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A Concise Comparative Study of Soil Physico-Chemical Parameters in Varied Agricultural Fields of Hazipur, Bihar, India

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ABSTRACT

Agricultural productivity is closely linked to soil quality, which plays a pivotal role in sustaining crop growth, maintaining ecosystem services, and supporting human well-being, especially under the pressures of global climate change. This study provides a comparative evaluation of soil physico-chemical parameters in wheat (A1), brinjal (A2), and control (C) fields in Hajipur, Bihar, India, with the aim of understanding soil variability and its implications for sustainable management. Results showed that soil pH (7.1–8.3) and electrical conductivity (130–291 µS/cm) varied with crop type and management practices, while moisture content (70.98–85.39%) and bulk density (1.226–1.773 g/cm³) highlighted differences in soil structure and water retention. Salinity levels (1.1–2.4 dS/m) and macronutrient availability, including nitrogen (59.5–119.7 kg/ha) and potassium (130–272.6 kg/ha), further emphasized variability in soil fertility across fields. Calcium, magnesium, and soil organic carbon (0.27–0.80%) also displayed significant fluctuations, influencing soil health and resilience. These findings indicate that soil properties are strongly influenced by crop-specific requirements and management practices, with direct consequences for productivity and long-term sustainability. The study underscores the need for crop-tailored soil management strategies that enhance nutrient availability, improve soil structure, and increase organic carbon for better resilience against climate stressors. Overall, the research highlights the intricate interplay of soil physico-chemical parameters with agricultural practices and provides valuable insights for developing sustainable soil management frameworks to optimize productivity, strengthen food security, and mitigate the impacts of climate change.

Keywords Soil quality, Physico-chemical parameters, Sustainable management, Global climate change, Agricultural productivity.

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INTRODUCTION

The Food and Agriculture Organization (FAO) of the United Nations declared in the first Revised World Soil Charter that "soils constitute a crucial enabling resource, central to the generation of a variety of commodities and services integral to ecosystems and human wellbeing" (FAO 2015). In general, the capacity of a particular type of soil to function, within naturally occurring and controlled ecosystem bounds, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation is known as soil quality (Brevik *et al.* 2020). In the context of agriculture, soil quality is typically characterized in terms of soil productivity (for example, a good quality soil provides abundant, high quality crops), and more particularly in terms of a soil's ability to support and foster plant growth (Carton and Zhou 1997). Concern over the future of agriculture has given rise to the idea of soil quality (Wander and Drinkwater 2000). Defining soil quality and coming to a consensus on the particular, the evaluation standards have proven challenging. The variety of traits that must be taken into account due to the many alternative uses of soil resource's, such as the production of agronomic, vegetable and forestry crops, the removal of agricultural, municipal, and food-processing wastes, or as a filter to protect groundwater resources (Karlen and Stott 1994). Healthy soil is characterized by resistance and speedy recovery from disturbances, whether they be natural or man-made (Schaeffer *et al*. 2016). The combination of many parameters, including physical, chemical, biological and enzyme activity, can result in a more accurate and superior soil assessment (Maurya *et al.* 2020). These wide range of parameters like physical chemical and biological parameters can be used to describe soil quality. Specific soil usage requires the selection of certain attributes (Carton and Zhou 1997). According to Seybold *et al.* (1998) a single soil attribute cannot be used to define soil quality assessment. Thus, a minimum dataset (MDS), which consists of a core set of characteristics including physical, chemical and biological soil properties that help to monitor soil fertility, health and quality, is required since it would be impossible to use all soil characteristics for assessing soil quality and it is important to quantify and analyze it qualitatively (Maurya *et al.* 2020, Mukhopadhyay and Mishra 2025). The conditions specific to the agro-ecological location determine which indicators are used in an MDS (Govaerts *et al.* 2006, Yao *et al.* 2013). Multiple methods can offer a more accurate and realistic representation of the microbiome, which can be used for soil quality monitoring (Jansson and Baker 2016). Understanding the proportions of the soil's water, mineral and organic components can help us to determine the productivity of soil and the optimal use for it. Several easily tested or examinable soil features are used to characterize and differentiate between various soil types.

Due to the dynamic, interconnected character of these processes, it is frequently challenging to precisely distinguish between soil functions in terms of chemical, physical and biological processes. Infiltration outcomes are taken into account when farming soil. Variations in terrain, climate, physical weathering processes, vegetation cover, microbiological activity, and a number of other biotic and abiotic factors, distinct soils' physico-chemical properties vary throughout time and space (Tale and Ingole 2015). Different types of soil are produced by many factors. When land use is changed, notably from agriculture and forestry, the physical and chemical characteristics of the soil deteriorate (Manirakiza *et al*. 2018). Years of normal vegetation development cannot be supported by fertile or barren soil as a result of the change in the physico-chemical qualities of the soil (Tale and Ingole 2015). Soil physical and chemical parameters play a great role in determining the soil quality. The physical-chemical characteristics of the soil utilized for agriculture determine all agricultural production (Delgado and Gómez 2024). The public's interest in the quality of the products produced by soil testing and the many methods used for their output have immediately raised the necessity for soil testing. India is an agricultural nation, thus preserving soil fertility is a significant concern. In agriculture, the significance of soil physico-chemical analysis is crucial. Agriculture is the foundation of the Indian economy. The majority of people rely on agriculture. Maximum crop production is produced when soil nutrients are at their ideal levels (Ghule *et al.* 2020). As a result, soil nutrient content affects production. It is important to examine the physico-chemical examination of soil in order to determine the soil's quality (Gowthamchand *et al.* 2023, Mukhopadhyay and Mishra 2025, Mukhopadhyay *et al.* 2025).

In terms of agricultural output, India comes win second. 50% of the workforce was employed in agriculture and related industries including forestry and fisheries in 2013, which contributed 13.7% to the GDP (Gross Domestic Production) (Arjun 2013, Deshpande 2017). The Indian economy is heavily reliant on the agricultural sector. More than 70% of rural households are dependent on agriculture (Joshi 2015). The efforts of humans to protect themselves from hunger and take control of their food supply are directly related to the history of wheat domestication and utilization. Now cultivated on a global scale, wheat has taken over as the primary food source in agriculture. Since wheat has the advantage of requiring less water for production than other comparable crops and is a key component of many processed meals favored in modern, primarily urban life, China and India are currently the world's top two producers of wheat (Igrejas and Branlard 2020, Das *et al.* 2021). Wheat is the main crop grown in India's Indo-Gangetic Plains during the *rabi* season. Due to extensive tillage, nonrecycling of agricultural residues, monoculture, and unbalanced use of agrochemicals, the soil quality is under danger (Kumar *et al.* 2013). On a sandy loam soil wheat following rice yielded less than that following maize (Gangwar *et al.* 2006). The decrease in yield was ascribed to loss of surface soil structure and greater nutrient removal by rice. Few disturbed surface soil samples were used by these authors to examine their physical characteristics. A similar decline in the physical characteristics of surface soil was observed in various other research using disturbed soil samples (Sur *et al.* 1980). Bihar is one of the strongest agricultural states of India. Around 80% of the population of Bihar is employed in agricultural production, which is significantly higher than the national average. Based on agro-climate, Bihar can be divided into four regions. Because it is situated in the Gangetic Plain, the North West region of Bihar is the most agriculturally productive of the four regions and has been the primary producer of the main crops, namely wheat and rice, for a number of decades (Khan and Sadaf 2022). Study on soil physical properties and organic carbon was conducted in a rice-wheat rotation in the Indo-Gangetic Plains of Bihar. According to the study it was found that increased rice or wheat yields were not directly correlated with improvements in soil physical condition, but overall system productivity rose significantly (Mondal *et al.* 2016).

Vegetable crops are edible herbaceous, viny, shrubby, or tree-like plants that thrive in habitats, but are typically succulent plants. They can be consumed in cooked, semi-cooked, or raw form with staple foods as a main course or as a supplemental diet (Singh *et al.* 2013). India produces more than 97 million tons of vegetables annually, making it the second largest producer in the world. By raising national productivity at least to the global average and preventing post-harvest losses, it can overtake other countries as the top producer of vegetables in the world. Among all the important indigenous vegetables crop grown in India, brinjal is also one of them which contribute 9% total vegetables production of the country. It is due to advancements in agricultural technology, safety precautions, and genetic enhancement, yield, quality, disease resistance, and insect-pest resistance have all significantly improved (Sidhu and Dhatt 2006). In tropical and subtropical areas around the world, it is commonly cultivated. In terms of nutrition, brinjal is low in fat, protein and carbs. It is abundant in sodium, potassium, sugar and dietary fiber. Additionally, it has crucial vitamins like A, B6, C, and D as well as calcium, iron and magnesium (Kumar 2016). In addition to being very sensitive to abiotic stress conditions, eggplant (*Solanum melongena* L.) has one of the top five and the quality of the fruit spoils even more as the incidence of soil-borne diseases develops (Wakchaure *et al.* 2020).

Many farmers use synthetic and inorganic fertilizers to get high yields. Because the nutrients from these fertilizers are not directly absorbed by the plants, they may stay in the soil for a long time, changing its quality. In addition to the environmental issues brought on by the use of fertilizers, pesticide use also causes a number of issues. These include its environmental persistence, toxicity in the soil, plants, and water supplies, as well as its use in relation to human health. Numerous soil properties affect many pesticides chemicals' toxicity and durability. It aids farmers in increasing crop yield and ensuring sufficient nutrient availability for healthy growth (Tale and Ingole 2015). Hajipur is the headquarters of Vaishali district of Bihar under Patna. The farmers of the city enjoy being the most fertile land because the Ganga and Gandak rivers flowed into the floodplain (Singh *et al.* 2022). The soil of this country is mostly alluvial and therefore the farmers profitably use this superiority of soil for the cultivation of vegetables, fruits Administrative Department. The service sector dominates the agro economic scenario of Hajipur, which also contributes significantly to the success of the region. If the share of the service sector is 55% according to the data, the agricultural sector is not far behind with its 35% shares of the urban economy. The agro economic scenario of Hajipur is dominated by the service sector, which also contributes a lot to the prosperity of the region. The main crops grown in that headquarter are wheat, paddy, rice, maize, vegetables, potatoes and oil seeds. Hajipur being an agriculture area it was selected to study the essential soil physical and chemical parameters required for proper agricultural development. Two different lands having different cultivation practices and crops were selected for the study and was compared to a control land of the same region.

MATERIALS AND METHODS

Study area

The study area selected was Hajipur (Fig. 1), the headquater of Vaishali District of Bihar. It is located at 25.69°N, 85.22°E. It is located 10 km from Patna, transversely on sacred river Ganga. The farmers of the city enjoy being the most fertile land because the Ganga and Gandak rivers flowed into the floodplain. The soil of this country is mostly alluvial and therefore the farmers profitably use this superiority of soil for the cultivation of vegetables, fruits, Administrative Department. The service sector dominates the agroeconomic scenario of Hajipur, which also contributes significantly to the success of the region. If the share of the service sector is 55% according to the data, the agricultural sector is not far behind with its 35% shares of the urban economy. The agroeconomic scenario of Hajipur is dominated by the service sector, which also contributes a lot to the prosperity of the region. The main crops grown in that headquarter are wheat, paddy, rice, maize, vegetables, potatoes and oil seeds.

Collection of samples

The most crucial stage of evaluating soil parameter is soil sampling. The main objectives of soil sampling is to collect the soil sample and to estimate different physico-chemical parameters in the soil. An area is considered as a simple sampling unit. Samples were collected from three different sites (random sampling): i.e. Wheat (A1), Brinjal (A2) and uncultivated land (C). Five locations from each cultivated field (A1 and A2) were selected (four from the corner and one from the middle of the field) and three locations from the uncultivated land (which is considered as the control, three along the diagonal of the field). Leaves, grass and external objects were removed before taking samples. Samples were collected by digging up to 0–15 cm and 15–30 cm depth with the help of soil digger and samples were stored in zip-lock bags. The zip-lock bags were labelled with permanent marker according to sites, location and depth. For bulk density test, a steel pipe of diameter 2 inches and length 4 inches was taken and it was buried in the field with the help of hammer. After that the samples were collected in a separate zip-lock bag. These samples were then further processed using different methods. The collection was done using gloves to avoid any form of external and body contamination. Further the samples were also collected and analyzed using standard protocols. Step wise collection of samples are attached herewith.

Sample preparation

The samples were air dried by lying them out on a newspaper. Air drying was done at room temperature in open place with no contamination and kept it to dry until its moisture content was removed. The soil contained large aggregate grains or some clods, formed due to clay particles. After drying it for 3-4 days, once the moisture content was removed it was then grinded and crushed using a mortar and pastle (Blake 1965). This was done by mechanical means. Sample was passed through sieve size of 2 mm, which has been adopted as international standard in soil monitoring.

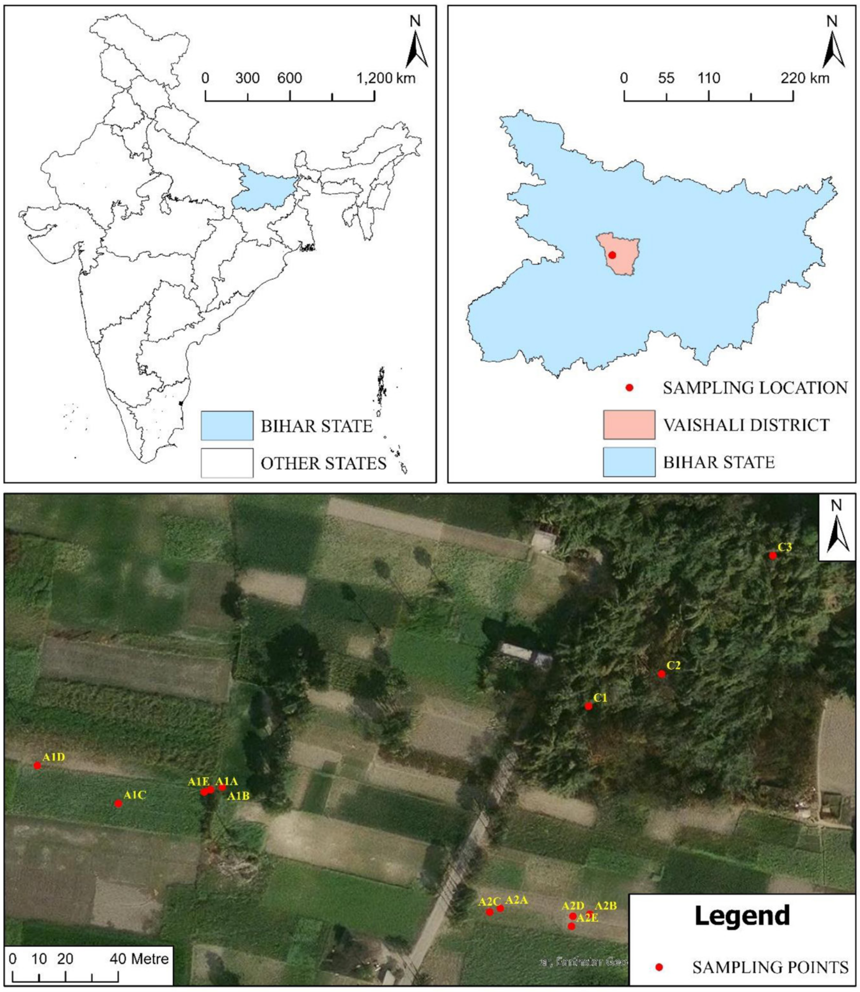

Fig. 1. Map of study area.

Methods of analysis

Soil samples has been air-dried and sieved using a 2 mm sieve following grinding by mortar pestle. BD samples has been procured following guidelines (Blake & Hartge 1986) and acquired samples has been oven dried for 3 days with the temperature set at 100°C to obtain constant dry weight. The following formula was used (USDA 2008) :

BD (g/cc) = Dry weight/ volume of soil core

Soil pH, salinity and electrical conductivity (EC) has been determined by pH, EC and salinity meter (soil: distilled water = 1:2.5) of Digital Water and Soil Analysis Kit, Model No. 161. Conventional routine methods has been used to analyze the available nitrogen (N) and available phosphorus (P). The Kjeldahl digestion-distillation method has been used to determine soil available Nitrogen (Jones 1991). Soil available phosphorus has been measured by the molybdenum blue colorimetric method using an $HClO_4$–H_2SO_4 solution for digestion (Tandon *et al.* 1968). The soil moisture contents of the samples will be measured by oven drying at 105˚C for 24 h (Zhao *et al*. 2018). Available potassium has been tested by using 5 g of soil sample and adding 25 ml of neutral ammonium acetate solution to it, followed by filtering it through Whitman No.1 filter paper and measuring it in flame photometer (Stanford and English 1949). The organic carbon was analyzed using H_2SO_4 at a stable concentration of $K_2Cr_2O_7$ to identify the organic carbon percentage (Walkley and Black 1934). Soil calcium and magnesium was measured using EDTA titration method (Barrows and Simpson 1962).

RESULTS

Electrical conductivity (EC), bulk density (BD), salinity, pH, and moisture content are all significantly different among the three sites (Table 1). At a 0 to 15 cm depth, the pH readings across the wheat, brinjal, and control fields were 7.8b ± 0.58, 8.2a ± 0.40 and 7.5c ± 0.48. The electrical conductivity (EC) showed a similar trend, with the control field having the lowest value (145.0b ± 1.07), followed by the Wheat field (288.0a ± 1.44), and the brinjal field (146.8b ± 1.46). Control field has the highest moisture content (83.94a ± 0.61) followed by the Brinjal field (80.38b ±0.98), and the wheat field (78.16b ± 0.84). At this depth, the bulk density (BD) and salinity varied significantly between fields. A similar pattern appeared at depths ranging from 15–30 cm. The control field exhibited the lowest pH (7.2c ± 0.03), whereas the Wheat (7.5 b ± 0.08) and Brinjal fields (7.9 a ± 0.04) had higher values. Electrical conductivity was most significant in the Wheat field (270.4a ± 0.40), preceded by the control field (139.0b ± 0.37) and the Brinjal field (132.8c ± 1.02). Moisture content, bulk density and salinity varied significantly among the fields at this depth as well.

At a depth of 0–15 cm, wheat field had significantly higher nitrogen content at 0–15 cm (118.10a ± 0.90 kg/ha) than Brinjal field (81.70 c ± 1.31 kg/ha) and Control field (Table 2). Brinjal field had

Table 1. The physical parameters of wheat field, brinjal field and control field at two different depths. C = Control field, A1 = Wheat field, A2 = Brinjal field. The ± signs represent the standard error of the mean. The alphabetical notations signify statistically significant differences between the respective means (p < 0.05).

Sample ID		pH	EC	Moisture (%)	BD (g/cm^3)	Salinity
Code	Depth (cm)					
C	0-15	7.5^c ± 0.48	145.0^b ± 1.07	83.94^a ± 0.61	1.27^c ± 0.01	1.10^b ± 0.01
A1	0-15	7.8^b ± 0.58	288.0^a ± 1.44	78.16^b ± 0.84	1.47^b ± 0.03	1.48^a ± 0.05
A2	0-15	8.2^a ± 0.40	146.8^b ± 1.46	80.38^b ± 0.98	1.65^a ± 0.04	1.20^b ± 0.03
Code	Depth (cm)					
C	15-30	7.2^c ± 0.03	139.0^b ± 0.37	84.39^a ± 0.23	1.23^c ± 0.01	0.93^c ± 0.03
A1	15-30	7.5^b ± 0.08	270.4^a ± 0.40	73.42^b ± 1.07	1.39^b ± 0.02	2.34^a ± 0.04
A2	15-30	7.9^a ± 0.04	132.8^c ± 1.02	75.21^b ± 1.09	1.52^a ± 0.02	1.68^b ± 0.05

Table 2. The chemical parameters of wheat field, brinjal field and control field at two different depths. C = Control field, A1 = Wheat field, A2 = Brinjal field. The ± signs represent the standard error of the mean. The alphabetical notations signify statistically significant differences between the respective means (p< 0.05).

Sample ID		Nitrogen (kg/ha)	Potassium (kg/ha)	Calcium (meq/100 g)	Magnesium (meq/100 g)
Code	Depth (cm)				
C	0-15	100.20^b ± 0.30	101.10^c ± 0.16	0.12^c ± 0.01	0.20^b ± 0.01
A1	0-15	118.10^a ± 0.90	158.28^b ± 0.41	0.51^a ± 0.01	0.21^b ± 0.01
A2	0-15	81.70^c ± 1.31	271.94^a ± 0.22	0.32^b ± 0.01	0.33^a ± 0.02
Code	Depth (cm)				
C	15-30	94.26^a ± 0.25	93.80^c ± 0.39	0.09^c ± 0.01	0.18^a ± 0.01
A1	15-30	112.88^a ± 1.13	147.48^b ± 0.85	0.41^a ± 0.01	0.14^a ± 0.02
A2	15-30	60.76^c ± 0.41	262.08^a ± 1.02	0.24^b ± 0.02	0.21^a ± 0.04

the highest potassium level (271.94a ± 0.22 kg/ha), followed by wheat field and control field. Compared to Brinjal field and Control field, wheat field (0.51a ± 0.01 meq/100 g) had significantly higher calcium levels. Brinjal field had significantly higher magnesium levels (0.33a meq/100 g) than either wheat field (0.21b meq/100 g) or Control field. In the depth of 15 to 30 cm: The wheat field (112.88a ± 1.13 kg/ha) had a much greater nitrogen content than the brinjal field (60.76c ± 0.41 kg/ha) and Control field (94.26b ± 0.25 kg/ha). The Brinjal field has the greatest potassium content (262.08a ± 1.02 kg/ha), followed by the wheat field and control field. The wheat field had a higher calcium level (0.41a ± 0.01 meq/100 g) than the Brinjal field and Control field. Furthermore, the brinjal field had a considerably greater magnesium level (0.21a ± 0.04 meq/100 g) than the wheat field and control field.

At a depth of 0–15 cm, wheat field had significantly higher nitrogen content at 0–15 cm (118.10a ± 0.90 kg/ha) than Brinjal field (81.70 c ± 1.31 kg/ha) and Control field (Table 2). Brinjal field had the highest potassium level (271.94a ± 0.22 kg/ha), followed by wheat field and Control field. Compared to Brinjal field and Control field, wheat field (0.51a ± 0.01 meq/100 g) had significantly higher calcium levels. Brinjal field had significantly higher magnesium levels (0.33a meq/100 g) than either Wheat field (0.21b meq/100 g) or Control field. In the depth of 15 to 30 cm: The wheat field (112.88a ± 1.13 kg/ha) had a much greater nitrogen content than the Brinjal field (60.76c ± 0.41 kg/ha) and Control field (94.26b ± 0.25 kg/ha). The Brinjal field has the greatest potassium content (262.08a ± 1.02 kg/ha), followed by the Wheat field and Control field. The wheat field had a higher calcium level (0.41a ± 0.01 meq/100 g) than the brinjal field and Control field (Fig. 2). Furthermore, the brinjal field had a considerably greater magnesium level (0.21a ± 0.04 meq/100 g) than the wheat field and Control field.

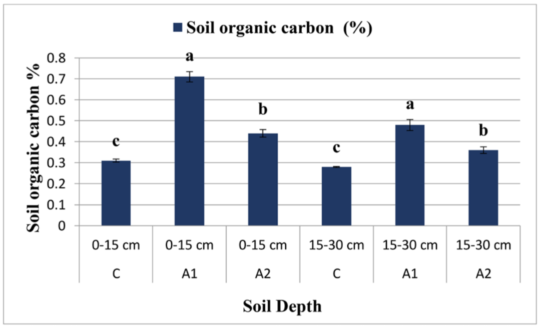

Fig. 2. Soil organic carbon content (%) of wheat field (A1), brinjal field (A2), and control field (C) at two different depths. The alphabetical notations signify statistically significant differences between the respective means ($p < 0.05$).

The correlation matrix below represents the relationships between various soil parameters in the studied fields, including pH, Electrical Conductivity (EC), Moisture, Bulk Density (BD), Salinity, Nitrogen, Potassium, Calcium, Magnesium, and Soil Organic Carbon (SOC) (Table 3). pH has a strong correlation with moisture, potassium, calcium, magnesium, and SOC. EC correlates positively with salinity and potassium. Moisture has negative correlations with BD, Nitrogen, and Salinity. Bulk Density (BD) is positively correlated with nitrogen and salinity. Salinity

Table 3. Correlation matrix of soil properties and nutrient levels. *Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

Correlations	ph	EC	Moisture	BD	Salinity	Nitrogen	Potassium	Calcium	Magnesium	SOC
ph	1	0.04	0.45*	0.21	0.06	-0.39*	0.86**	0.43*	0.60**	0.35
EC		1	0.06	0.01	0.53**	0.57**	-0.05	0.74**	-0.20	0.74**
Moisture			1	0.25	-0.42*	0.26	0.05	0.19	0.50**	0.34
BD				1	-0.28	0.17	0.13	0.21	0.44*	0.19
Salinity					1	0.20	0.19	0.59**	-0.35	0.38*
Nitrogen						1	-0.66**	0.45*	-0.34	0.51**
Potassium							1	0.31	0.57**	0.16
Calcium								1	0.05	0.91**
Magnesium									1	0.10
SOC										1

shows positive correlations with EC and potassium, and a negative correlation with moisture. Nitrogen negatively correlates with EC, moisture, and salinity. Potassium positively correlates with calcium (0.31) and magnesium. Calcium and magnesium showed a positive correlation. Soil Organic Carbon (SOC) positively correlates with pH, EC, moisture, potassium and magnesium.

DISCUSSION

The variations in soil parameters such as Electrical Conductivity (EC), Bulk Density (BD), Salinity, pH, and Moisture Content observed at two depths (0-15 cm and 15-30 cm) between the Wheat, Brinjal, and Control fields highlight the complex interplay between soil characteristics and agricultural activities (Rowe 2018). The pH values at both depths clearly distinguished the fields, with the Brinjal field having the greatest pH, followed by the Wheat field, and the Control field having the lowest pH levels. This trend highlights the impact of agricultural methods on soil acidity or alkalinity, demonstrating how different crops and management techniques affect soil pH levels (Müller *et al.* 2021). The similar pattern of electrical conductivity (EC) values obtained across the fields at both 0-15 cm and 15-30 cm depths demonstrates how various crops affect soil EC levels. The Control field had the lowest EC values, while the Wheat field consistently had the highest, with the Brinjal field in the middle. This trend demonstrates how agricultural techniques and crop kinds may have a major influence on soil EC, reflecting differences in salt and nutrient levels (Corwin & Lesch 2003, Eigenberg *et al.* 2002).

The differences in Moisture Content and Bulk Density noted between the Control, Brinjal and Wheat fields at 0–15 cm and 15–30 cm depths demonstrate the impact of agricultural methods on soil structure and water retention capacity (Makovníková *et al.* 2017). The Control field had the highest moisture content readings, followed by the Brinjal and Wheat fields, demonstrating variations in water availability and retention between the fields. The control field had lower Bulk Density values than the Brinjal and Wheat fields, indicating variations in soil compaction and porosity due to agricultural operations (Blanco-Canqui 2017, Batey 2009).

Soil salinity levels have a significant impact on soil health and agricultural output. The differences in salt levels between the Control, Wheat, and Brinjal fields at both depths demonstrate the effect of different crops on soil salinity. The Control field exhibited greater saline levels than the Wheat and Brinjal fields, indicating possible issues in soil health and plant growth (Machado & Serralheiro 2017, Wong *et al.* 2009). Furthermore, it underlines the role of salt in soil carbon dynamics, demonstrating that excessive salinity levels can harm plant life and soil organic carbon stocks. This highlights the interrelated nature of soil salinity with soil characteristics and plant development, emphasizing the necessity for solutions to preserve soil health in salt-affected locations (Wong *et al.* 2009).

The differences in nutrient content detected at different depths between the Wheat, Brinjal and Control fields provide information on the various nutrient dynamics driven by agricultural techniques. At a depth of 0–15 cm, the Wheat field had considerably greater nitrogen content than the Brinjal and Control fields, indicating that higher nitrogen availability might lead to increased plant growth and production in the Wheat field (Rawat *et al.* 2022). In contrast, the Brinjal field had the greatest potassium levels, indicating its potential for potassium absorption, but the Wheat field had much higher calcium levels than the Brinjal and Control areas. Furthermore, the Brinjal field had considerably higher magnesium levels than the Wheat and Control fields, indicating variations in nutrient intake and soil fertility across the fields (Shalini *et al.* 2022).

At the 15–30 cm depth, the Wheat field maintained substantial nitrogen content compared to the Brinjal and Control fields, further highlighting the nutrient-rich environment in the Wheat field conducive to plant growth. The Brinjal field continued to exhibit the highest potassium content, indicating its efficient potassium uptake capacity, while the Wheat field showed higher calcium levels compared to the Brinjal and Control fields. Moreover, the Brinjal field maintained significantly higher magnesium levels than the Wheat and Control fields, underscoring its unique nutrient profile and potential impact on plant health and growth (Shalini *et al.* 2022). In order to optimize crop growth and sustainability in agricultural ecosystems, it is imperative to understand the complex relationships that control soil health, nutrient availability, and agricultural productivity. It is important to consider survey and study using remote sensing as a major tool to get a constant monitored data through time (Mukhopadhyay and Mishra 2024). These relationships are highlighted by the correlations among the soil parameters.

CONCLUSION

This analysis provides valuable insights into the physical and chemical parameters of the Wheat field (A1), Brinjal field (A2), and Control field (C). The pH levels across all fields indicate a slightly alkaline soil environment, which is generally favorable for plant growth. Electrical Conductivity (EC) values suggest moderate salinity levels in all fields, which may require appropriate soil management practices. Moisture content varies among the fields, with the Wheat field (A1) generally having lower moisture levels compared to the Brinjal field (A2) and Control field (C). Bulk Density (BD) values are within the acceptable range, indicating reasonable soil structure and compaction levels. Salinity values are generally low, suggesting a non-saline soil condition in all fields. Nitrogen (N) levels are relatively higher in the Wheat field (A1), indicating a potentially favorable nutrient supply for wheat crops. Brinjal field (A2) and Control field (C) have relatively lower nitrogen levels. Potassium (K) levels are similar in the Wheat field (A1) and Control field (C), while the Brinjal field (A2) shows slightly higher potassium levels. Calcium (Ca) and Magnesium (Mg) levels are consistent among all fields, suggesting similar availability of these essential nutrients. Soil Organic Carbon (SOC) levels are higher in the Wheat field (A1), indicating better soil fertility and nutrient-holding capacity. Brinjal field (A2) and Control field (C) have relatively lower SOC levels.

Overall, the data highlights the importance of nutrient management in optimizing crop productivity. The Wheat field (A1) demonstrates favorable nutrient levels, suggesting a potentially more suitable environment for wheat crops. The Brinjal field (A2) and Control field (C) exhibit relatively lower nutrient levels, indicating the need for careful nutrient management practices to ensure optimal plant growth. Farmers and agricultural practitioners can use this information to tailor their nutrient management strategies, such as adjusting fertilizer application rates, incorporating organic matter, and implementing appropriate soil amendments, to address specific nutrient deficiencies or imbalances in each field. Additionally, regular monitoring and soil testing can help track changes in nutrient levels over time and guide future management decisions for sustained agricultural productivity.

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