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Survey, Classification and Geoinformatics Analysis of Soil Parameters, in Shahrazoor District, Kurdistan Region, Iraq

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ABSTRACT:

The study, conducted in Sulaimani City, Kurdistan Region, Iraq, employed Agglomerative Hierarchical Clustering (AHC) and Principal Component Analysis (PCA) to analyze and group 25 soil samples based on their chemical and physical properties. During the study area survey, soil samples were taken systematically in order to assess important parameters governing soil fertility and degradation. PCA grouped the samples into four groups, of which Classes 1 and 2 were moderately diverse, while Classes 3 and 4 exhibited higher variation in soil content. AHC also confirmed the clustering, which had three large groups with variations in within-class variation, centroid distance, and spatial spread, evidencing the soil property heterogeneity of the region. Organic matter content analysis revealed a range of 0.6% to 2.3%, with lower contents indicating degradation due to intensive agriculture and higher contents indicating good soil fertility and structure. Total lime content varied widely and was high for some, like S12 (27.5%) and S17 (25%), with high alkalinity, and this influences the availability of nutrients. Electrical conductivity (EC) readings were consistently low (0.10 to 0.26 dS m-1), verifying the absence of a salinity problem with plant growth. Soil pH varied from 7.15 to 8.27, typically between alkaline to neutral levels, with higher pH being more linked to increased lime content. Correlation analysis revealed weak positive correlations between soil organic matter, lime content, and pH, suggesting complex interactions among these variables. The spatial mapping of soil properties provided valuable information on soil heterogeneity and enabled the possibility of having a better understanding of the variation in soil parameters across the study area. The research demonstrates the great variability of soil properties and highlights the significance of certain soil management practices for improving fertility as well as enhancing sustainable agricultural systems within the region.

Keywords: Sulaimani City; Soil Survey; Soil pH; Organic Matter; Total Lime, Soil EC

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1 INTRODUCTION

Soil and its diverse characteristics are the foundation upon which the productivity of a piece of land can be evaluated, the potential sustainability of an ecosystem determined, and stability in an ecosystem ensured [1, 2]. Soil quality is defined by several interrelated parameters that are physical, chemical, and biological in nature, and all of these have a monumental influence on its fertility, water-holding capacity, and overall resistance to deterioration [3]. Soil's physical characteristics, such as texture, porosity, structure, and compaction, directly affect water infiltration, aeration, and root penetration, all of which are critical for plant growth and agricultural production. Chemically, nutrient availability, organic matter, pH level, and cation-exchange capacity define the soil's ability to support plant life as well as the regulation of interaction among minerals, moisture, and microorganisms [4]. In addition, biological factors, including microbial diversity, rates of organic matter decomposition, and populations of desirable organisms, are behind nutrient cycling and disease control and hence influence soil health and sustainability. On this account, the discovery and preservation of soil attributes are thus essential to effective land-use planning, sustainable farming, and environmentally friendly resource management [5]. But soil systems are extremely complicated because they are interdependent and subject to a variety of factors such as climate, topography, vegetation cover, and human activity [6]. Among these methods is the use of spatial information infrastructure due to its effective and key role in introducing geographic information systems (GIS) technologies into global environmental monitoring Security (GEMS) initiative [7]. In order to create high-resolution maps of soil properties and to show the relationships between these properties, a large number of advanced technologies are employed to obtain, extract and process a large amount of spatial information, this is done through the use of SDI [8]. Spatial data analysis (SDI) enhances the effectiveness to imagine soil pattern distributions, tracking environmental changes through the time, and interpreting discrepancies between different geographic regions through GIS and RS modeling [9]. By using RS and GIS techniques, SDI helps in better understanding soil dynamics, enhances decision making related to land and natural resources, and promotes environmentally friendly planning [10,12]. In order to support a more general and accurate record of soil status over a wide range of landscapes and ecosystems, SDI provides a unique ability to organize statistical variables through the use of sophisticated data analysis [13].

Sharazur area is located in the Sulaymaniyah Governorate, Kurdistan Region of Iraq. It is an agricultural region with an environmental character characterized by a diverse climate and topography, and the use of the land for many agricultural purposes [14]. In a similar study, he stated that soil properties are the result of the interaction between geological features and phenomena, environmental elements, and the effectiveness of human activity [15]. Soil characteristics such as organic matter, electrical conductivity, availability of nutrients, and acidity play a pivotal role in determining whether the soil is suitable for agriculture or not, in addition to the quality of the soil in general [16]. Soils have different characteristics that affect the amount of water they can hold, the availability of nutrients, and the ease with which they are eroded. All of these play a vital role in determining both the productivity and environmental sustainability of an area [17 ,18]. For the purpose of classifying and evaluating soil quality, understanding spatial patterns is extremely important. This can be achieved through organized classification and correlation analysis, which helps in identifying the patterns and relationships between soil characteristics in different areas of the region [19]. The use of GIS techniques in spatial modeling is an effective way to interpret soil properties within a clear and spatially integrated framework. By using GIS, researchers can draw maps, create a number of layers of soil data, form thematic maps, and perform spatial analysis to reveal the forms of soil variations [20]. This information allows those in charge to plan land use based on evidence, enhance farming effectiveness and apply soil conservation techniques that suit particular areas [21]. By using advanced spatial modeling, it is possible to predict the risks of soil degradation, enhance soil fertility, and support the allocation of resources on a broad scale. The use of spatial analysis through GIS in the Sharazoor region also provides important recommendations for the sustainable management of natural land resources, which permanently maintains the balance between the environment and agricultural productivity [22].

This study, which was conducted in some soils of Sharazoor district, is about employing spatial analysis techniques through GIS in a broader understanding of soil properties such as organic matter, total lime, soil electrical conductivity, and soil reaction, which play a role in increasing agricultural production and improving soil quality. Therefore, this study focuses on the following:

1- Conducting a survey of the study area.

2- Using spatial analysis techniques based on GIS to classify the relationship between soil properties.

3- Analyzing the statistical and geo informatically correlation among soil properties and linking them to the soil situation.

4- Conducting a general assessment of the soil fertility condition.

5- A deeper understanding of soil dynamics through the form of the correlation relationship between the different soil properties and their consequences on agricultural production, sustainable land management, and environmental conservation.

2 METHODOLOGY

STUDY AREA

This study was conducted in the Sharazoor district, in Iraq's Kurdistan Region, between 35.40°N to 35.70°N latitude and 45.60°E to 46.00°E longitude with an area of 147.043 km2 (Figure 1). The study area climate is located in a continental semiarid by PE (Potential Evapotranspiration), which described by [23] that greatly influenced by soil moisture regimes and fertility. The diversified topography of Sharazoor, with plains, undulating hills, and Zagros foothills, is responsible for soil property variations in space. The usage of the area is represented by agriculture, pastures, and scattered habitation, which brings about differential soil organic matter content, salinity, and nutritional status. Geologically, the area is mainly covered by sedimentary rocks of limestone, marl, and sandstone that influence the soil texture and makeup. The soil types in the district vary from clayey and silty-loam in agricultural land to rocky and sandy substrates in uncultivated land, creating a soil pattern that is intricate and calls for systematic classification. The identification of these spatial variations by GIS-based analysis is relevant to identifying relationships between soil parameters, improving land-use planning, agricultural production, and the management of the environment in the region.

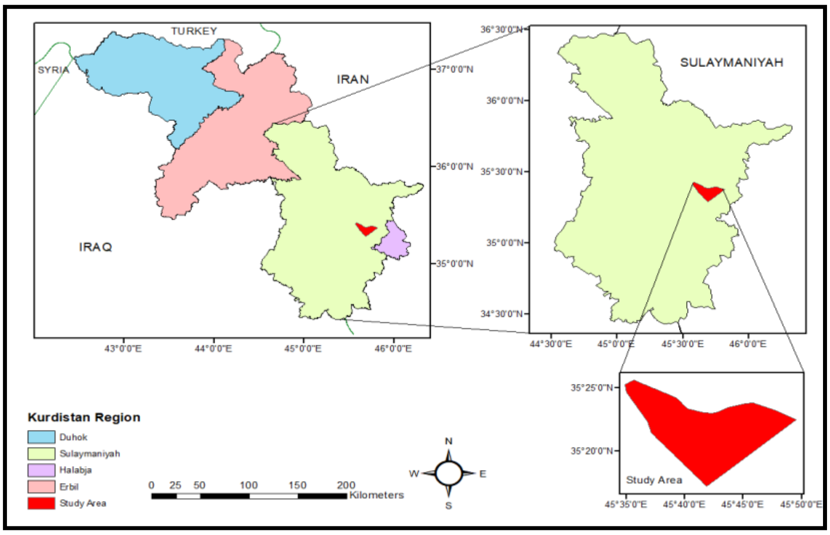

FIGURE 1. The Study area

SOIL SAMPLING AND GPS MAPPING

In this study 25 soil samples were collected systematically from different locations based in Sulaymaniyah City, Sharazoor District in order to achieve representative spatial coverage of the diverse land-use categories including agricultural fields, urban soils, forests, and rangelands. The precise coordinates of each sampling location were recorded with a GPS to facilitate spatial mapping and geostatistical analysis. The sampling sites were selected from land cover, topography, and soil management practice to reflect heterogeneity of organic matter, total lime, electrical conductivity and soil pH with the relation among them. The research approach was in accordance with the objective of the study to categorize relationships among soil parameters using RS and GIS analysis.

SAMPLE COLLECTION AND PREPARATION

DATA ANALYSIS AND SPATIAL MAPPING

The top 0–30 cm depth was sampled from the ground with a stainless-steel auger to preserve surface soil variation. Three subsamples within a 5-meter radius were taken at each location, then combined to form a composite sample for better representativeness. The samples were dried at room temperature, sieved through a 2 mm mesh to remove debris, and stored in airtight plastic bags for laboratory analysis. Laboratory Analyses "The analyzed soil samples underwent a series of chemical analyses including analysis of organic matter determined by wet oxidation method using chromic acid, the organic carbon converted to organic matter by the equation; Organic matter= organic carbon X 1.72 [24 ,25] and total lime content by [26] which described [27]. The soil pH and electrical conductivity (EC) were determined in a 1:2 soil-to-water suspension with the help of digital pH meter using pH meter device, model-pH 211-Microprocessor pH meter-HANNA Com.-Italy and EC meter using EC meter- Lovibond – con 200 – Germany, the EC was expressed in dS m-1". Descriptive statistics and correlation analysis were applied to the data received in order to examine relationships among SOM and physicochemical parameters of soil. Geostatistical tools of GIS software were employed to characterize the spatial organization of study area soil parameters [28]. The causes of spatial variance were also identified by applying PCA. Mapping and distribution of soil properties data were done for all data (Table 1), including sample coordinates, organic matter, total lime, pH, electrical conductivity, and elevations according to mean sea level (MSL), which were entered into Excel tables and then imported into the ArcMap application used in ArcGIS 10.8.1.

Table 1. Spatial distribution and selected chemical properties of surface soil samples

No.	Longitude (E)m	Latitude (N)m	O.M. %	T.L. %	E.C. (dS m^{-1}) at 25 ℃	pH (extract)1:2
S1	553768.58	3919568.65	1.5	14.6	0.15	8.09
S2	555561.42	3917750.82	0.6	9	0.13	7.15
S3	558256.09	3917819.94	1	24.5	0.19	7.26
S4	556950.52	3915168.23	1.4	12	0.2	7.28
S5	560699.43	3915946.92	0.7	5	0.18	7.87
S6	559520.59	3913986.89	0.9	6	0.26	7.45
S7	558621.95	3911938.05	1.3	17	0.19	7.75
S8	563458.88	3915279.63	1.1	5.5	0.18	7.57
S9	562501.46	3912940.91	1.4	14.6	0.17	7.51
S10	561508.77	3910601.12	1.3	13.4	0.14	7.7

O.M. (Organic matter); T.L. (Total Lime); E.C. (Electrical Conductivity); pH (Soil Reaction)

3 RESULTS AND DISCUSSION

3.1 SURVEY OF THE STUDY AREA

The study analyzed 25 surface soil samples that had been collected using a systematic grid sampling method with a spatial interval of 3 km between samples (Figure 2). The terrain of the study area was predominantly flat to slightly undulating, and exhibited a slope gradient that ranged from 1% to 5%. The land was primarily utilized for wheat cultivation and was covered with gravel and stones, which indicated minimal surface lithic material. From a pedological perspective, the soils in the region were classified within the Mollisols order, characterized by well-developed soil horizons, which was consistent with the findings by [29]. The results highlight a significant influence of the melanization process, as evidenced by the dark-colored surface horizon, indicative of Pachic conditions associated with high organic matter accumulation. This organic-rich Mollic epipedon contributes to enhanced soil structure, water retention, and overall soil fertility. Such soils are typically found in semi-arid to humid climatic zones, aligning with the classification criteria established by the Soil Survey [30, 31]. The dominant soil color varies from dark brown (10YR 3/3) to dark yellowish brown (10YR 3/4), further supporting the presence of organic matter-enriched horizons. Texturally, the soils range from clay loam to loam, with a moderate medium angular blocky structure, which enhances soil stability and root penetration. the plasticity is slightly hard (D), sticky slight plastic (W) and friable, the inter-pores are moderate fine vesicular pores with few fine roots. It was noted that there are little knots of calcium carbonate in some locations.

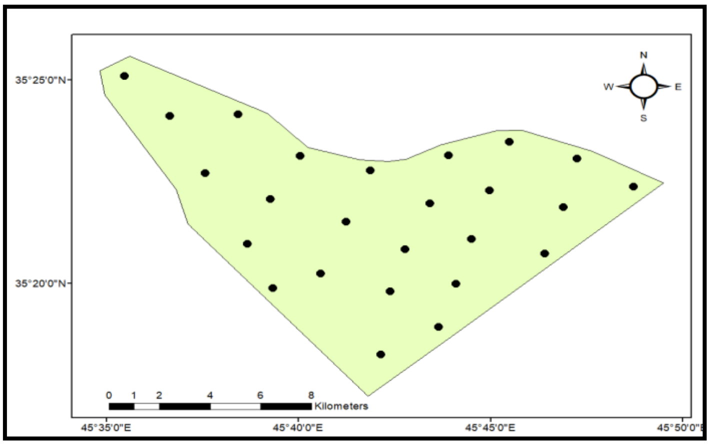

FIGURE 2. Soil sample's locations

3.2 THE CLASSIFICATION OF THE 25 SOIL SAMPLES USING PRINCIPAL COMPONENT ANALYSIS. PCA

In figure 3 depicts the PCA classification of the 25 soil samples into four groups with varied amounts of samples. Class 1, which consists of six samples (S6, S5, S8, S4, S16, and S23), has a distinct clustering pattern, showing that these samples share similar soil qualities that distinguish them from the other classes. The grouping of these six samples points to similarities in their chemical compositions, which are hopefully represented in the principal components considered. Class 2, comprising six samples (S7, S15, S19, S20, S21, and S25), forms another cluster that is separate, albeit with subtle differences from Class 1. This indicates that while there are similarities in this group, the soil properties for these samples also exhibit notable differences compared to Class 1, indicating distinct compositional characteristics in PCA space. Class 3, which consists of seven soils (S2, S10, S11, S3, S14, S9, and S22), is slightly larger and more scattered in the PCA plot, suggesting that these soils have a wider range of composition of properties than Classes 1 and 2. The considerably larger size of Class 3 may reflect greater variety in soil qualities, maybe due to changes in organic matter, mineralogy, or textural. In the end, Class 4, consisting of six samples (S1, S12, S13, S17, S18, and S24), shows a distinctive clustering tendency that distinguishes it from the other groups. This particular group most likely contains soil samples with unique traits not shared by the other groups, reflecting special climatic or geographical variables that may characterize their composition. The spatial distribution of soil samples over these four classes in the PCA plot demonstrates extensive variance in the chemical and physical attributes of the soils in the study region. Each class represents a distinctive set of physical and chemical qualities. An overview of the variability of the soil samples and demonstrate the utility of PCA in extracting hidden patterns and relationships in multivariate data [32, 33].

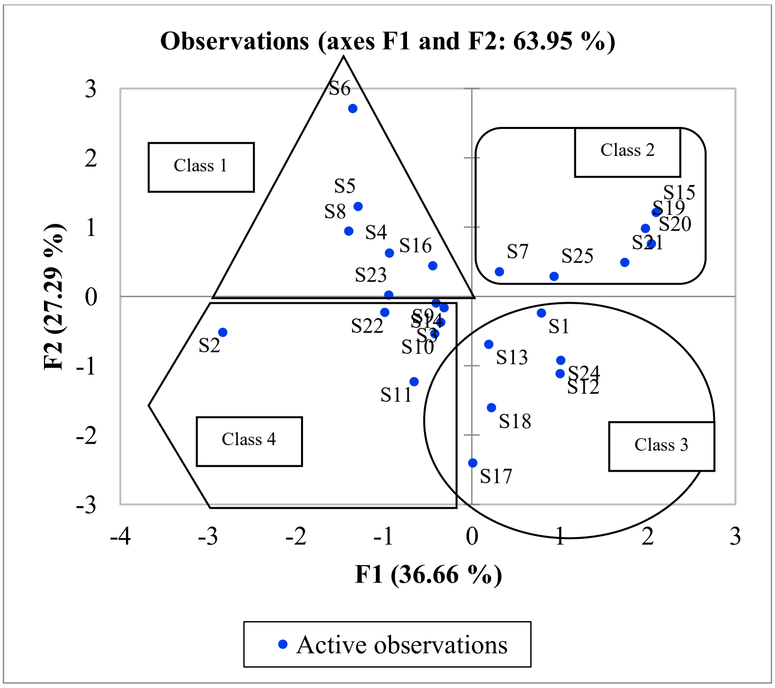

FIGURE 3. The classification of 25 soil samples based on principal component analysis PCA

3.3 CLUSTERING OF THE 25 SOIL SAMPLES USING AGGLOMERATIVE HIERARCHICAL CLUSTERING (AHC)

This agglomerative hierarchical clustering (AHC) for the 25 soil samples in Table 2 as well as Figure 4 has various classes depending on within-class variance, least, mean, as well as max to center. Based on the analysis, the samples were split into three broad classes. Class 1 had a within-class variance of 4.450, indicating higher variety in the samples of this class than the others. This class had the smallest minimum distance to the centroid (0.157), indicating that the samples of this class were nearer to the centroid. The maximum distance (4.484) indicates some outliers that are away from the centroid, indicating the higher variability. The average distance to the centroid for Class 1 was 1.647, indicating that while some samples are nearer to the centroid, the rest are more scattered. Class 2 also recorded a comparatively lower within-class variance of 3.370, indicating less but very noticeable diversity. Class 2 recorded a minimum centroid distance of 0.394, a bit greater than that of Class 1, but its mean distance to the centroid of 1.350 clearly indicates that samples here were quite closer to their centroid. The high of 2.660, less than in Class 1, once again indicates the lesser spread of this class. In-class variance was 4.184 in Class 3 and was equal to the measure of variation for Class 1. The shortest distance to the centroid was 0.393, near Class 2, but the mean distance to the centroid was 1.631, higher, which indicated greater dispersion within the samples. The maximum distance to the centroid (4.128) was also smaller than Class 1, showing a more balanced spread among samples in this class. Each class's individual soil samples were identified, where Class 1 consisted of samples S1, S2, S3, S4, S5, and S12; Class 2 consisted of S7, S6, S13, S9, S8, S15, S10, and S17; and Class 3 consisted of S11, S18, S14, S19, S16, S20, S22, S21, S23, S24, and S25. This clustering illustrates the heterogeneity of soil composition and properties in the sample set and reveals the compositional and structural relationships between the groups and the heterogeneity and distribution pattern of the groups in the sampled area [34].

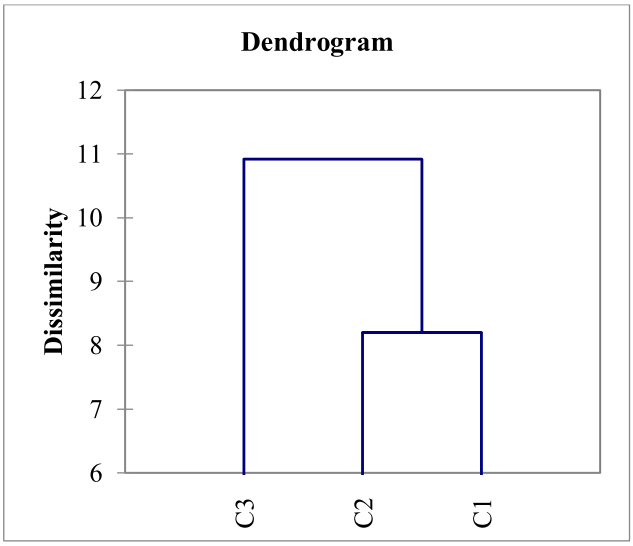

FIGURE 4. **Classification of 25 soil sampmles based on Agglomerative hierarchical clustering (AHC)**

Table 2. **Classification of of 25 soil sampmles based on Agglomerative hierarchical clustering (AHC)**

Classes	1	2	3
Within-class variance	4.450	3.370	4.184
Minimum distance to centroid	0.157	0.394	0.393
Average distance to centroid	1.647	1.350	1.631
Maximum distance to centroid	4.484	2.660	4.128
	S1	S2	S3
	S4	S5	S12
	S7	S6	S13
	S9	S8	S15
	S10		S17
	S11		S18
	S14		S19
	S16		S20
	S22		S21
	S23		
	S24		
	S25		

Table 3. **Showing the normal range of organic matter, total lime, electrical conductivity (EC), and pH in soil**

Soil Parameter	Normal Range	Unit
Organic Matter	1 – 6	%
Total Lime	0 – 10	%
EC (Electrical Conductivity)	0 – 2	dSm^{-1}
pH	5.5 - 8.5	-

3.4 ORGANIC MATTER

Results indicate in the tables 1 and 3 that soil organic matter (O.M.) content across the samples is extremely fluctuating, with values ranging between 0.6% and 2.3%. By comparing these results with the 1%–6% value range as depicted in Table 2, a series of samples (S2, S5, S6, S8, S22, and S23) are below the lowest value, reflecting low content of organic matter, whose causes include intensive farming practices, erosion, or lack of organic inputs. On the other hand, S24 (2.1%) and S25 (2.3%) contain the maximum O.M., which could be due to more organic inputs, minimum tillage, or enhanced moisture retention capacity. Except a few samples (S1, S3, S4, S7, S9-S21), all others are in or near the range of acceptability and indicate moderately maintained soil fertility. The reduction in O.M. in certain samples suggests potential degradation due to overcropping, organic matter loss, and soil erosion, while higher O.M. values indicate improved structure and fertility of the soil. Good soil management practices such as composting, cover cropping, and reduced tillage can help maintain or enhance O.M. levels, hence ensuring overall soil well-being and farm sustainability [35, 36]. In addition to following proper planting rotation and not straining the soil, it increases organic matter in the soil and thereby increases soil fertility.

3.5 TOTAL LIME (CACO3)

The Total Lime (T.L. %) results in the tables 1 and 3 showed that samples widely varied, and most of them were beyond the normal range of 0-10% as indicated in Table 2. It was only S2 (9%) that fell within the normal limit, but the remaining samples contained excessive lime content. The highest T.L. % was in S12 (27.5%), followed by S17 (25%) and S3 (24.5%), indicating a highly calcareous soil profile. The soils of the study area were calcareous because the parent material of the region was formed by calcareous bedrocks. The other notably high values included S18 (23.2%), S21 (23.3%), and S15 (22%), suggesting very high lime content that can affect soil chemistry. Extremely high lime content in these samples reflects high carbonate accumulation, which can be due to low rainfall, inadequate drainage, or parent material rich in calcium carbonate. This can lead to alkaline soil pH, rendering the vital micronutrients such as iron, phosphorus, and zinc less available, thus suppressing plant growth. On the other hand, samples S5 (5%), S6 (6%), and S8 (5.5%) recorded relatively lower T.L. values, closer to the normal range. The decrease in the total lime values indicates the prevalence of less calcareous conditions, which helps in the availability of nutrients and thus increases soil fertility. It is also noted from the results that there is a difference in the total lime values, which may be attributed to the geological composition, parent material of the soil in the study area, soil texture, and prevailing climatic conditions in the region. Total lime ratios increase due to the increase in temperatures, and thus increase evaporation and decrease the leaching of lime to the lower layers of the soil. This leads to an increase in the alkalinity of the soil, which affects the decrease in agricultural productivity. Understanding the differences in the total lime ratio between one site and another in the same region is of great importance in order to carry out activities such as proper soil management, treating acidity and alkalinity of the soil, and improving some soil characteristics by adding organic materials or planting plants resistant to high lime levels. In general, the results show the importance of field activities for soil management to achieve mitigation of the negative effects of high lime content and increase soil fertility to achieve satisfactory and permanent results, also this is what both [37,38] pointed out.

3.6 ELECTRICAL CONDUCTIVITY EC

As shown in Tables 1 and 3, the EC values range between 0.1 and 0.26 dS m^{-1} at 25°C, which is within the level of non-saline soils according to the American Soil Salinity Laboratory classification [39]. These low EC values indicate the suitability of the soil for growing all agricultural crops in terms of the sensitivity of plants to soil salinity, which makes it suitable and safe for plants without any salt stress. The decrease in EC values may be attributed to soil texture which allows the leaching of dissolved salts to the lower layers, content of organic matter, concentration of dissolved salts, in addition to the parent material that makes up the soil. A value of (0.10 dS m-1 in S11 and S17) indicates a slight decrease in dissolved ions, and this may be due to leaching, low urbanization, or the nature of the parent material. On the contrary, the peak EC value (0.26 dS m-1 in S6) indicates slightly higher soluble salts level, probably resulting from local accumulation due to irrigation practice, fertilizer application, or native mineral content. Regardless of minor differences, the mean EC values fall within reasonable standards, and the soil salinity does not represent a limiting parameter for plant production and agricultural practice [40,41].

3.7 SOIL ACIDITY (PH)

The pH ranges of the soil samples vary between 7.15 and 8.27, within the 5.5 to 8.5 range which is typical of soil, as illustrated in Table 2. Variation in pH ranges among different samples reflects variation in soil structure, organic matter, and environmental factors such as precipitation, land use, and agriculture practices. The highest pH value recorded (8.27 in S15, S20) indicates weakly alkaline soil conditions, possibly caused by the presence of calcium carbonate, low organic acid concentrations, or weaker leaching of basic cations. The lowest pH (7.15 in S2) is also in the weakly alkaline to neutral range, indicating few acidifying processes such as over-fertilization with nitrogen or humus decomposition [42]. The general pH stability in these samples indicates that the soil condition favors microbial activity and nutrient availability, although very high readings nearing the maximum limit S19, S21) may constrain the solubility of vital micronutrients such as phosphorus and iron, which might impede plant growth based of results in the tables 1 and 3.

3.8 RELATIONSHIP BETWEEN SOM WITH (CACO3), EC AND (PH)

The association between soil organic matter (SOM), total lime ($CaCO_3$), electrical conductivity (EC), and pH is complex and is controlled by many agricultural and environmental factors. SOM concentration is highly diverse among samples, ranging from 0.6% to 2.3%, illustrating varying soil fertility and organic matter contributions. Higher SOM, found for S24 and S25, generally improves soil structure, water retention, and microbial condition, whereas reduced values indicate deterioration from intensive agriculture or erosion. The total lime ($CaCO_3$) content also varies widely, with most samples greater than the normal 0-10% range, indicating highly calcareous conditions that affect soil chemistry and nutrient availability. High lime, exhibited by samples S12 (27.5%) and S17 (25%), causes alkalinity, which can suppress the solubility of important micronutrients such as iron, phosphorus, and zinc. High $CaCO_3$ can also influence SOM decomposition rates by immobilizing organic matter and decreasing microbial degradation, leading to carbon sequestration for extended durations but also to nutrient imbalance. Electrical conductivity (EC) readings are within acceptable limits (0-2 dS m-1), showing that salinity is not an issue, though minor differences show differences in dissolved ions, organic matter content, and texture of the soil. The highest EC reading (0.26 dS m^{-1} in S6) shows localized salt accumulation, possibly due to irrigation or application of fertilizer, while the lowest readings show efficient leaching and minimal ion retention. As SOM is accountable for cation exchange capacity (CEC), differences in organic content may have an effect on EC by changing the mobilization and retention of salts along the soil profile. Soil pH, ranging from 7.15 to 8.27, also corresponds to SOM and CaCO3 concentration, since calcareous soils will exhibit alkalinity due to carbonate buffering and lowered pH values may be due to production of organic acids during decomposition. Higher SOM content generally favors microbial activity and organic acid generation, which lowers pH slightly, whereas excess lime stabilizes alkalinity and may limit nutrient availability. The stable pH of the samples suggests that even though there is high lime content, there is a moderation of extreme alkalinity, presumably due to interactions with organic matter and environmental conditions [44]. Overall, SOM management with sustainable practices such as organic amendments, minimum tillage, and cover crops is essential for balancing soil pH, optimizing nutrient supply, and avoidance of adverse effects of excess lime and salinity, hence long-term soil productivity and health improvement [45].

3.9 CORRELATION BETWEEN SOIL ORGANIC MATTER, TOTAL LIME %, ELECTRICAL CONDUCTIVITY EC AND SOIL PH

SOM against major soil parameters—like pH, total lime percentage (T.L. %), and electrical conductivity (EC)—correlation analysis indicates both positive and negative correlations, underlining the complexity of interactions in soil composition. SOM is weakly positively correlated with total lime content (0.168) and pH (0.152), indicating that higher organic matter could have a minimal contribution to higher lime content and slight rise in soil pH This indicates that soils with higher organic matter contents might exhibit slight alkalization, potentially via microbial decomposition processes. SOM is weakly correlated with EC is low (0.041), which indicates that SOM has negligible or no direct influence on soil salinity, possibly because organic matter in itself does not significantly affect amounts of soluble salts. Total lime content is weakly negatively related to EC (-0.094), which means increasing lime content lowers soil salinity slightly, possibly owing to precipitation of soluble salts or dilution in high-lime soils. The strongest correlation within this dataset is between total lime and pH (0.328), which supports those higher levels of lime content are strongly related to more alkaline soils, as lime acts as a natural buffer that raises pH and EC is also moderately positively correlated with pH (0.219), which indicates that elevated salinity would generally be accompanied by elevated alkalinity, perhaps due to dissolved alkaline salts such as bicarbonates and carbonates being present. Statistically significant correlation at a 0.05 level is denoted by the bolded values in the dataset, confirming the accuracy of such correlations. Despite the observed trends, the relatively poor correlation coefficients suggest that other factors in the environment, chemicals, and biology determine these soil parameters beyond SOM itself, lime amendment, and salinity [46,47]. Understanding how these interact can be of paramount importance in soil management such that optimization of organic matter, lime amendments, and pH balance optimizes soil condition and agriculture this explained based in the table 4.

Table 4. Correlation Between Soil Organic Matter, Total Lime %, Electrical conductivity EC and Soil pH

Variables	O.M. %	T.L. %	E.C. (dS m-1)	pH
O.M. %	**1**			
T.L. %	0.168	**1**		
E.C. (dS m-1)	0.041	-0.094	**1**	
pH	0.152	0.328	0.219	**1**

Values in bold are different from 0 with a significance level alpha=0.05

3.10 MAPPING SPATIAL DISTRIBUTION OF SOIL PROPERTIES INSIGHTS INTO SOIL HETEROGENEITY

The organic matter in the study area ranges from 0.6 to 2.3%, which is within the low organic matter methods due to the continuous cultivation of the lands. It is noted from (Figure 5) that the soils have been classified into 5 categories based on the data taken from the study field. There is a lack of homogeneity in the distribution of organic matter in the study area, which may be due to a difference in soil fertility due to the lack of homogeneity in adding fertilizers to this soil because the ownership of these lands goes back to many people and they are cultivated with multiple crops. The total lime of the study area is classified to 5 categories (Figure 5), the soils of the study area are rich in total lime because the bedrocks are limestone rocks, where the percentages range between 5% to 2.7%, and they are within the medium-calcareous to high-calcareous soils [48]. There is an uncoordinated form in the distribution of total lime due to the continuous exploitation of the land for agricultural purposes. As for the salinity of the soil in the study area, is located between 0.1 to 0.26 dS m-1, the soils are within the less than 2 dS m-1, so it is located within the non-saline soils(Tomar et al.)2014 . The soil salinity of the study area was classified into 5 categories based on the data taken in the study area, (Figure 5). The soil pH is between 7.15 and 8.27, it is neutral to slightly basic, and this is due to the effect of the lime present in abundance in the study area because it is a calcareous soil. The soil pH was classified into 5 categories based on the data present in the study area, (Figure 4).

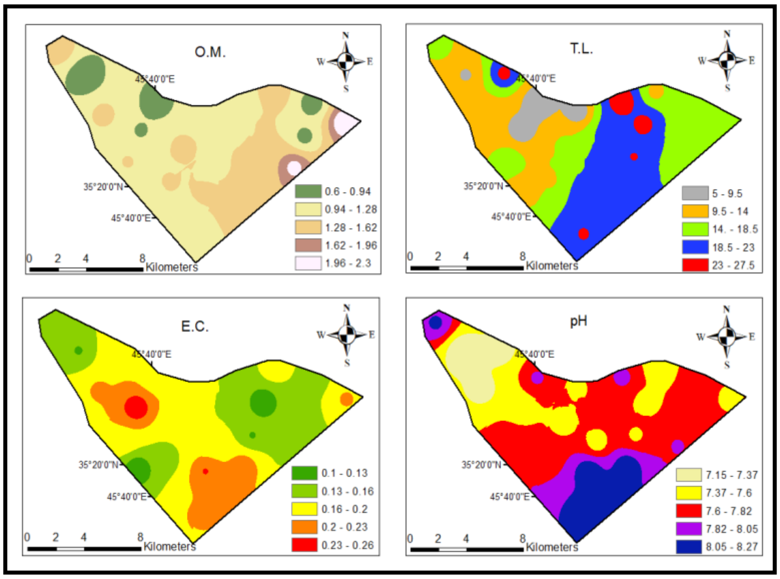

FIGURE 5. Spatial distribution of soil (O.M., T.L., E.C. and pH)

CONCLUSION

The agglomerative hierarchical clustering (AHC) and principal component analysis (PCA) of the 25 soil samples indicate considerable variability in the properties of the soils and depict the complex nature of the soil composition in the study area. PCA identified four distinct classes of soil with unique patterns of chemical, physical, or mineralogical characteristics, which were also supported by the AHC grouping the samples into three general classes based on within-class variance and distances to centroids. The differences between the values of soil properties indicate different influences such as land use for types of agricultural crops, according to the seasons and agricultural operations followed, the geological structure of the region, the parent material of the soil, the environmental condition and the prevailing climatic conditions. The organic matter, total lime, Ec and pH were studied, and the results indicated the variation in the content of organic matter, as these percentages differ according to soil management and agricultural land use. As for total lime, the high percentages of total inertness in some samples affected the degree of soil pH and nutritional elements, which affect the productivity of soils and agricultural crops.

By studying some soil properties, this study provides important and valuable information confirming the importance of soil management and utilization. The results reveal the relationship between organic matter, total lime, EC, and pH. These relationships are complex and illustrate the fertile state of soil. The presence of organic matter in the soil improves permeability and soil structure, reduces the negative impact of soil texture, increases soil fertility, and provides nutrients to plants and microorganisms. It also increases the level of water conservation in the soil. However, excessively high levels of total lime in the soil lead to soil alkalinity and reduces the overall availability of nutrients. The level of relationship among organic matter, total lime, and pH is moderate, but through proper agricultural practices, organic matter balance in the soil, and avoiding soil stress, a balance between the different soil properties can be achieved. The results indicate the need for correct practices in land management and exploitation, reducing the negative effects of lime, and adopting soil cultivation with agricultural rotations that maintain soil fertility and improve its physical and chemical properties. Through PCA and AHC analyses, the research typically emphasized the variability and intricacy of soil features. The findings highlighted the impact of geological, climatic, and agricultural elements on soil fertility and makeup. Excess lime lowered nutrient availability while organic material enhanced soil quality. To keep the soil in good condition and productive, good land management and agricultural methods are necessary.

To improve the soil properties and preserve its fertility for the purpose of increasing agricultural production, we recommend the following:

1- Implement sustainable land management techniques that control organic matter, reduce soil stress, and increase soil productivity.

2- Practice crop rotation and appropriate farming techniques to counteract the harmful effects of too much lime and maintain soil balance.

3- Monitoring important soil indicators like organic matter, total lime, EC, and pH on a regular basis to help with efficient soil use and management.

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REFERENCES

[1] U. C. Sharma, M. Datta, and V. Sharma, "Global Status and Extent of Acid Soils," In Soil Acidity: Management Options for Higher Crop Productivity, Cham: Springer Nature Switzerland. pp. 49-119, 2025

[2] R. Lal, "Managing world soils for food security and environmental quality," Advances in Agronomy, vol. 74, pp. 155-192. 2001.

[3] Z. Yu, X. Deng, P. Fu, S. Grebby, and E. Mangi, " Assessment Of Land Degradation Risks In The Loess Plateau. Land Degradation & Development, vol. 35, pp. 2409-2424, 2024.

[4] X. Jing, S. Tao, H. Hu, M. Sun, and M. Wang, "Spatio-Temporal Evaluation Of Ecological Security Of Cultivated Land In China Based On Dpsir-Entropy Weight Topsis Model And Analysis Of Obstacle Factors," Ecological Indicators, vol. 166, pp. 112579, 2024.

[5] J. Zhang, H. Yong, and N. Lv, "Balancing Productivity And Sustainability: Insights Into Cultivated Land Use Efficiency In Arid Region Of Northwest China," Journal Of The Knowledge Economy, vol.15, pp.13828-13856, 2024a

[6] P. Sharma, P. Sharma, and N. Thakur, "Sustainable Farming Practices And Soil Health: A Pathway To Achieving Sdgs And Future Prospects," Discover Sustainability, vol.5, pp.250, 2024.

[7] M. Ahmad, A. Ali, and H. Hussain, H., "Spatial Data Infrastructure for Effective Information Management: A Case Study of Pakistan," In Essential Information Systems Service Management, IGI Global, pp. 251-278. IGI, 2025.

[8] M. Ahmad, A. Ali, T. Tin, and A. Ali, "Harnessing the Power of Geospatial Data: The Convergence of SDI, Big Data, and Cloud Computing," In Emerging Trends in Cloud Computing Analytics, Scalability, and Service Models, IGI Global Scientific Publishing, pp. 312-330, 2024.

[9] A. Ali, H. Z. Hadeed, S. Safavi, and M. Ahmad, "Leveraging GIS for Environmental Planning and Management," In Global Challenges for the Environment and Climate Change, IGI Global, pp. 308-331, 2024

[10] N. E. Fard, I. Raeisi, Z. Yousefipour, and R. Mosavin, “Review of metal sulfide-based MXene nanocomposites for environmental applications, gas sensing, energy storage, and photothermal therapy,” ACS Applied Nano Materials, vol., 7, no. 6, pp.5698-5728. 2024.

[11] B. Pranoto, E. Hartulistiyoso, M. N. Aidi, D. Sutrisno, I. Nahib, N. Purwono, N. Hudayat, A. F. Rais, and Y. I. Rahmila, “Assessing The Sustainability Of Small Hydropower Sites In The Citarum Watershed, Indonesia Employing Ca-Markov And Swat Models,” Water Supply, vol. 24, pp. 3253-3268, 2024.

[12] J. A. Gómez-Limón, J. Martín-García, and R. Granado-Díaz, “Building A Typology Of Farms Based On Their Performance: A Tool To Support Agricultural Policy-Making,” Journal Of Environmental Planning And Management, vol. 69, no. 2, pp: 1-27, 2024.

[13] A. Khalil, O. A. I. Abdullah, and A. T. Kareem, “Gis Application For Creating Potential Flood Map Using Ahp: A Case Study In Chaq-Chaq Valley, Sulaymaniyah City, Kurdistan Region, Iraq,” The Iraqi Geological Journal, vol. 57, no. 2C, pp.254-263, 2024.

[14] W. Li, S. Zhang, F. Gao, Z. Chen, J. Jiang, and G. X. Sun, “Spatial Distribution, Sources Apportionment And Risk Assessment Of Heavy Metals In The Changchun Black Soil Area, China,” Journal Of Hazardous Materials Advances, vol. 13, pp. 100402, 2024.

[15] Z. Liu, X. Ma, D. Zhou, L. Lu, H. Zhang, Y. Bai, and H. Han, “The Geological Origins And Soil Properties Of Loess-Like Silty Clay: A Case Study In The Jinan Area,” Scientific Reports, vol. 14, pp. 12612, 2024.

[16] J. Li, X. Ke, X.Wang, L.Wang, J. Luo, S. Feng, “Analysis Of Soil Organic Carbon Composition Characteristics And Causes In Wuming Region Karst Landforms, Nanning, Guangxi Province, China,” Environmental Earth Sciences, vol. 83, pp. 349, 2024.

[17] J. N. Quinton, and P. Fiener, “Soil Erosion On Arable Land: An Unresolved Global Environmental Threat,” Progress In Physical Geography: Earth And Environment, vol. 48, pp.136-161, 2024.

[18] Z. Li, Y. Fan, R. Zhang, P. Chen, X. Jing, C. Lyu, R. Zhang, Y. Li, and Y. & Liu, “Synergistic Impacts Of Landscape, Soil, And Environmental Factors On The Spatial Distribution Of Soil Aggregates Stability In The Danjiangkou Reservoir Area,” Catena, vol. 237, pp.107840, 2024.

[19] A. Fowler, B. Basso, F. Maureira, N. Millar, R. Ulbrich, and W. F. Brinton, “Spatial Patterns Of Historical Crop Yields Reveal Soil Health Attributes In Us Midwest Fields,” Scientific Reports, vol. 14, pp.465, 2024.

[20] Y. Wang, M. Li, and G. Jin, “Optimizing Spatial Patterns Of Ecosystem Services In The Chang-Ji-Tu Region (China) Through Bayesian Belief Network And Multi-Scenario Land Use Simulation,” Science Of The Total Environment, vol. 917, pp. 170424, 2024

[21] E. Benami, A. Carroll, K. D. Messer, W. Zhang, and M. Cecil, “Seeding Change: Growing Insights From Four Programs to Support Climate-Resilient Soil and Water Conservation in US Agriculture,” Agricultural Economics, vol. 56, pp. 457–473, 2025.

[22] D. Mehta, P. Patel, N. Sharma, and S. Eslamian, “Comparative Analysis Of Drastic And God Model For Groundwater Vulnerability Assessment,” Modeling Earth Systems And Environment, vol. 10, pp. 671-694, 2024.

[23] N. Kharrufa, “Simplified Equation For Evapotranspiration In Arid Regions,” Beiträge Zur Hydrologie, vol.5, pp. 39-47, 1985.

R. Mylavarapu, F. Sikora, and K. Moore, “Walkley-Black Method,” Soil Test Methods from The Southeastern United States, Southern Cooperative Series Bulletin No. 419 ISBN# 1581614195 January, 2014.

[24] A. Walkley, and I. A. Black, “An Examination Of The Degtjareff Method For Determining Soil Organic Matter, And A Proposed Modification Of The Chromic Acid Titration Method,” Soil Science, vol. 37, pp. 29-38, 1934.

[25] C. Piper, “Soil And Plant Analysis,” Univ. Of Adelaide. Interscience Publishers. Inc. New York, 1950.

[26] P. R. Hesse, and P. Hesse, A Textbook Of Soil Chemical Analysis, 1971.

[27] O. A. Wani, V. Sharma, S. S. Kumar, A. R. Malik, A. Pandey, K. Devi, V. Kumar, A. Gairola, D. Yadav, and D. Valente, “Geostatistical Modelling Of Soil Properties Towards Long-Term Ecological Sustainability Of Agroecosystems,” Ecological Indicators, vol. 166, pp. 112540, 2024.

[28] S. S. Shahadha, and O. Wendroth, “Modeling the effect of tillage and irrigation management on water and barley productivity for different soil textures,” Soil and Tillage Research, vol. 250, p.106505, 2025.

[29] A. del Pino, J. Henández, G. Arrarte, “Soil Survey Staff,” Keys to soil taxonomy Hand book. 10th ed. Natural Resources conservation service. Washington D.C, 2006.

[30] N. H. Batjes, " Overview Of Procedures And Standards In Use At Isric Wdc-Soils," Isric, 2016.

[31] J. Katzer, J. Kobaka, K. Seweryn, "A Study Of Lunar Regolith Obtained During The Apollo And Luna Space Programs Based On Principal Component Analysis," Aerospace, vol. 11, pp. 348, 2024.

[32] J. N. Bougiouklis, P. E. Barouchas, P. Petropoulos, D. E. Tsesmelis, and N. Moustakas, "Precision Soil Sampling Strategy For The Delineation Of Management Zones In Olive Cultivation Using Unsupervised Machine Learning Methods," Scientific Reports, vol. 15, pp. 8253, 2025.

[33] M. Fekhar, Y. Daghbouche, N. Bouzidi, and M. El Hattab, "Rapid Assessment Of Smokeless Tobacco Quality Parameters Using Atr-Ft-Mir Spectroscopy: Comparison Of Analytical/Mathematical And Machine Learning Approaches," Microchemical Journal, vol. 201, pp. 110670, 2024.

[34] J. Geng, J. Lv, J. Pei, C. Liao, Q. Tan, T. Wang, H. Fang, L. Wang, "Prediction Of Soil Organic Carbon In Black Soil Based On A Synergistic Scheme From Hyperspectral Data: Combining Fractional-Order Derivatives And Three-Dimensional Spectral Indices," Computers And Electronics In Agriculture, vol. 220, pp. 108905, 2024.

[35] A. Sakhaee, T. Scholten, R. Taghizadeh-Mehrjardi, M. Ließ, and A. Don, "Spatial Prediction Of Organic Matter Quality In German Agricultural Topsoils," Agriculture, vol. 14, pp.1298, 2024.

[36] H. Kadifeci, H.Dikici, and Ö. F Demir, "The Effect Of Active Lime On The Availability Of Metal Micronutrients In Narlı Plain Soils," Turkish Journal Of Agricultural & Natural Sciences, vol. 11, no. 2, pp. 347-356, 2024.

[37] M. Jalali, M. Jalali, and D. Weaver, "Critical soil phosphorus levels: a review," Nutrient Cycling in Agroecosystems, vol. 131, no. 1, pp.1-46, 2025.

[38] R. Adhikary, and A. Pal, "Unveiling Hydromorphic Soil Formation Dynamics in Andem, Gabon: A Soil Survey Approach," Indian Journal of Agricultural Research, vol. 59, no.3, pp. 489-494, 2025.

[39] M. B. N. Namdeo, "Geospatial Mapping Of Soil Properties In Maheshgad Watershed," Mahatma Phule Krishi Vidyapeeth, 2024.

[40] Z. Zhang, J. Ren, Y. Wang, Y. and H. Zhou, "Study On The Ec Prediction Of Cracked Soda Saline-Alkali Soil Based On Texture Analysis Of High-Resolution Images From Ground-Based Observation And Machine Learning Methods," Soil And Tillage Research, vol. 244, pp.106234, 2024b.

[41] B. Bastakoti, "Assessing Soil Health And Environmental Sustainability Focusing On Land-Use Change And The Soil Map Units In Vermilion-Teche Basin, Louisiana," University Of Louisiana At Lafayette, 2024.

[42] A. Tlili, I. Dridi, F. Mlaiki, C. Schillaci, and S. Saia, S., "Description of representative "in-situ" soil profiles in northwestern Tunisia," Discover Soil, vol.2, no.1, pp.1-21, 2025.

[43] M. C. Rowley, J. Pena, M. A. Marcus, R. Porras, E. Pegoraro, C. Zosso, N. O. et al., "Calcium is associated with specific soil organic carbon decomposition products," Soil, vol. 11, no.1, pp.381-388, 2025.

[44] Y. Kanzaki, N. J. Planavsky, S. Zhang, J. Jordan, J. Suhrhoff, and C. T. Reinhard, "Soil cation storage is a key control on the carbon removal dynamics of enhanced weathering," *CDRXIV*, 2025.

[45] K. Quispe, S. Mejía, C. Carbajal, L. Alejandro, P. Verástegui, and R. Solórzano, "Spatial Variability Of Soil Acidity And Lime Requirements For Potato Cultivation In The Huánuco Highlands," Agriculture, vol. 14, pp. 2286, 2024.

[46] H. M. Salem, L. R. Schott, J. Piaskowski, A. Chapagain, J. L. Yost, E. Brooks, et al., "Evaluating Intra-Field Spatial Variability For Nutrient Management Zone Delineation Through Geospatial Techniques And Multivariate Analysis," Sustainability, vol. 16, pp. 645, 2024.

[47] D. E. Clarke, E. A. Stockdale, J. A., Hannam, B. P. Marchant, and S. H. Hallett, "Spatial-Temporal Variability In Nitrogen Use Efficiency: Insights From A Long-Term Experiment And Crop Simulation Modeling To Support Site Specific Nitrogen Management," European Journal Of Agronomy, vol. 158, pp. 127224, 2024.