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Research Article

Analysis of the Physicochemical Characteristics of the Soil in the Malakand District, Khyber Pakhtunkhwa, Pakistan

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Abstract: The aim of the present study was to assess the physicochemical characteristics of the soil of 20 selected sites in the district of Malakand, Pakistan. The study showed that the soil texture of District Malakand was predominantly sandy loam (50%) to silty loam (25%) and loamy sand (25%). The pH value of the soil ranged from 6.7 to 8.2. The electrical conductivity of soil samples ranged from 0.201 dS/m to 0.683 dS/m. The organic matter content has a range of 0.70% to 2.27%. In the macronutrients, the Nitrogen content was found in the range of 300 ppm to 1500 ppm, Potassium from 28 ppm to 190 ppm, Phosphorus from 6.2 ppm to 14.4 ppm, Calcium element from 2.18 ppm to 7.75 ppm, Magnesium from 3.24 ppm to 6.09 ppm and Sodium from 12.21 ppm to 18.29 ppm. Similarly, microelements such as Zinc ranged from 1.37 ppm to 2.22 ppm and Manganese from 0.53 ppm to 1.63 ppm. The results showed a significant Positive Pearson's correlation coefficient, with the highest correlation were observed between Pb-Na (r = 0.803), followed by P-N (r = 0.759) and N-EC (r = 0.677); whereas, a significant negative Pearson's correlation coefficient were found for Ca-K (r = -0.579), Mg-K (r = -0.467) and Ni-P (r = -0.454). The probability values show a significant correlation ($p < 0.01$* and $p < 0.05$**) between pH and Ec (0.023**), Ca-K (0.003*), N-Mg (0.041**), K-Mg (0.018**), Zn-Ca (0.038**), and Zn-Mg (0.046**). This study provides valuable insights into the physicochemical characteristics of soil in Malakand Distrcit, contributing to a better understanding of soil health and its implications for agriculture and environmental sustainability.

Keywords: Soil Texture, Soil Organic Matter, Micronutrients, Macronutrients, Malakand.

1. INTRODUCTION

Soil contamination with heavy metals is a significant environmental and health issue in Malakand district, Khyber Pakhtunkhwa, Pakistan due to industrial activities and agricultural practices. The lack of comprehensive data on soil quality in the region hinders effective policy making and mitigation strategies, potentially threatning agricultural productivity, environmental sustainability and human health. The economic prosperity and happiness of a country are reliant on its natural properties and resources. If a country is to continue as a successful and prosperous unit, that country needs to have a widespread and perfect account of all its main resources [1]. Among all the resources, the actual capital and the ultimate asset of a country is its soil. For the production of more and good quality crops, the soil must have all essential nutrients in a balanced quantity. The insufficient

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quantity of nutrients in the soil will produce serious diseases in plants. The nutrients in the soil are grouped into two categories such as macro and micronutrients. Macronutrients are required by plants in greater quantity and include N, P, K, S, Ca, and Mg while micronutrients are required by plants in lesser quantity and include Fe, Cu, Zn, B, Mo, Cl and Mn [2, 3]. These macronutrients and micronutrients are required by plants for various physiological functions in their bodies. Nitrogen element enhances the growth and development of living tissues in the plant body whereas Phosphorus element is needed for the development of seeds and fruits, cell division and stimulation of root initiation and development. Potassium element enlarges the size of grains or seeds and develops the quality of fruits. In addition, Potassium may also activate about 60 enzymes in the plant body [4].

Soil has an important and crucial role in achieving the aims and objectives of sustainable development goals (SDGs) [5]. According to an estimate about 50% - 70% of overall soils are deteriorated or polluted due to extensive human-induced soil erosion which has eventually resulted in food security issues [6]. Moreover, it is believed that only 11% of the total land surface all over the world in arable land types is supposed to be available to keep up with the increasing demand for 50% farming products to nourish about 9.5 billion individuals by 2050 [7]. As a result, it is necessary and crucial to know and understand soil, its genesis, development, properties and behavior to support land use preferences and choices that may affect the ecological health and sustainable produce of the soil [8, 9]. Soils and their properties are substantially affected by geographic and topographical dynamics such as temperature, gravity, water, vegetation, pressure differences, wind, chemical interaction, topography and living organisms [10]. Diverse characteristics of soil like moisture content, permeability, porosity, temperature, depth, constancy, nutrient substances, etc., can significantly impact the nature of flora growing upon it [11]. The soil has a dynamic zone made up of minerals (parent rocks), organic matter (debris from animals and plants), soil water, and soil air [12].

The soil-plant association is significant as both are dependent on each other and the surrounding environment. The sustenance, water, minerals and nutrients required by plants to grow and survive are provided by soil whereas, the formation and improvement of soil are interlinked with plants [13]. The utility of soil for maintaining and sustaining human, plant, and animal activities, including farming, is influenced by the quality of the soil [14]. The quality of soil can be measured by a set of parameters including physical, chemical and biological properties of soil. An appropriate parameter should have a solid correlation with the specific soil function, which can be reproducible and economical to evaluate [15].

The physicochemical properties of soil determine the health of particular ecosystems [16-18]. Deforestation, overgrazing, and other human activities for agricultural and farming purposes have consistently and progressively diminished vegetation cover, leading to embraces for soil erosion, particularly in the mountainous regions [19]. Additionally, it may result in waterlogging that can cause nutrients to leak out of the soil depriving the soil of some essential nutrients [20]. Consequently, regular monitoring of the physicochemical characteristics of soil is essential to ensuring the sustainability of the environment and ecosystem. The physicochemical characteristics of soil in Malakand district vary significantly due to factors such as location, land use, and irrigation practices. In order to determine the soil fertility and production, the objective of this research was to assess and evaluate the physicochemical characteristics of the soil in the study region district of Malakand, Pakistan.

2. MATERIALS AND METHODS

2.1. Research Area

The present research was conducted in the district of Malakand, Khyber Pakhtunkhwa, Pakistan. The study area is located at 34° 35′ North latitude and 71° 57′ East longitude (Figure 1). It has a lush green valley of Malakand bounded by mountains. The area has sandy-loamy soil with sufficient moisture content which is a peculiar feature of the area. The mean annual rainfall recorded ranged between 600 to 650 mm. The area has diverse climatic conditions because the winters are cooler and the summers are warmer. Malakand district has historic significance and it has a rich floristic composition. The local people mostly get their livelihood from farming and

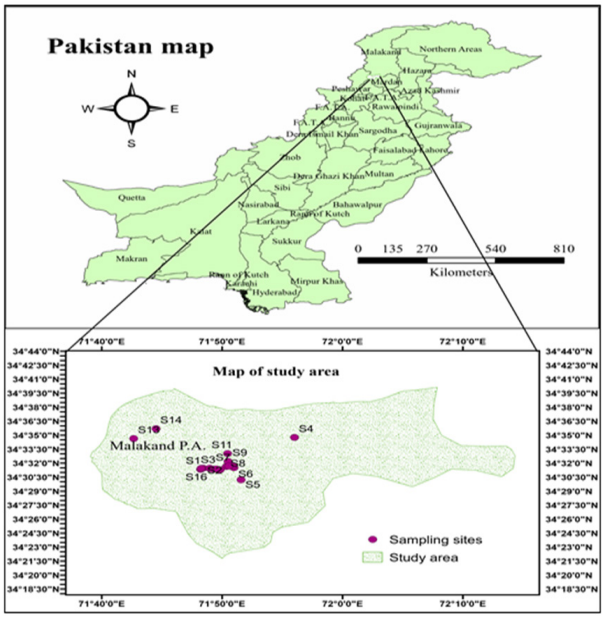

Fig. 1. Map of the study area.

livestock rearing. The majority of the people speak the Pashto language whereas, a few Gujjar families speak Gujari language [21].

2.2. Sample Collection

Twenty soil samples were randomly taken at a depth of 0–20 cm from the selected sites. The collected soil samples were retained in polythene bags and were properly labeled then dried and made fine powder with the sieve of 2 mm mesh for further analysis. The unbroken soil samples were collected using the core drill and wrapped instantly in air-tight bags and properly sealed with candle wax to prevent loss of moisture [3, 22].

2.3. Physicochemical Analysis of the Soil Samples

The soil samples were analyzed physicochemically at the Pakistan Tobacco Board, soil research laboratory, Khan Ghari Mardan, Khyber Pakhtunkhwa, Pakistan.

2.3.1. Determination of soil texture

The soil texture of the collected soil samples was determined by using the hydrometer method [23].

2.3.2. Determination of soil pH

An electrode pH meter (PCE-228) was used to determine the soil samples' pH in a 5:1 water-to-soil solution [24].

2.3.3. Determination of soil electrical conductivity (EC)

An electrical conductivity meter was used to measure the electrical conductivity of soil samples.

2.3.4. Determination of soil organic matter

In order to calculate the organic matter content of soil samples, the organic carbon contents of the soils were first calculated by using the Walkley and Black technique [25] and then multiplied by 1.724 [26].

2.3.5. Determination of total Nitrogen and Phosphorus in the soil

Micro-Kjeldhal digestion distillation procedures [27] and electro-photometer methods [28] were used to calculate the total content of nitrogen and phosphorus.

2.3.6 Elemental analysis of soil sample

For the examination of various elements present in soil samples, the AB-DTPA (Ammonium Bicarbonate-diethylenetriaminepentaacetic Acid) method was used [29]. An inductively coupled plasma (ICP) Spectrophotometer can be used to use the AB- DTPA soil test more effectively [30].

2.4. Statistical Analysis of Collected Data

The collected data were analyzed for basic descriptive statistical analysis through Microsoft Excel (Version 2016) and Origin (2019). The Pearson correlation coefficient of the data was also determined to study the inter-relationship among the different parameters of soil.

3. RESULTS AND DISCUSSION

3.1. Physicochemical Analysis of the Soil

3.1.1. Physical characteristics

Physical properties of the selected plant samples across the study area showed that sand particles were found in the range from 20.18% to 85.28%

with a mean value of 59.21%. The silt particles were in ranged from 10.35% to 74.60% with a mean value of 35.64%. The clay particles ranged from 3.23% to 7.11% with a mean value of 3.43%. The soil texture of the collected 20 samples showed that based on texture 50% soil samples tested were sandy loam, followed by textural class silty loam and loamy sand 25% each (Table 1). The soil of Kot, Maina, Hayankot, Salgro, Ghari Usmainkheil, Wazirabad, Kharkai, Mekhband, Aladand, Thana and Piran was sandy loam while the soil of Wartair, Musamena, Meherday, Sakhakot and Kopar was found silty loam (Figure 2). The textural distribution of soil reveals that the soil of Agra and Selai Patai is loamy sand. The soil of Kot, Maina, Hayankot, Salgro, Ghari Usmainkheil, Wazirabad, Kharkai, Mekhband, Aladand, Thana and Piran was sandy loam while the soil of Wartair, Musamena, Meherday, Sakhakot and Kopar was found silty loam (Figure 2). The physical properties of soil play a significant role in the water-holding capacity, saturation of root zone, aeration and absorption of water by plants [31]. The development of soil aggregates mainly depends on soil texture. One of the basic alterations in the soil texture is the superficial layers and it is one of the key causes that controls water potential, organic matter binding cation exchange as well as other activities [32]. The results of the present study for textural class determination are in with the results of previous studies in the area [1, 3, 33].

3.2. Chemical Properties

Chemical properties of selected soils reveal that:

pH value: pH value ranged from 6.7 to 8.2 with a mean value of 7.6 indicating the slightly alkaline nature (Table 2). This is considered to be the best soil for plant growth, root absorption and nutrient uptake [34]. The study showed that the pH value was recorded highest in plain areas as compared to hilly areas which is might due to the presence of more organic matter in plain areas than in hilly areas.

Electrical conductivity (Ec): Electrical conductivity of the tested soil samples ranged from 0.21 dS/m

Table 1. Physical properties of soil of district Malakand, Pakistan.

S. No.	Locality name	Textural class	Sand (%)	Silt (%)	Clay (%)
1	Kopar	Silty Loam	21.25	74.6	4.15
2	Sakhakot	Silty Loam	20.35	76.42	3.23
3	Meherday	Silty Loam	21.47	74.37	4.16
4	Musamena	Silty Loam	20.18	76.27	3.55
5	Wartair	Silty Loam	20.44	74.27	5.29
6	Piran	Sandy Loam	70.56	23.12	6.32
7	Thana	Sandy Loam	67.24	26.4	5.36
8	Alladand	Sandy Loam	70.19	25.47	4.34
9	Totakan	Sandy Loam	69.43	24.15	6.42
10	Mekhband	Sandy Loam	70.55	25.23	4.22
11	Kharkai	Sandy Loam	68.26	24.63	7.11
12	Wazirabad	Sandy Loam	67.37	26.5	6.13
13	Ghari Usmani Khel	Sandy Loam	67.16	27.24	5.6
14	Salgaro	Sandy Loam	68.27	27.3	4.43
15	Haryankot	Sandy Loam	66.28	26.31	7.41
16	Maina	Loamy Sand	70.46	25.19	4.35
17	Kot	Loamy Sand	75.25	18.26	6.49
18	Selai Patay	Loamy Sand	80.14	14.48	5.38
19	Agraa	Loamy Sand	84.16	12.41	3.43
20	Khanorai	Loamy Sand	85.28	10.35	4.37

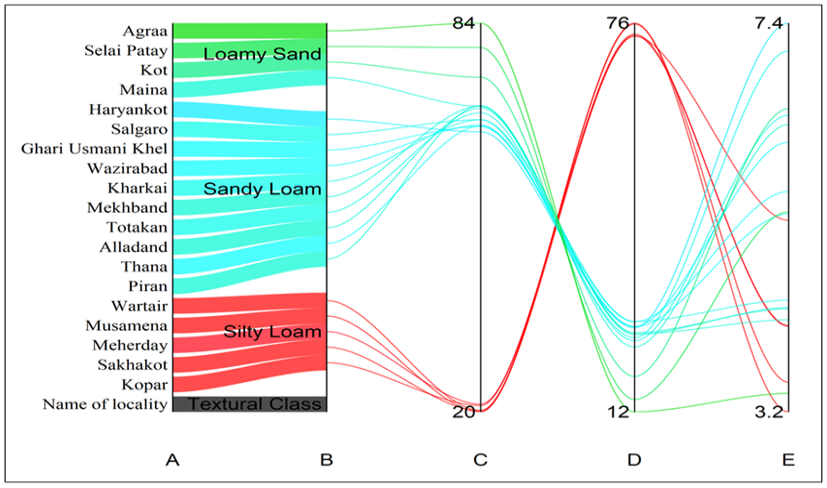

Fig. 2. Soil Texture classes distribution in different localities of District Malakand.

to 0.68 dS/m with a mean value of 0.43 dS/m. The electrical conductivity of the soil (EC) is a characteristic used to examine the salinity of the soil and is a crucial aspect in determining the quality of the soil. The results of the current analysis demonstrated that the soil's electrical conductivity (EC) is within a normal range. The sources of salts in the soil are mainly irrigation water, solubility of minerals, rise in water table and use of excessive fertilizers in the study area.

Organic matter: Organic matter content in the soil ranged from 0.70% to 2.27% with a mean value of 1.37%. Soil organic matter is rich in mineral substances and promotes soil fertility. It also has a role in soil texture and promoting water holding capacity of the soil. It also adds important minerals like nitrogen, phosphorus, sulphur, calcium, etc. to the soil and affects greatly to soil's physical and chemical properties [35].

Nitrogen content: Nitrogen content ranged from 300 ppm to 1500 ppm with a mean value of 735 ppm. The Phosphorus content ranged from 6.2 ppm to 14.4 ppm with a mean value of 9.46 ppm. A substantial amount of organic matter in the soil may be entrusted with the highest nitrogen and phosphorus content [36, 37].

Other macro elements: Other maceo elements reported from tested soil were K which ranged from 28 ppm to 190 ppm with a mean value of 62.20 ppm, Ca element ranged from 2.18 ppm to 7.75 ppm with a mean value of 5.62 ppm, Mg element ranged from 3.24 ppm to 6.09 ppm with a mean value of 4.74 ppm and Na element ranged

Table 2. Descriptive analysis of soil data by using statistical tools.

Descriptive analysis	**Chemical parameters of soil**										
	pH	EC (dS/m)	OM (%)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Zn (ppm)	Mn (ppm)
Min	6.70	0.20	0.70	300	6.20	28.00	2.18	3.24	12.21	1.37	0.53
Max	8.20	0.68	2.27	1500	14.40	190.0	7.75	6.09	18.29	2.22	1.63
Mean	7.66	0.43	1.37	735	9.46	62.20	5.62	4.74	15.36	1.66	0.95
Median	7.80	0.40	1.38	650	9.20	50.10	5.90	4.79	15.49	1.61	0.90
SD	0.48	0.15	0.35	380.2	2.51	37.56	1.38	0.76	1.35	0.19	0.27
SE	0.11	0.03	0.08	85	0.56	8.40	0.31	0.17	0.30	0.04	0.06
Kurtosis	-0.04	-0.66	1.56	-0.66	-0.94	6.83	0.63	-0.32	1.32	2.45	1.14
Skewness	-0.10	0.26	0.76	0.69	0.42	2.38	-0.71	-0.03	-0.42	1.27	1.06

Key: Max-Maximum, Min-Minimum, SD-Standard Deviation, SE-Standard Error and ppm-Parts per Million.

from 12.21 ppm to 18.29 ppm with a mean value of 15.36 ppm. The relatively small values of these macro elements may be accredited to the loss of macro elements from the soil may be due to human activities like farming, harvesting, or climatic aspects leading to percolating that can speed up the movement and inertness of these elements [12, 34, 38]. The value of microelement Zinc ranged from 1.37 ppm to 2.22 ppm with a mean value of 1.66 ppm. The value of Manganese ranged from 0.53 ppm to 1.63 ppm with a mean value of 0.95 ppm. Low values of these microelements were observed in the soil samples, which is reflective of the low unevenness in the soil's geochemical attributes [39]. It was found that the microelement concentrations in the analyzed soil samples were within the recommended standard range for typical soils [40]. The results of the present research on the chemical characteristics of soil were comparable and associated with those of earlier investigations, with a few minor variations that could be driven by a number of geomorphological features of the region under investigation [41-44].

3.3. Pearson's Correlation Coefficients among the Soil Parameters

To investigate the correlations between these various chemical features in the soil, Pearson's correlation coefficients were calculated, as shown in Table 3. The results showed a significant Positive Pearson's correlation coefficient, with the highest correlation observed between Pb-Na (r = 0.803), followed by P-N (r = 0.759) and N-EC (r = 0.677); whereas, a significant negative Pearson's correlation coefficient were found for Ca-K (r = -0.579), Mg-K (r = -0.467) and Ni-P (r = -0.454). The correlation coefficients between 0.9 and 1.00 are considered to be very highly correlated, 0.7 and 0.9 are considered to be highly correlated, 0.5 to 0.70 are considered to be moderately correlated, 0.25 to 0.50 are considered to be a low correlation, and values less than 0.2 are considered to have a low correlation [45]. The findings of past investigations [46, 47] are consistent with and comparable to the results of Pearson's correlation coefficients among various chemical characteristics of soil.

3.4. Probability Values among the Soil Parameters

The Probability values of the chemical properties of soil showed that significant correlations existed at ($p < 0.01$* and $p < 0.05$**) between different chemical properties of soil such as pH and Ec (0.023**), Ca-K (0.003*), N-Mg (0.041**), K-Mg (0.018**), Zn-Ca (0.038**), Zn-Mg (0. 046**) as shown in table 4. The results of Probability values of the chemical properties of soil and significant values at ($p < 0.01$* and $p < 0.05$**) of the current study are parallel and in line with the results of previous studies [48-50].

Table 3. Pearson's correlation coefficient among the soil parameters.

Correlation	PH	EC	OM	N	P	K	Ca	Mg	Na	Zn	Ni	Cd	Cr	Pb	Mn
PH	1														
EC	-0.449	1													
OM	0.303	0.255	1												
N	-0.280	**0.677**	0.453	1											
P	-0.075	0.493	0.181	**0.759**	1										
K	0.178	0.251	0.422	0.408	0.250	1									
Ca	0.080	-0.296	-0.062	-0.368	-0.092	**-0.579**	1								
Mg	-0.188	-0.087	-0.330	-0.398	-0.252	**-0.467**	0.377	1							
Na	0.184	0.091	0.381	0.142	0.148	0.448	0.052	-0.100	1						
Zn	0.148	0.051	0.275	0.097	0.086	0.624	0.404	-0.385	0.460	1					
Ni	-0.284	-0.171	0.152	-0.218	**-0.454**	-0.156	0.007	0.253	0.272	-0.150	1				
Cd	0.147	0.286	0.388	-0.048	-0.133	0.583	0.312	-0.070	0.525	0.657	0.115	1			
Cr	0.043	-0.001	0.076	0.046	-0.059	-0.390	-0.446	-0.236	0.219	0.459	0.308	0.289	1		
Pb	0.433	0.140	0.618	0.157	0.163	0.527	-0.063	-0.263	**0.803**	0.448	0.258	0.573	-0.084	1	
Mn	0.172	-0.270	0.396	-0.244	-0.344	0.291	-0.096	-0.055	0.366	0.335	0.601	0.538	0.403	0.431	1

Key: EC stands for electrical conductivity, OM for organic matter.

Table 4. Probability among the soil parameters.

Probability	pH	EC	OM	N	P	K	Ca	Mg	Na	Zn	Ni	Cd	Cr	Pb	Mn
pH	1														
EC	**0.023****	1													
OM	0.903	0.861	1												
N	0.115	0.999	0.977	1											
P	0.375	0.986	0.777	0.999	1										
K	0.774	0.857	0.968	0.963	0.856	1									
Ca	0.632	0.101	0.396	0.067	0.348	**0.003***	1								
Mg	0.213	0.356	0.089	**0.041****	0.141	**0.018****	0.949	1							
Na	0.781	0.649	0.938	0.723	0.734	0.976	0.413	0.337	1						
Zn	0.733	0.585	0.879	0.658	0.640	0.998	**0.038****	**0.046**	0.979	1					
Ni	0.111	0.234	0.738	0.177	**0.021****	0.255	0.512	0.859	0.122	0.262	1				
Cd	0.732	0.889	0.954	0.418	0.286	0.996	0.089	0.383	0.991	0.999	0.686	1			
Cr	0.572	0.496	0.625	0.577	0.401	**0.044****	**0.024****	0.157	0.176	0.979	0.906	0.891	1		
PB	0.971	0.722	0.998	0.746	0.755	0.991	0.394	0.130	0.999	0.976	0.135	0.987	0.362	1	
Mn	0.763	0.124	0.958	0.149	0.068	0.893	0.34	0.408	0.943	0.925	0.997	0.992	0.961	0.971	1

Key: EC stands for electrical conductivity, OM for organic matter. Bold r-values are significant at **p < 0.01*** and **p < 0.05****.

4. CONCLUSIONS

The present research encompassed the physicochemical characteristics of the soil in District Malakand, Pakistan. Three types of soil make up the distinctive soil textural class: sandy loam, loamy sand, and silty loam. The pH levels in the sites selected were found to be slightly alkaline to neutral, indicating their compatibility with the growth of plants. The soil had good pH ranging between 6.7 to 8.2, significant organic matter content ranged from 0.70% to 2.27% and The electrical conductivity of soil samples ranged from 0.201 dS/m to 0.683 dS/m clearly pointed to the soil's fertility in the study area. In the macronutrients, the Nitrogen content was found in the range of 300 ppm to 1500 ppm, Potassium from 28 ppm to 190 ppm, Phosphorus from 6.2 ppm to 14.4 ppm, Ca element from 2.18 ppm to 7.75 ppm, Magnesium from 3.24 ppm to 6.09 ppm and Sodium from 12.21 ppm to 18.29 ppm. Similarly, microelements such as Zinc ranged from 1.37 ppm to 2.22 ppm and Manganese from 0.534 ppm to 1.634 ppm. The content of the micronutrients and macronutrients were found to be within the permissible range, indicating that it is suitable for planting of different forest species, especially the Pinus forests. The soil of the farmed land was found to be ideal for the cultivation of numerous fruit and vegetable species. Although soil erosion and deforestation were the two main threats that were identified to be damaging the natural physicochemical composition of the soil in the selected sites, they need to be conserved. The present study reveals that the soil in district Malakand has favourable physicochemical charateristics, including organic matter, optimal nitrogen level, suitable moisture content, and a pH range conducive to plant growth. Additionally, the soil contains sufficient amounts of macro and micronutrients, indicating a fertile and productive soil environment. Based on these findings, it is recommended that farmers can adopt sustainable agricultural practices, such as crop rotation and optimal fertilizer application, to maintain soil fertility and productivity.

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6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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