Soil Fertility Status of Selected Panchayats in DeehBlock of Raebareli district, Uttar Pradesh, India

ABSTRACT

The present investigation aimed to assess soil fertility across twenty-five villages within group gram panchayats in the Deeh block of Raebareli district, Uttar Pradesh. The study evaluated soil nutrient status using the nutrient index approach, which focused on analyzing nutrients while also identifying correlations among various soil parameters.

The soil fertility assessment in Deeh tehsil, Raebareli, revealed significant variability in pH (5.47–8.46), organic carbon (OC:0.02–1.12%) and available nitrogen (70.25–716.26 kgha^{-1}), indicating moderate soil health. Phosphorus availability was high (mean 77.31 kgha^{-1}), whereas potassium was low (mean 103.48 kgha^{-1}), suggesting nutrient imbalances. Micronutrient deficiencies were noted, particularly for zinc (0.016-2.17 ppm), while copper was sufficient (0.14-2.98) in majority of soils in the study villages. The nutrient index classified nitrogen as medium (1.79), phosphorus as high (2.73), and organic carbon (1.67), potassium (1.19)and Zn (1.46) as low, highlighting the need for targeted soil management. Soil pH showed a significant positive correlation with EC and OC but a strong negative correlation with Fe, indicating reduced iron availability in alkaline soils. ~~OC~~ Organic carbonhad a strong positive correlation with N and P, supporting nutrient retention. Fe had significant negative correlations with pH, EC and K, emphasizing its reduced availability in alkaline, saline, and potassium-rich soils.The study concludes that site-specific soil fertility management and regular soil testing are essential for maintaining soil health and enhancing crop productivity.

Key Words: Soil Fertility, Nutrient Index, Nutrient Correlation, Raebareli.

1. INTRODUCTION

Soil is one of nature's most invaluable gifts to mankind, forming the foundation of agricultural productivity and sustainability. Despite its critical importance, soil remains one of the most overlooked and underestimated resources on Earth. Managed judiciously, this enduring treasure possesses the potential to yield abundant harvests and sustain livelihoods. Recognizing the immense value of soil and implementing appropriate management practices are essential for unlocking its productivity and ensuring its sustainability over time.Soil fertility is a dynamic and multifaceted attribute that directly influences agricultural output, serving as a cornerstone of food security and ecosystem stability. It encompasses the availability of essential macro and micronutrients, which play a pivotal role in determining crop yield (Tisdale et al., 1993). However, soil fertility is not uniform; it varies significantly in depth and across landscapes due to the complex interplay of physical, chemical and biological factors. This variability is compounded by intensifying cropping patterns, nutrient depletion, erosion and inadequate soil management practices, which collectively contribute to the degradation of soil fertility on a global scale (Bashagaluke et al., 2018).

In the context of intensive agriculture, the fertility of soils is increasingly threatened by the erosion of nutrient-rich topsoil and the depletion of organic matter—both vital for maintaining soil health. Conducting a thorough soil evaluation prior to crop cultivation is imperative for identifying nutrient deficiencies and adopting suitable corrective measures. Such proactive steps ensure optimal crop production and long-term soil health (Kadam et al., 2022). Periodic assessments of soil fertility are crucial, particularly in regions where intensive cropping practices continually exhaust both macro and micronutrients with each season.Key fertility parameters, including organic carbon (C), nitrogen (N), phosphorus (P) and potassium (K), significantly influence the physical, chemical, and biological properties of soil (Cao, 2011). These parameters, in turn, determine the productivity and sustainability of agricultural lands. Soil testing emerges as an indispensable tool for evaluating the fertility status of soils, offering precise insights into nutrient availability and forming the basis for tailored fertilizer recommendations. Such recommendations not only boost crop yields but also help maintain optimal soil fertility over time (Singh et al., 2018).Assessing soil fertility through robust methodologies, such as nutrient index analysis, enables the systematic evaluation of spatial and temporal variations in soil properties. This approach has been successfully employed to assess fertility status in various regions of India, including the Deomali hill-range valley zone of Odisha (Choudhury et al., 2021), the Tiruchirappalli district of Tamil Nadu (Amar and Shanmugasundaram, 2020), and Ausa Tehsil of Latur district, Maharashtra (Kadam et al., 2022). These studies highlight the importance of region-specific assessments to inform localized soil management practices.

This study focuses on the soil fertility assessment of selected panchayats in Deeh Tehsil of Raebareli district, Uttar Pradesh. By employing nutrient index and soil fertility indicators, the research aims to provide a comprehensive understanding of the fertility status of the region’s soils. Such insights will guide the development of tailored management strategies to enhance agricultural productivity and ensure the sustainable use of soil resources in this agriculturally significant region.

2. MATERIAL AND METHODS

2.1 Location

Deeh Tehsil is situated within Raebareli district in southern Uttar Pradesh, India. The district lies between latitudes 25°49'N and 26°36'N and longitudes 100°41'E and 81°34'E. The region is part of the Gangetic plain, characterized by flat to gently undulating terrain with elevations ranging from approximately 100 to 120 meters above sea level.The climate of Raebareli district is classified as sub-humid, featuring hot summers from March to early June, followed by a monsoon season from mid-June to mid-September and cool winters from December to February. The average annual rainfall is about 1,150 mm, predominantly received during the monsoon months (June to September). While the district's terrain is generally flat or gently undulating, specific elevation details for Deeh Tehsil are not readily available. However, the district's elevation varies from about 120.4 meters above sea level in the northwest to 86.9 meters above sea level in the southeast, along the banks of the Ganges River. Key crops in the region include Rice, Maize, Wheat, Barley and Gram.The 25 cluster villages in Uttar Pradesh, where BAIF-BISLD, UP is implementing the HDFC Bank-sponsored Livelihood Enhancement Programme, from which soil samples were selected (Fig. 1), include Purethamman, PadmanpurBijauli, Majhilaha, TekariSahan, Deeh, Dela, KurapurGaura, Gadwa, Purbanayan, TekariDadu, Nigohi, Saraimanik, Ahal, Goera, Ghisigarh, Dilawalpur, Kachanavo, SadipurKotwa, Jagdishpur, GangapurKamwa, Dhankesara, Gopalpur, Vakalanagar andGovindpur.

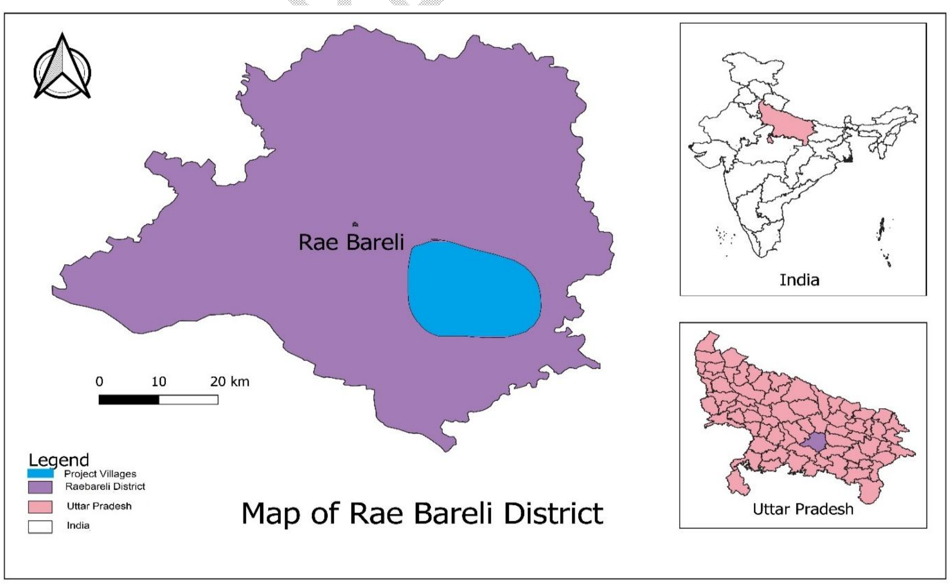

Fig. 1 : Location Map of the Project Villages

2.2 Study Details

2.2.1 Soil Sampling

A total of 550 surface soil samples were collected from different farmers' fields spanning across 25 villages of located in the Deeh block of Raebareli,Uttar Pradesh.These samples were collected from the plough layer, which is at a depth of 0-15 cm. After collection, they were air-dried and then sieved through a 2 mm mesh to ensure consistency and remove larger particles.

2.2.2 Analysis of Chemical parameters

The pH and EC of the soils were determined by digital pH meter (Jackson, 1973) & digital EC meter (Wilcox, 1950) by using 1:2.5 soil-water suspension. The Organic Carbon (%) was determined by Rapid titration method~~.~~ (Walkley andBlack, 1934).

2.2.3 Analysis of Primary nutrients and Micro nutrients

The available N content of the soils were determined by Pelican Nitrogen Auto-Analyzer following the alkaline permanganate method (Subbiah and Asija, 1956). The available P content of the soils were determined by Bray and Kurtz P1 method for acidic to neutral soils (Bray and Kurtz, 1945) while for neutral to alkaline soils, Olsen's method (Olsen and Sommers, 1982) was used. The available potassium (K_2O) extracted using the neutral normal ammonium acetate then estimated by flame photometry method given by Hanway and Heidel (1952).The available micronutrients (Iron, Manganese, Zinc and Copper) were extracted using the DTPA extraction method and determined using an Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). The organic carbon content, available nitrogen, available phosphorous, and available potassium content in the soil were categorized as low, medium, or high. The available micronutrient content in the soil was categorized as deficient, sufficient, or in excess.

Table 1: Soil test rating chart for ~~O~~organic~~C~~carbon and macro- nutrients

	Low	Medium	High
Organic Carbon (%)	<0.50	0.5-0.75	>0.75
Available N (kgha^{-1})	<250	250-500	>560
Available P (kgha^{-1})	<28	28-56	>56
Available K (kgha^{-1})	<140	140-280	>280

Table 2: Soil test rating chart for available micro- nutrients

	Deficient	Sufficient	Excess
Fe (ppm)	<5.0	5.0-10.0	>10.0
Mn (ppm)	<5.0	5.0-10.0	>10.0
Zn (ppm)	<0.5	0.5-1.0	>1.0
Cu (ppm)	<0.2	0.2-0.4	>0.41

2.3 Nutrient Index (NI)

Nutrient Index introduced by Ramamurthy and Bajaj (1969) was usedto evaluate the fertility status of soils. NI was computed by the following formula:

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$$\text{Nutrient Index (NI)} = \frac{(1 \times A) + (2 \times B) + (3 \times C)}{\text{Total Number of samples}}$$

where,

A = Number of samples in low category;

B = Number of samples in medium category;

C = Number of samples in high category.

Table 3: **Nutrient index with rank and remark**.

Nutrient index	Range	Rating
I	Below 1.67	Low
II	1.67-2.33	Medium
III	Above 2.33	High

2.4 Statistical Analysis

Descriptive statistics are used to summarize and interpret the fundamental characteristics of data in a study. They provide straightforward insights into the sample and its key measures. Statistical parameters such as mean, standard deviation, skewness and kurtosis coefficients can effectively assess the soil characteristics of Deeh Block in Raebareli district. These measures are calculated using standard statistical formulas to ensure accuracy and reliability in data analysis. The correlation analysis of data was computed in relation to available major and micronutrients contents with different physico-chemical properties of the soils as suggested by Pearson's correlation coefficient(r) using standard formula.

3. RESULTS AND DISCUSSIONS:

3.1 Descriptive statistics for physicochemical parameters of soil

The analysis of field-collected soil samples was conducted by examining physicochemical parameters (pH, EC, OC, N, P, K, Fe, Mn, Cu, and Zn) using conventional statistical methods, as presented in Table 4. Standard deviation is a measure of data dispersion from the mean representing the absolute variability of a distribution. A higher standard deviation indicates greater variability, meaning the data points deviate more significantly from the mean.

Table 4: Descriptive statistics for physicochemical parameters of soil.

	Min	Max	Mean ± SD	Median	Mode	Kurtosis	Skewness
pH	5.47	8.46	7.12±0.48	7.12	7.18	0.04	0.18
EC(ds/m)	0.01	1.67	0.21±0.17	0.16	0.20	14.73	2.97
O.C.(%)	0.02	1.12	0.52±0.23	0.50	0.47	-0.53	0.19
N($kgha^{-1}$)	70.25	716.26	339.98±152.43	307.96	246.49	-1.03	0.41
P($kgha^{-1}$)	14.26	182.01	77.31±28.2	75.58	68.40	0.02	0.41
K($kgha^{-1}$)	23.52	451.85	103.48±52.48	92.87	104.29	4.17	1.37
Fe(ppm)	1.77	25.39	10.1±4.87	8.90	6.60	0.76	1.07
Mn(ppm)	0.30	26.86	6.86±3.69	6.59	8.44	2.57	1.05
Zn(ppm)	0.02	2.17	0.51±0.3	0.44	0.17	3.20	1.37
Cu(ppm)	0.14	2.98	1.11±0.45	0.98	0.79	1.96	1.42

The analyzed soil fertility parameters from the selected panchayats in Deeh Tehsil of Raebareli district highlight significant spatial and quantitative variability, indicative of the diverse soil properties in the region.pH values ranged from 5.47 to 8.46, with a mean of 7.12 ± 0.48, suggesting that the soils vary from slightly acidic to moderately alkaline. The median (7.12) and mode (7.18) confirm the predominance of neutral to slightly alkaline conditions. The low kurtosis (0.04) and near-zero skewness (0.18) indicate a normal distribution, highlighting the suitability of most soils for a wide range of crops.Electrical conductivity ranged from 0.01 to 1.67 dSm^{-1}, with a mean of 0.21 ± 0.17 dSm^{-1}suggest that most soils are non-saline, making them conducive for agricultural productivity. It might be due to negligible salt content having no remarkable effect on soil physico-chemical and biological properties.

Organic carbon levels varied between 0.02% and 1.12%, with a mean of 0.52 ± 0.23%. The median (0.50) and mode (0.47) reflect moderate organic carbon content, critical for soil health. The slightly negative kurtosis (-0.53) and low skewness (0.19) indicate an overall balanced distribution of organic carbon but also highlight specific areas of deficiency, particularly in the villages of Purbanayan, Saraimanik, Ahal, Goyara, Purethamman and Dhankesra, emphasizing the need for organic amendments.Similar findings were reported by Kumar et al. (2015).Available nitrogen exhibited substantial variation, ranging from 70.25 to 716.26 $kgha^{-1}$, with a mean of 339.98 ± 152.43 $kgha^{-1}$. The median (307.96 $kgha^{-1}$) and mode (246.49 $kgha^{-1}$) indicate low to moderate nitrogen levels, consistent with agricultural intensification depleting nitrogen reserves. The slightly negative kurtosis (-1.03) and positive skewness (0.41) suggest that most samples have low nitrogen content, particularly in the villages of Dilvarpur, Purbanayan, Saraimanik, AhalandPurethammanemphasizing the need for nitrogenous fertilizers. The extensive variability in available nitrogen can be attributed to increased anthropogenic inputs. This includes nitrogen from fertilizer runoff, the leaching of dissolved organic nitrogen and the accelerated transformation rates of inorganic nitrogen, which are particularly pronounced in surface soils and areas with varying topography. Available phosphorus ranged from 14.26 to 182.01 kg/ha, with a mean of 77.31 ± 28.20 $kgha^{-1}$. The median (75.58 $kgha^{-1}$) and mode (68.40 $kgha^{-1}$) indicate moderate phosphorus availability. Available potassium varied significantly from 23.52 to 451.85 $kgha^{-1}$, with a mean of 103.48 ± 52.48 $kgha^{-1}$. The high kurtosis (4.17) and skewness (1.37) indicate substantial variability, with many soils being potassium-deficient despite a high mode (104.29 $kgha^{-1}$).The poor soil texture with high sand content, low organic matter content, leading to reduced availability of potassium in soils of Deeh tehsil.Micronutrients also showed marked variability. Iron levels ranged from 1.77 to 25.39 ppm, with a mean of 10.1 ± 4.87 ppm. Manganese exhibited a wide range (0.30–26.86 ppm), suggesting moderate availability but localized deficiencies. Zinc, essential for crop growth, varied from 0.02 to 2.17 ppm, with a mean of 0.51 ± 0.30 ppm and a high kurtosis (3.20), indicating widespread zinc deficiency. Low soil zinc levels in Deeh tehsil are primarily attributed to factors like low organic matter content, intensive cropping practices and the prevalent use of high-analysis fertilizers with minimal zinc content, leading to significant zinc depletion in the soil over time.Copper ranged from 0.14 to 2.98 ppm, with a mean of 1.11 ± 0.45 ppm, suggesting moderate sufficiency. The findings underscore the importance of tailored soil management practices, including the judicious application of fertilizers, micronutrient amendments, and organic matter to address nutrient deficiencies and enhance agricultural productivity in the region. These insights provide critical guidance for optimizing resource use and improving crop yields sustainably.

3.2 Nutrient index of soil fertility parameters in Deeh tehsil of Raebareli districts.

Table 5 presents the nutrient index of various soil fertility parameters in Deeh tehsil of Raebareli district, categorizing them into low, medium, and high ratings based on their respective values. The organic carbon content is low (1.67), indicating poor soil organic matter, which may affect microbial activity and nutrient availability. Lower organic matter in the area may be due to prevailing high temperature and good aeration in the soil which increases the rate of oxidation of organic matter content. The nitrogen index is 1.79, categorized as medium, suggesting moderate fertility status but potential limitations in sustaining high crop yields.The nitrogen content of the study region is medium probably due to the low organic carbon content present in the soil. Phosphorus exhibits a high index (2.73), implying sufficient availability for plant uptake, possibly due to past fertilizer applications. Potassium, however, is low (1.19), which could constrain plant growth and productivity. Among micronutrients, iron and manganese are rated medium, with indices of 2.26 and 1.94, respectively. Zinc shows a low index (1.46), indicating a potential deficiency that may hinder enzymatic functions and plant metabolism. In contrast, copper is high (2.99), ensuring adequate levels for physiological processes.

Table 5: Range, mean values and nutrient index of soil fertility parameters in Deeh tehsil of Raebareli districts.

Parameters	Range	Mean	Nutrient Index (NI)	NI Ratings
O.C. (%)	0.02-1.12	0.52	1.67	Low
N (kg/ha)	70.25-716.26	339.98	1.79	Medium
P (kg/ha)	14.26-182	77.31	2.73	High
K (kg/ha)	23.52-451.85	103.48	1.19	Low
Fe (ppm)	1.77-25.39	10.10	2.26	Medium
Mn (ppm)	0.29-26.86	6.86	1.94	Medium
Zn (ppm)	0.016-2.17	0.51	1.46	Low
Cu (ppm)	0.14-2.98	1.11	2.99	High

Table 6: Correlation Matrix between Physicochemical Parameters of Soil

	pH	EC	O.C.	N	P	K	Fe	Mn	Zn	Cu
pH	1.000									
EC	0.201**	1.000								
O.C.	-0.121**	0.282**	1.000							
N	0.095*	0.240**	0.753**	1.000						
P	0.017	0.067	0.145**	-0.130**	1.000					
K	0.065	0.153**	0.091*	0.125**	0.005	1.000				
Fe	-0.328**	-0.164**	0.093*	-0.154**	0.076	-0.299**	1.000			
Mn	-0.079	-0.149**	0.276**	-0.274**	-0.232**	-0.083	0.093*	1.000		
Zn	-0.035	-0.043	0.073	-0.114*	0.004	-0.003	0.130**	0.040	1.000	
Cu	-0.075	0.046	0.047	0.065	0.030	0.111*	-0.084	-0.052	0.001	1.000

"*" and "**" correlations are significant at the 0.05 and 0.01 level, respectively.

3.3 Correlation Matrix between Physicochemical Parameters of Soil

The correlation matrix provides valuable insights into the relationships between various physicochemical parameters of the soil in the study area, offering critical implications for soil fertility and management practices. The Pearson's correlation coefficient matrices for the analyzed parameters are presented in Table 6. Correlation coefficients below 0.5 are not considered significant. Understanding the interrelationships among different parameters is valuable for assessing the associations between soil properties (Andrew et al., 2018).

Soil pH exhibited a highly significant positive correlation with EC (r = 0.201**) and a weak positive correlation with nitrogen (r = 0.095*), indicating that stable pH supports better nutrient retention. However, pH was negatively correlated withOC (r = -0.121**) and micronutrients, with a significant negative correlation with Fe (r = -0.328**), suggesting reduced iron availability at higher pH due to precipitation in alkaline conditions. Electrical conductivity (EC) showed a significant positive correlation with OC (r = 0.282**) and N (r = 0.240**), indicating that increased salinity is associated with increased organic matter and nitrogen levels, while its negative correlation with Fe (r = -0.164**) and Mn (r = -0.149**) suggests potential micronutrient deficiencies in saline soils. Organic carbon (OC) was significantly and positively correlated with available nitrogen (r = 0.753**), likely due to mineralizable nitrogen release and NH_4-N adsorption by humus complexes, as reported by Kumar et al. (2014). Its positive correlation with available phosphorus (r = 0.145**) may be attributed to the acidulating effect of organic matter and reduced phosphorus fixation, aligning with Singh *et al*. (2014). A significant positive correlation (r = 0.091*) between OC and K content may result from the improved soil environment due to organic matter presence, consistent with Malakar et al. (2022). Meena et al. (2006) observed similar significant and positive correlation between organic carbon and available K. This might be due to creation of favourable soil environment with presence of high organic matter. Nitrogen (N) was positively correlated with K (r = 0.125**), indicating their interdependence in nutrient cycling, while its negative correlations with P (r = -0.130**), Fe (r = -0.154**) and Mn (r = -0.274**) suggest that micronutrient deficiencies may hinder nitrogen uptake, particularly in intensively cultivated soils. Phosphorus (P) exhibited a significant negative correlation with Mn (r = -0.232**), implying that phosphorus dynamics are largely independent of micronutrient availability. Potassium (K) showed a weak negative correlation with Fe (r = -0.299**). Among micronutrients, Fe had significant negative correlations with pH, EC and K, highlighting its reduced availability in alkaline, saline and potassium-rich soils. Manganese (Mn) was negatively correlated with N and P. Zinc (Zn) showed no significant correlations with most parameters except for a weak positive relationship with Fe, indicating limited interaction with other soil factors. Copper (Cu) exhibited no strong correlations apart from a weak positive relationship with K, suggesting its relatively independent behavior in the studied soils.

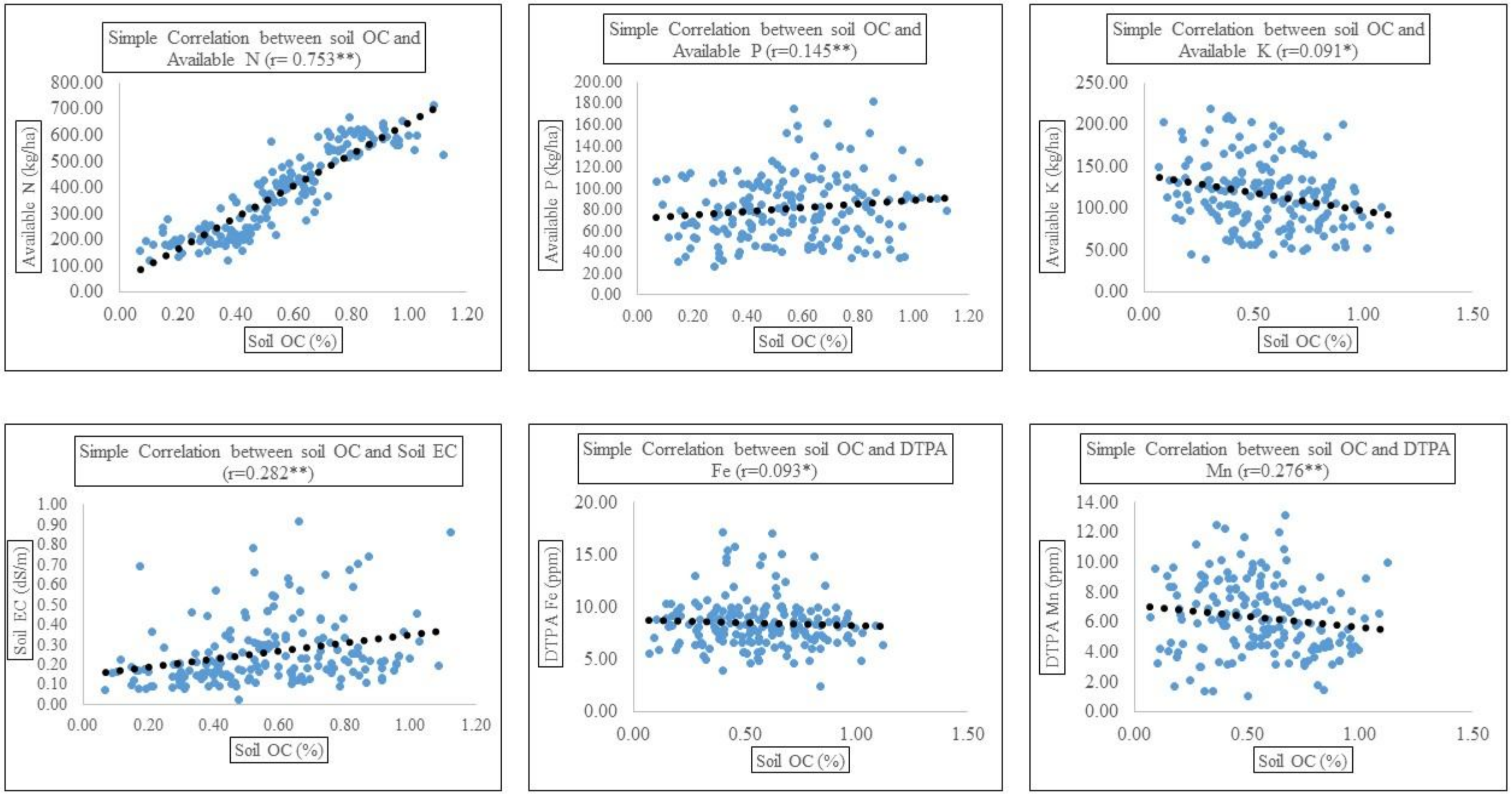

Fig 2: Simple Correlation between Soil Organic Carbon and other parameters

4. CONCLUSION:

The findings emphasize the critical need for site-specific soil fertility management to sustain agricultural productivity in Deeh Block of Raebareli district, Uttar Pradesh, India. The study reveals that while phosphorus and copper levels are adequate, there are significant deficiencies in organic carbon, nitrogen, potassium, and zinc. Addressing these deficiencies requires a comprehensive and integrated approach, including balanced fertilization strategies, the application of organic amendments such as farmyard manure, compost and green manure, as well as the judicious use of micronutrient fertilizers. Long-term soil fertility monitoring is crucial for sustainable management practices. GIS-based mapping and research on soil-nutrient interactions will aid targeted nutrient management. Climate-resilient practices and conservation techniques can further enhance soil sustainability. Developing decision-support tools and farmer training programs will ensure widespread adoptionto improve agricultural productivity and environmental sustainability.

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Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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