural gypsum to the soil in order to improve it. While the higher values of available K and ESP watched close to the middle parts of the studied area. From these data demonstrated that the studied soils were non-sodic, according to the ESP values and these results are consistent with **(Elseedy, 2019a)**. Gypsum is important for regulating the exchangeable Ca and Mg ratio in an ideal range and for the continued dealkalization process of soils **(Sahakyan et al, 2022).**

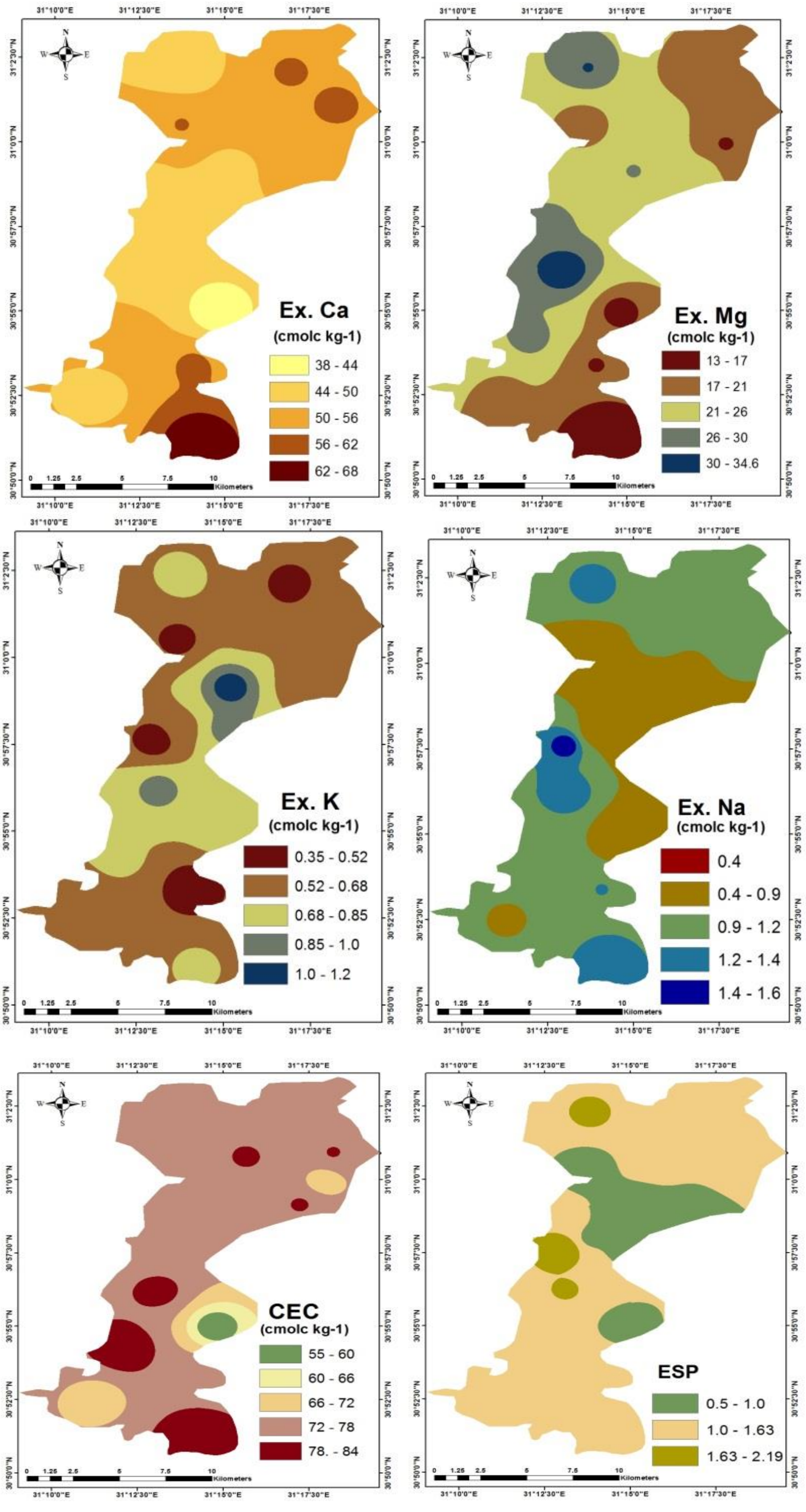

Fig. 6. Spatial variability of Exchangeable Cations, CEC and ESP in Samanoud region.

As shown in Figure 7, in general, the higher content of OM and available P was observed in the northern parts of the studied area. In this regard, there are positive relationships between SOM and available P as shown in Fig. 8. The amount of soil-available phosphorus increased when organic phosphorus mineralized. As a result, the relationship between soil organic matter and phosphorus that is readily available is precisely proportional **(Khadka 2016)**. The diversity of soil texture and its clay content are primarily responsible for the degree of organic matter content in the studied area. According to numerous research, the amount of organic matter in soils with low clay contents ranged from 1% (very low) to (low), and it gradually rose in step with the increase in soil clay contents **(Plante et al., 2006; Hartati and Sudarmadji, 2016).**

On the opposite, the higher values of available N were observed in the southern parts. While the higher values of available K watched close to the middle parts of the studied area. The NPK concentration was evaluated as low in relation to soil fertility in some locations and medium in others, as a result, some of the soils in the study region need to be fertilized with additional nitrogen, phosphate, and potassium **(Hamissa et al., 1993).**

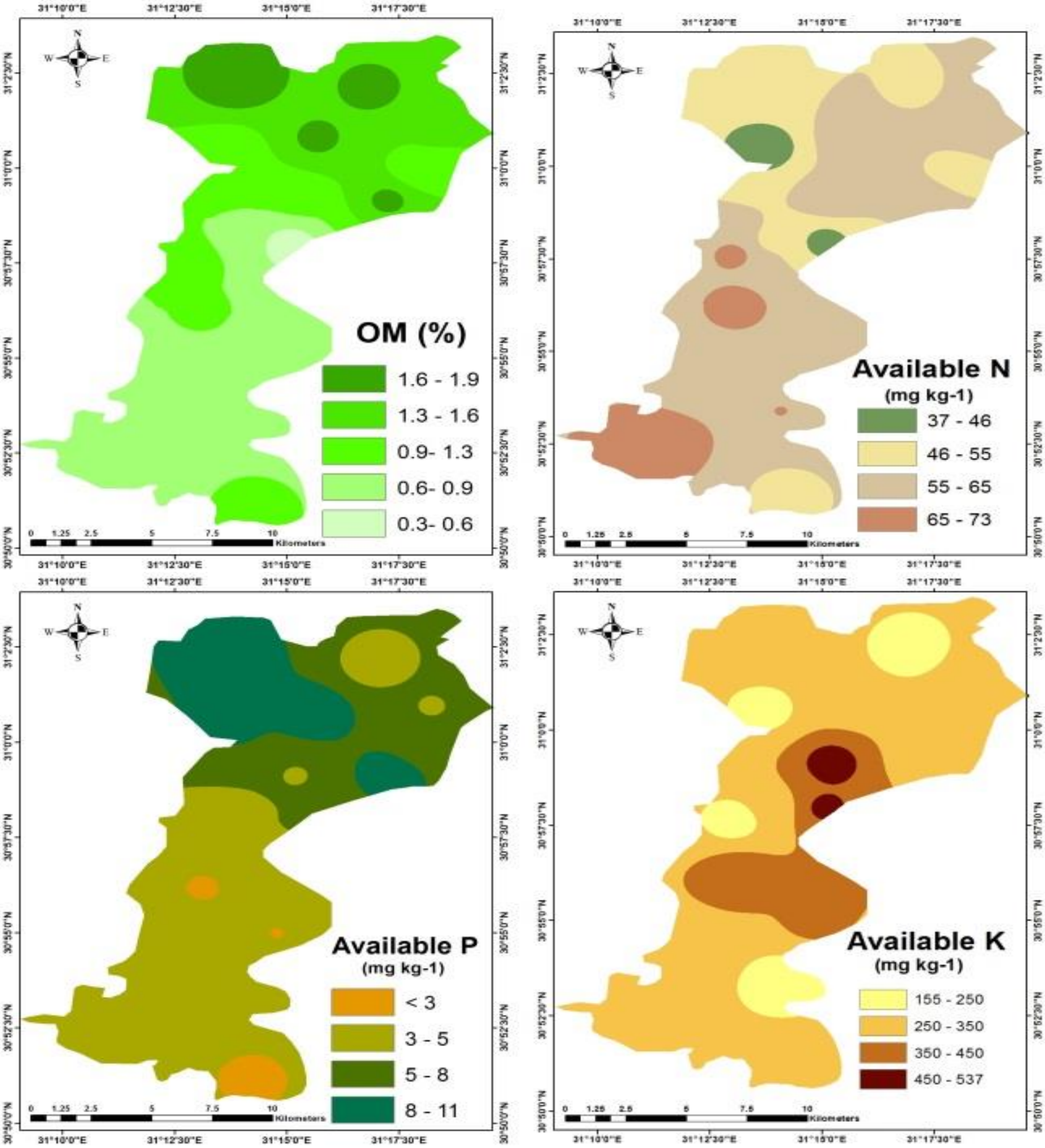

Fig. 7. Spatial distribution of OM and available **NPK in the studied area.**

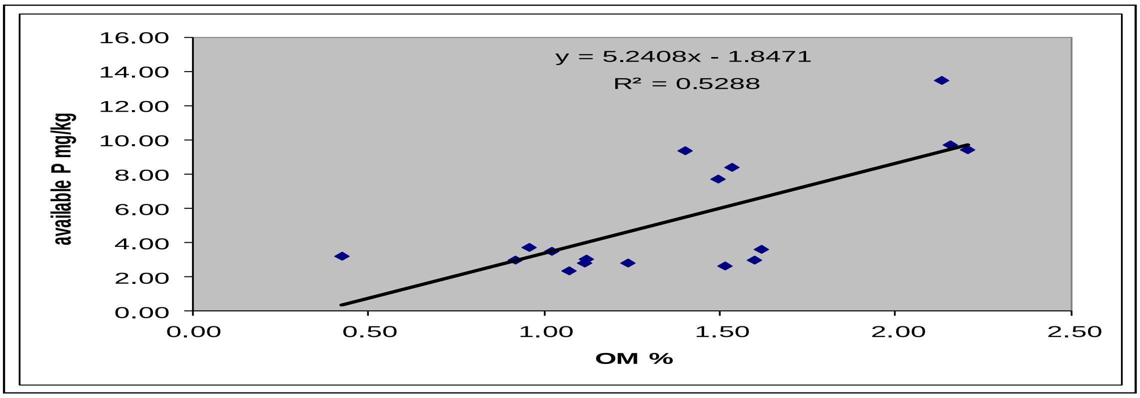

Fig. 8. Linear relationship between OM % and available phosphorus mgkg^{-1}.

Figure 9 shows how the fertility index is divided into two categories: Fair-C3 and Poor-C4. But in general, the figure shows that most of the studied area was fair (C3), and these results support the results of **Thomas et al. (2006)**. The declining soil fertility in some locations may be caused by lower levels of soil organic matter (OM), available N, P, and K **(Nada, et al, 2022)**. The linear connections between the OM index and Fertility index % in the investigated soils are shown in Fig. 10. It has been found that the OM and fertility index-FI have positive linear associations and substantial correlations (r = 0.61). The primary component of the fertility index is soil organic matter; it serves as the primary source of added nitrogen and carbon. Additionally, it has a significant role in the bulk density of the soil as well as in the dynamics of water flow and aeration. The main factor influencing soil organic matter variation is the environment (such as precipitation or drought). The bulk density of the soil and its associated indices, such as porosity, hydraulic conductivity, and air transfer, will be affected by this fluctuation in soil organic matter **(Golabi, et al. 2004; Thomas et al. 2006 and G-L, 2017).**

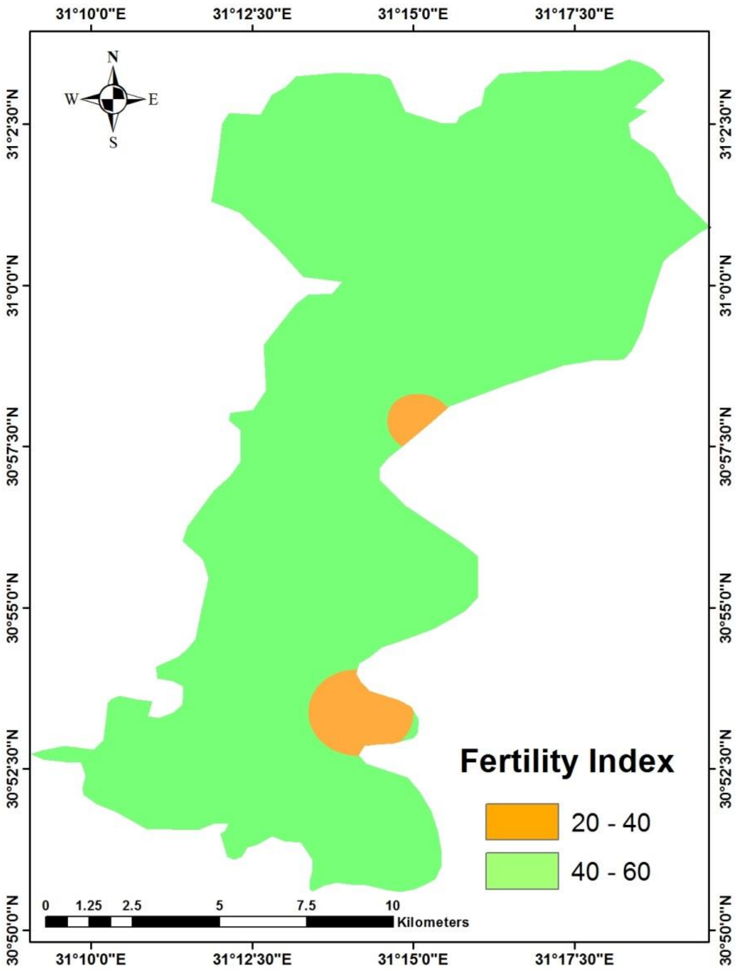

Fig. 9. Spatial distribution of soil fertility index mapping in the studied area.

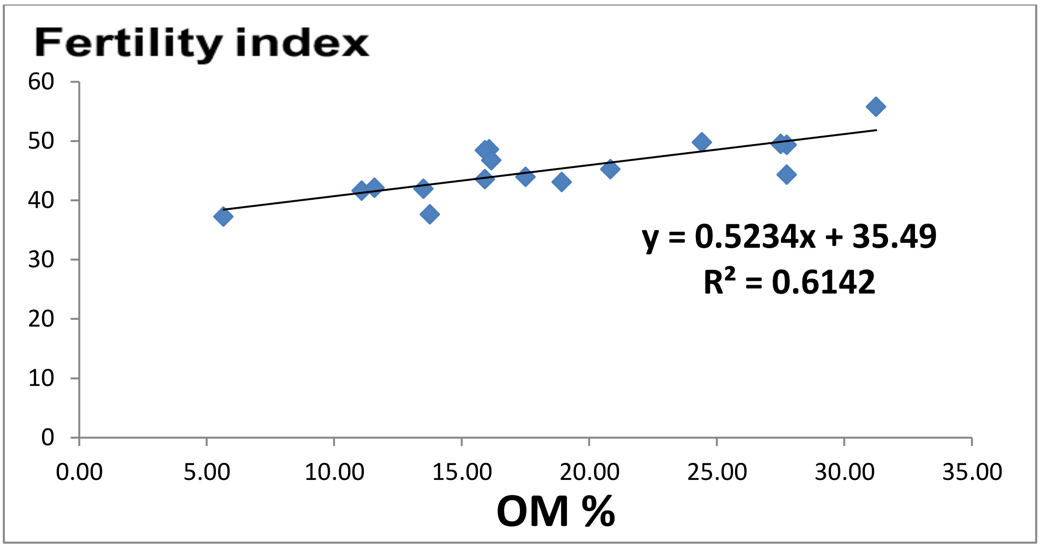

Fig. 10. Linear relationship between OM index and FI in the studied area.

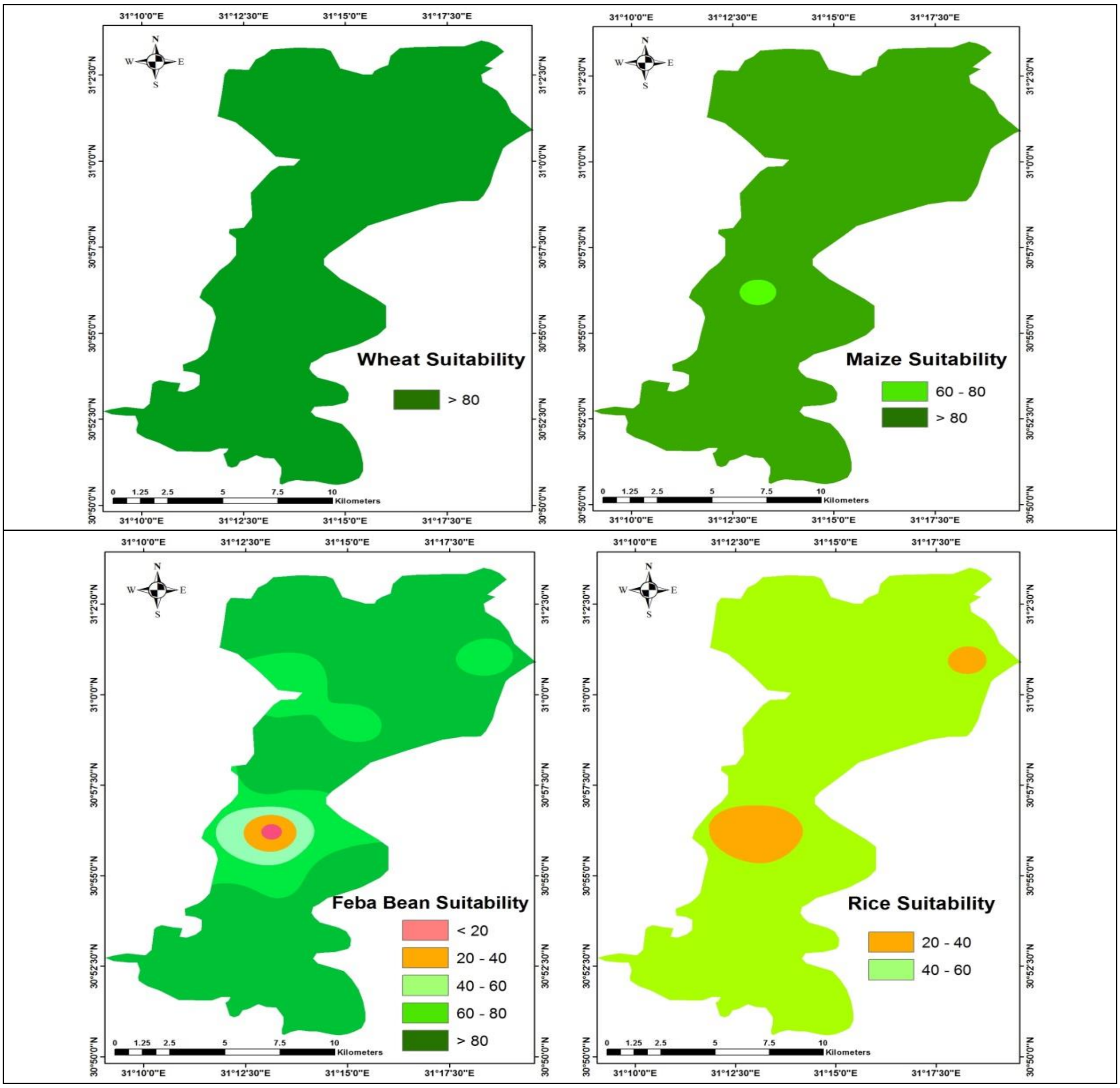

Fig. 11. Land suitability for Wheat, Maize, Feba Bean and Rice in the studied Soils

For growing wheat, 93.71 % of the studied area is very suitable-S1 (about 155.7 km^2 of the total study area). While, was 90.82 % for growing Maize are very suitable-S1 (average of about 150.9 km^2 of the total study area). With an average value of 134.4 km^2 (80.84%) for all soils under study was moderately suitable-S3 for growing Faba Bean. But, land suitability for planting Rice was 42.28% (with an average value of 70.3 km^2 of the total study area). The suitable field crops could be arranged by preference as Wheat < Maize < Faba Bean < and Rice, These results are consistent with **(Zamil et al. 2009), Aldabaa, and Yousif, (2020), Fadl and Sayed, (2020) and Jalhoum et al. (2022).**

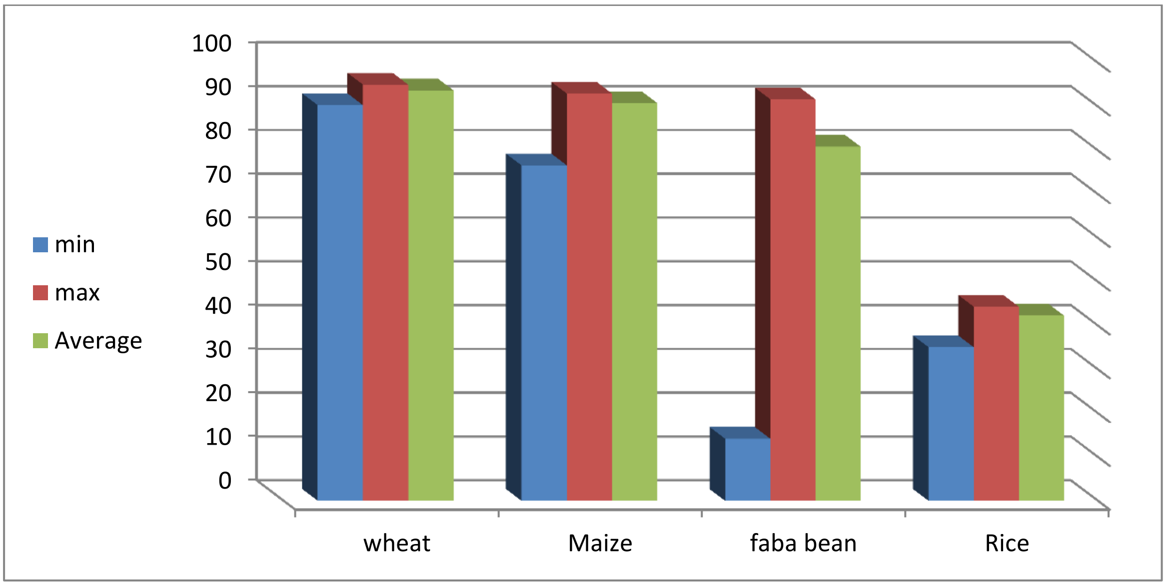

Fig 12. The percentage of land suitability for studied field crops, According to ASLE program.

Conclusions

Regular evaluation of soil fertility using ASLE and GIS can aid in the development of fertility management plans and assist in the improvement of agricultural practices to boost soil agricultural productivity. According to the fertility index developed by ASLE, the soils in the study area ranged from poor to fair. The soil in the study area was suitable for growing most crops. The appropriate field crops could be categorized as follows: wheat > maize > faba beans > rice (about 155.7, 150.9, 134.4 and 70.3 km^2 of the total study area, respectively). Additional research should be done in the study, taking other soil characteristics into account, to build a coherent strategy for managing soil fertility to maximize its potential for productivity and suitability for crops.

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