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Geospatial Variability Mapping of Soil Properties in Kukra Block of Muzaffarnagar District and its Impact on Agricultural Productivity

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ABSTRACT

The study was carried out in various villages of the Kukra block in Muzaffarnagar district-251001, Uttar Pradesh, India, from November, 2023 to June, 2024 to assess the soil properties and to prepare soil fertility maps of the area. Thirty-five (35) soil samples were collected from a depth of 0–15 cm utilising a random sampling method. Subsequently, soil samples were air-dried in the shade at ambient temperature and subjected to screening through a 2 mm mesh for nutrient analysis. Fifteen soil properties, namely sand, silt, clay, bulk density (BD), particle density (PD), porosity, pH, electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S) were assessed. The findings revealed that the soils examined varied from neutral to slightly salinised. 80% and 20% of the soil samples, respectively, were predominantly neutral and free from salinity hazards. Samples exhibited low, medium, and high concentrations of organic carbon. Soil organic carbon concentration is characterised as 48.57% low, 28.57% medium, and 22.86% high. Samples exhibited low and medium concentrations of accessible nitrogen (34.29% and 65.71%, respectively) in the soil. The phosphorus level in the soil samples was categorised as low (11.43%), medium (45.71%), and high (42.86%). The results for available sulphur were medium at 88.57% and high at 11.43%, respectively. The soil samples contained sufficient exchangeable calcium and magnesium.

KEYWORDS: GIS, GPS, nutrient index, soil fertility

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1. INTRODUCTION

Food security is a major global crisis due to the ever-increasing population. The global population is projected to grow from 7.6 billion in 2020 to 9.6 billion in 2050 (Anonymous, 2023). Many countries around the world are facing an acute shortage of land for agricultural production. Higher land use efficiency can increase yield per unit area and is the most appropriate way to ensure food security rather than expanding the agricultural sector (Xingwu et al., 2015). Therefore, the challenge is to increase crop production to meet the needs of the growing population (Tiruneh et al., 2022). Good soil is necessary for good crop production. Soil fertility is a property that is in dynamic equilibrium and can change according to natural and man-made conditions (Kavitha and Sujatha, 2021). In the last few decades, the use of high-yielding varieties and excess chemical fertilizers to increase crop production in Indian agriculture has resulted in several issues affecting soil health, fertility, productivity, the environment, and farmers. A general review of the available evidence shows that Indian soil is deficient in nitrogen. So the amount of nitrogen in the soil is less because the amount of nitrogen in the soil is directly proportional to the amount of organic carbon (Verma et al., 2023). About half of the country's arable land has low levels of phosphorus. High levels of phosphorus are available only in some districts, while others are in the moderate group(Bharteey et al., 2017; Sahu et al., 2024). The lack of potassium is much less than the lack of nitrogen and phosphorus, about three-quarters of the land falls into the category of medium to high fertility (Singh et al., 2021). Plants need at least 17 important nutrients to grow properly and complete their life cycle (Prajapati et al., 2024). Carbon, hydrogen, and oxygen, the most common plant nutrients, are universal elements given off by air and water (Bharteey et al., 2023). The remaining 14 nutrients are only absorbed by plants as minerals from the soil or must be provided as fertilizer. Plants need a sufficient amount of nitrogen, phosphorus and potassium. These nutrients are known as primary nutrients: nitrogen, phosphorus, and potassium (Maurya et al., 2024). Less amount of calcium, magnesium and sulphur are required as compared to the primary nutrients (Prajapat et al., 2023). Proper soil management can increase the supply of important nutrients. Crop nutrition at any location is highly dependent on the availability and comparable profile of soil nutrients. If all these issues are to be handled for the benefit of individual farmers and humanity then all these issues require a thorough investigation of the physicochemical health of the agricultural soil. Soil fertility assessment is the most fundamental decision-making tool for designing an optimal land use system (Havlin et al., 2010; Kumar et al., 2023). It is a major factor affecting plant growth (Singh et al., 2017). Soil fertility refers to the interaction between the physical, chemical and biological properties of soil and is directly related to agricultural production (Rakesh et al., 2012). Understanding soil fertility in a certain location or region is important for efficient and productive agricultural techniques (Meena et al., 2006). This research will use GIS and remote sensing to present and elucidate georeferenced laboratory analysis results of soil analysis through thematic soil maps of various soil physicochemical properties of the study area (Abdel Rahman et al., 2020; Yadav et al., 2022). Agriculture is not only the leading industry in the region but also plays a major role in the local and regional economy (Wangchu et al., 2024). Kukra block is located in the Muzaffarnagar district of the Indian state of Uttar Pradesh and is famous for its agricultural sector. The study regarding the soil properties of the Kukra block are lacking due to which farmers of the area are appliying excessive dosages of fertilizer which is declining their soil health in the long run and ultimately affecting their crop also. So, current study was conducted with the objective of assessing the soil properties of the area as well as developing soil fertility maps to provide farmers the correct status of their soil nutrients.

2. MATERIALS AND METHODS

2.1. *Description of study area*

The present investigation attempted to assess the soil variability status in ten villages of Kukra block namely Bajheri, Sarwat, Raghanwali, Pachenda Kalan, Ratheri, Nasirpur, Chandpur, Makhiali, Meghakheri and Pachenda Khurd from Muzaffarnagar district (U.P.) during November-2023 to June-2024. These villages weresituated at around 29°27'N latitude and77°42'E longitude, in an area well-known for its high agricultural outputs as a result of the diverse composition of soils (Figure 1). The climate of the study area located in the north Indian plains is varied

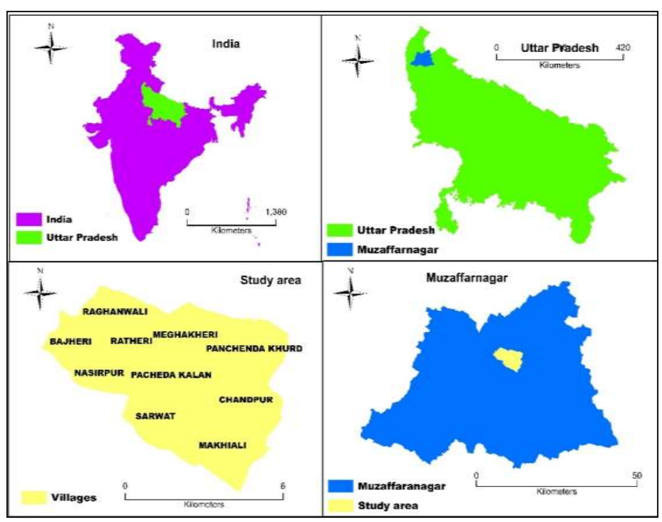

Figure 1: Location map

and often has very hot summers and cool winters. For the summer months of March to June, it was hot and dry with temperatures peaking at 40°C (104°F) during May and June. However, the region could experience some heat waves around this time and that means additional stress on agricultural works. The monsoons, which last from July to September, provided relief in the form of moderate (from 5 inches) to heavy rainfall.July and August were when some of the most important work as they accounted for major recharge into groundwater availability especially which acted crust upon *Kharif* sowing to rice, sugarcane, pulses, etc.

2.2. Soil sampling, processing and analysis

A total of thirty-five GPS-based surface soil samples were collected from 10 different villages such as rice, sugarcane, pulse, wheat, mustard,and fodder crops fields in an area dig up to a depth of 0–25 cm on a random basis in V-shape, soil samples were taken to the laboratory and dried in shade at room temperature (Figure 2). Wet soil samples were dried in the air and homogenized with a wooden roller after having passed through to 2.0 mm mesh sieve, then stored in polythene bags for further laboratory analysis.In the particle size distribution analysis by hydrometer method (Bouyoucos, 1962), the bulk density and particle density were determined by a pycnometer as described by Black (1965). Pore volume was calculated by employing the values of the bulk and the particle densities. The water holding capacity was estimated by using the keen box method (Piper, 1966). Electrical conductivity was recorded using an EC meter while pH was done using the potentiometric procedure whereby a 1:2.5 dilution was prepared, environmental soil water suspension (Jackson, 1973). Organic carbon was determined by the potassium dichromate acetic acid titration according to the Walkley and Black (1934) method. There was the use of the alkaline potassium permanganate method as described by Subbiah and Asija (1956), as well as Kjeltech semi-

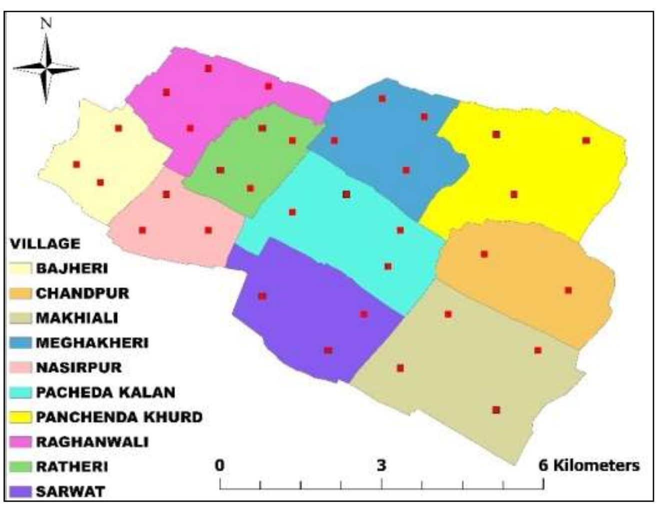

Figure 2. Sampling site map

automatic nitrogen analyzer. An analysis of the available phosphorus was carried out using Olsen method which was developed by Olsenet al. (1954). Potash was assayed, using a flammable photometer with normal neutral ammonium acetate as an extractant (Hanway and Heidal, 1952). To assess the levels of exchangeable calcium and magnesium Versanate titration was used as described by Cheng and Bray (1951). Available sulphur was also analyzed using the turbimetric method using a spectrophotometer based on the Chesnin and Yien method (1950). All soil analysis had to be done in the Department of Agricultural Chemistry and Soil Science lab of C.C.R. (P.G.) College, Muzaffarnagar, Uttar Pradesh.

2.3. Nutrient index evaluation

Data from the soil test summaries were used to determine the nutrient index values of the soils in the individual blocks whereby they were sorted into low, medium, and high based on the percentage distribution. The nutritional index was developed by Parker, et al in 1951. Nutrient Index=[% in high category x 3+% in medium category x 2+% in low category x 1]100, Against the nutrient index value less than 1.5 for low, 1.5 to 2.5 for medium and greater than 2.5 for high.

2.4. Data analysis

The descriptive statistical parameters like mean, median, minimum, maximum, standard deviation (SD), per cent of coefficient of variation (% CV) were calculated using an Excel spreadsheet to characterize the spatial distribution of soil available S in the study area. The spatial distribution of soil properties was investigated using inverse distance weighted interpolation techniques. Arc GIS 10.4.1 version was used to create all the maps. Principal component analysis is a multivariate method for extracting components from a group of variables. The PCs with the greatest Eigenvalues were believed to be the most accurate representations of soil properties (Deka et al., 2016).

3. RESULTS AND DISCUSSION

3.1. Physical properties

The soil properties of Kukra block of Muzaffarnagar about the estimation of spatial variability of soil are presented in Table 1 through statistical parameters viz. minimum, maximum, mean, median, and standard deviation. Various box plots as shown in Figure 3 display the dataset based on a five-number summary of minimum, maximum, median, first and third quartiles of the study area.The textural classification of the soils under several villages in the Kukra Block in the Muzaffarnagar district, the investigated soils had a range of textural characteristics, from clay to loamy sand, with a mean value of 76.90, the textural characteristics of the investigated soils were characterized by metrics such

Table 1: Status of physical properties of different villages of Kukra block of Muzaffarnagar district

Parameters	Min.	Max.	Mean	S.D.	S.E.	C.V.%
Sand (%)	50.0	86.0	76.9	6.79	1.15	8.84
Silt (%)	9.0	32.0	15.9	5.03	0.85	31.58
Clay (%)	3.0	20.0	7.2	3.33	0.56	46.29
Bulk density (g cm^{-3})	1.15	2.12	1.45	0.20	0.03	13.51
Pulk density (g cm^{-3})	2.03	2.55	2.24	0.14	0.02	6.03
Porosity (%)	27.01	47.72	36.86	5.76	0.97	15.64

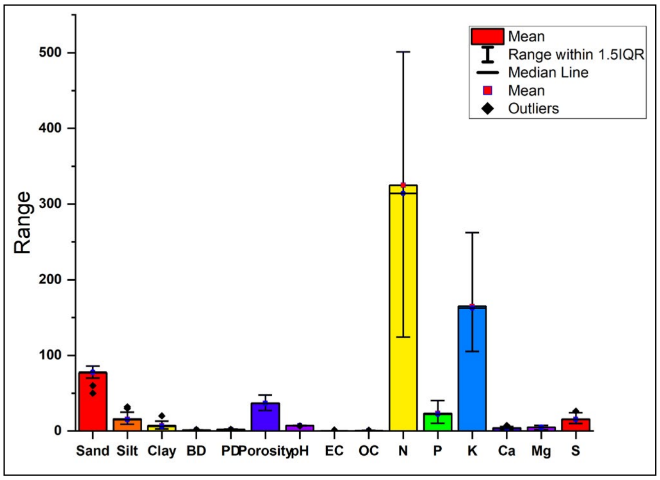

Figure 3: Box plot showing the level of physico-chemical properties of soil of Kukra block

as total sand content, which varied from 50.0 to 86.0%. The percentages of silt and clay ranged from 9.0 to 32.0% and 3.0 to 20.0%, respectively. For silt and clay, the shown mean values were 15.9 and 7.20%, respectively. Sand, however, had the highest standard deviation (6.79) and standard error (1.15). The coefficient of variation was lowest (8.84%) for sand and greatest (46.29%) for clay content. Because there wereflat surfaces, there wereno growing tendencies of finer materials being washed from the upper surface to the lower surface. Mishra et al. (2016) and Dora et al. (2023) also published results that were taken as comparable. The mean bulk density of the soils under study was 1.45 g cm^{-3}, with a range of 1.15–2.12 g cm^{-3} (Table 1), the coefficient of variation was 13.51% and the standard deviation was 0.03. Samples 7 and 12 reported the lowest bulk density in Bajheri and Ratheri villages, which may be related to the study area's less intensive agricultural methods. S_{10} and S_4 Nasirpur and Raghanwali villages discovered the highest bulk density, which might be attributable to the presence of low organic matter. In Bhubaneswar, Odisha, Behera et al. (2023) found a mean BD value that was comparable. The average particle density of the soil sample was 2.24 g cm^{-3}, with a range of 2.03–2.55 g cm^{-3}. Particle density had a standard deviation of 0.14 and a coefficient of variation of 6.03%. The highest particle density was recorded in Pachenda Kalan village (S_{20}), while the lowest particle density was recorded in Raghanwali village (S_4) (Walpola et al., 2011). The soil samples porosity percentages ranged from 27.01 to 46.72%, with a mean value of 36.66%. The porosity percentage was reported to have a standard deviation (S.D.) of 5.76 and a coefficient of variation of 15.64%. S_7 in the village of Bajheri had the highest value (52.31%), while S_{22} in the village of Pachenda Kalan had the lowest value (27.01%). The results demonstrated that soil particles fill up pore spaces as they erode, increasing the bulk density and decreasing the porosity of the soil. (Das et al., 2024) publish the comparable results. The spatial variability maps of sand, silt, clay, BD, PD and Porosity are presented in Figure 4.

3.2. Chemical properties

The investigated soils had a mean pH of 7.19 and ranged from 6.71 to 7.45 (Table 2). The highest was in S_8 of Bajheri village. The C.V. values were 2.15%. The samples in the slightly acidic group (6.0–6.9) were small; that is,

Table 2: Status of chemical properties of different villages of Kukra block of Muzaffarnagar district

Parameters	Min.	Max.	Mean	S.D.	S.E.	C.V.
Soil reaction (pH)	6.71	7.45	7.19	0.15	0.03	2.15
EC (dS m^{-1})	0.17	1.37	0.37	0.22	0.04	60.79
O.C. (%)	0.15	1.10	0.56	0.23	0.04	41.02
Av. N (kg ha^{-1})	124.21	501.21	324.80	113.86	19.25	35.06
Av. P (kg ha^{-1})	10.21	40.25	23.48	8.43	1.43	35.91
Av. K (kg ha^{-1})	105.24	262.35	165.02	41.97	7.09	25.43
Av. S (kg ha^{-1})	1.60	7.50	4.17	1.19	0.20	28.39
Av. Ca (cmol (P+) kg^{-1})	2.10	7.70	4.90	1.40	0.24	28.48
Av. Mg (cmol (P+) kg^{-1})	10.11	26.25	15.73	3.92	0.66	24.91

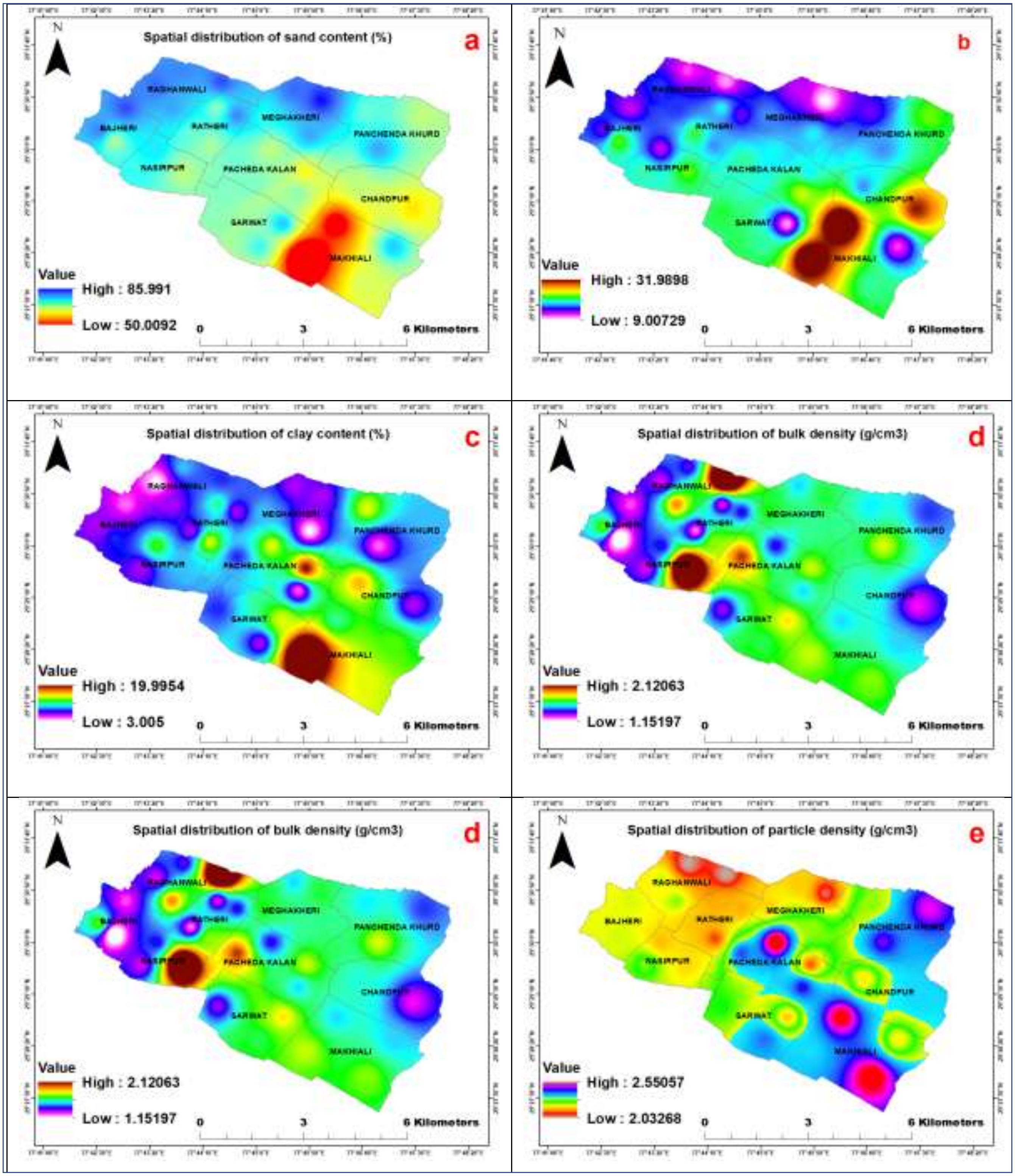

Figure 4: Spatial variability maps of sand, silt, clay, BD, PD, and Porosity of Kukra block of Muzaffarnagar district

80% of the total soil samples taken fell into the neutral category, and the remaining 20% fell into the moderately saline category (Table 3). This led to the conclusion that the majority of the Kukra Block's soils are neutral to slightly saline. The naturally occurring variety of the soils, fertilizer management techniques, and, to some extent, the influence of resource region-specific cultural characteristics could all be contributing factors to the saline reactivity of the examined

Table 3: Percentage wise distribution of soil chemical and nutrient properties of Kukra block of Muzaffarnagar district (Ramamoorthy and Bajaj, 1969)

Parameters	Range	Class	Total no. of samples	Percentage of samples
pH	6.0-6.6	Slightly acidic	0	0
	6.7-7.3	Neutral	28	80
	7.4-8.0	Moderately saline	7	20
EC (dS m^{-1})	<2	Negligible effect of salinity	35	100
	2-4	Sensitive crop affected	-	-
	4-8	Most crops are affected	-	-
	8-16	Only salt-tolerant crops grow satisfactory	-	-
	>16	Very salt-tolerant crops grow satisfactory	-	-
O.C. (%)	<0.5	Low	17	48.57
	0.5-0.75	Medium	10	28.57
	>0.75	High	8	22.86
Av. N (kg ha^{-1})	<280	Low	34.29	34.29
	280-560	Medium	65.71	65.71
	>560	High	-	-
Av. P (kg ha^{-1})	<12.5	Low	4	11.43
	12.5-25	Medium	16	45.71
	>25	High	15	42.86
Av. K (kg ha^{-1})	<135	Low	9	25.71
	135-335	Medium	26	74.29
	>335	High	-	-
Av. S (kg ha^{-1})	<10	Low	-	-
	10-20	Medium	31	88.57
	>20	High	4	11.43
Av. Ca (cmol (P+)/kg)	<1.5	Deficient	-	-
	>1.5	Sufficient	35	100
Av. Mg (cmol (P+)/kg)	<1.0	Deficient	-	-
	>1.0	Sufficient	35	100

soils. A similar reference was taken from (Aydinapl et al., 2010; Prazapati et al., 2024).The concentration of soluble salts in the soil was essentially measured by the electrical conductivity. The soils in the Kukra block under study had an EC range of 0.17 to 1.37 dS m^{-1}, with a mean value of 0.37 dS m^{-1} as well (Table 2). Samples No. 3, and 5 had the lowest EC value of all the 35 soil samples that made up 100% under the minimal influence of salt (Table 3). The highest EC value was 1.37 dS m^{-1} from Raghanwali, with S.D. and C.V. values of 0.22 and 60.79%, respectively. Similar results were observed by Kumar et al. (2023). According to Table 2, the range of organic carbon content for the soils under study was 0.15 to 1.10, with a mean value of 0.56%. With S.D. and C.V. values of 0.23 and 41.02%, respectively, the Makhiali villages had the greatest value. A similar observation was also made by Kumar et al. (2024). Of the 35 soil samples that were taken from the Kukrablock, 48% had low amounts of organic carbon, while 27% fell into the middle range and 22.86% fell in the range of high (Table 2). This happened as a result of the high temperatures and subtropical environment that predominated in that region, which caused the organic carbon to break down quickly. The variability maps of pH, EC and OC were presented in Figure 5.

3.3. *Available nutrient properties*

The studied soil samples from the Kukra block had an available nitrogen concentration ranging from 124.21 to 501.21 kg ha^{-1}, with a mean value of 324.80 kg ha^{-1}, the

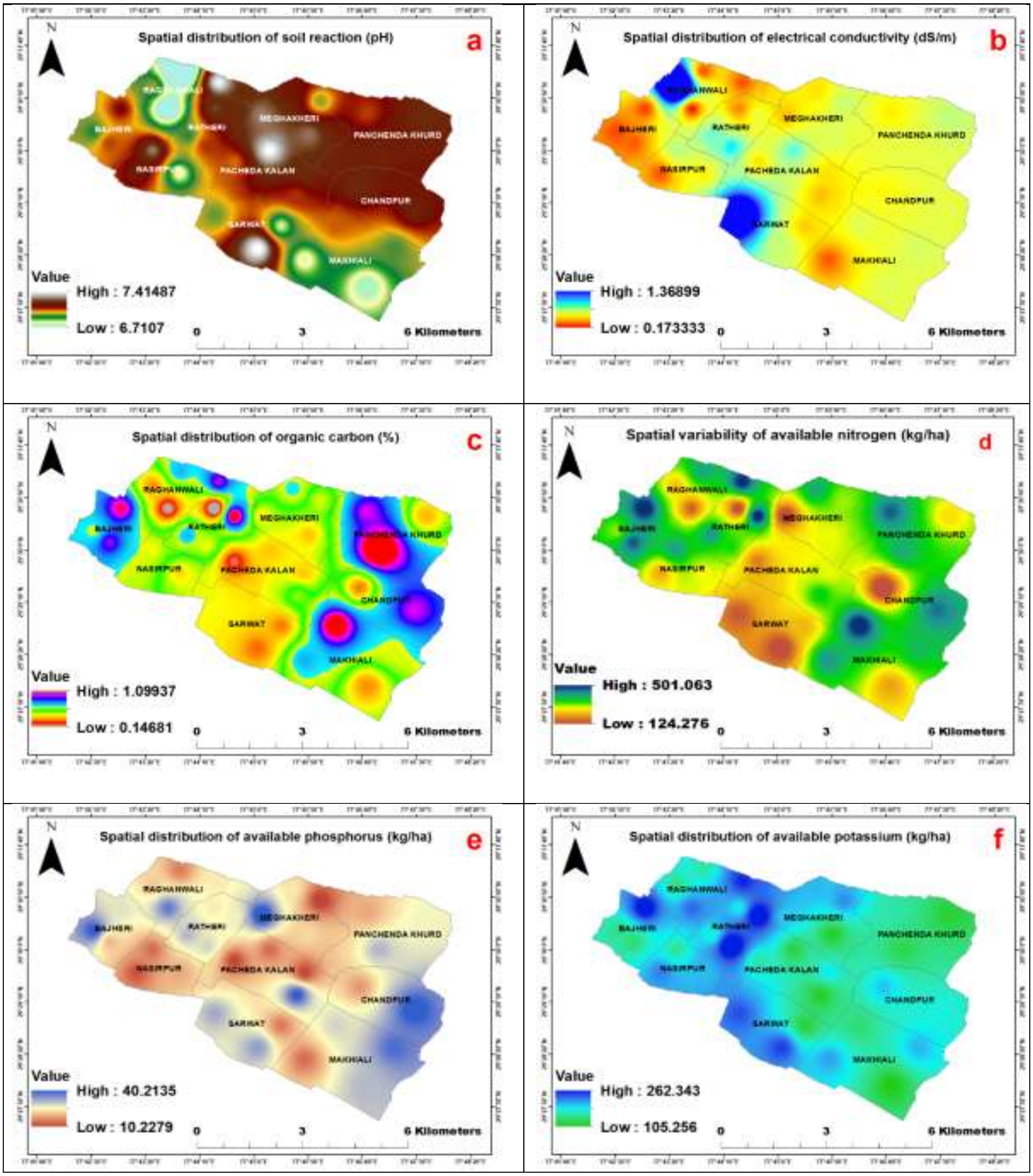

Figure 5: Spatial variability maps of pH, EC, OC, N, P, and K of Kukra block of Muzaffarnagar district

S.D. and C.V. values for the soil's available N, which were 113.86 and 35.06%, respectively (Table 2). The soil in Chandpur village had the lowest amount of nitrogen in it, whereas Makhiali village's soils had the maximum amount of nitrogen that was readily available. 35 soil samples were taken from the Kukra block; 34.29% of the samples fell into the low category and 65.71% into the medium category for available N (Table 3). Because of the high pH, which causes the OC status to fall more quickly and reflects poor available N, the examined soil had low available N. This wasalso observed by Gupta et al. (2019) and Maurya et al. (2024). The mean value of the P examined in the accessible soils was 23.48 kg ha^{-1} and ranges between 10.21 to 40.25 kg ha^{-1}, with the S.D. and C.V. values of 8.43 and 35.91% (Table 2). About 11.43%, 45.71%, and 42.86% of all soil samples fell into the low, medium, or high category. The low P status of these soils, as well as their fixation with sesquioxide (Fe and Al hydroxides) and the formation of calcium phosphate in calcareous soils, maybe the cause of their low P availability.Sharma et al. (2021) had similar results. Table 2 showed that the accessible potassium level in the soil ranged from 105.24 to 262.35 kg ha^{-1}, with a mean value of 165.02 kg ha^{-1}. This observation is also done by Bharteey et al. (2023). The potassium values in Samples 34 and 14 from Makhiali and Ratheri village were the lowest and the highest was found in all 35 samples, with S.D. and C.V. values of 41.97 and 25.43%, respectively. According to limitations (<136–337.5 kg ha^{-1}) established by Baruah et al. (1997), out of 35 soil samples, 25.71% and 74.29% of the examined region are low and medium in available K(Table 3). With a mean value of 4.17 cmol (P^+) kg^{-1}, the accessible calcium in the research region varied from 1.60 to 7.50 cmol (P^+) kg^{-1}. Slightly similar results were observed by Rai and Singh (2018). The variability maps of N, P and Kwere presented in Figure 5. According to Table 2, the S.D. and C.V. values were 1.19 and 28.39%, respectively. The lowest amount of available calcium was found in the soils of Raghanwali village, whereas the highest amount of available calcium was found in Sample No. 20 of Pachenda Kalan. The majority of the samples fell into the adequate category for the Ca that was available. Because limewas applied to the soil of Kukra block, the soil received fertilizers high in calcium. The available magnesium concentration in the soils of the Kukrablock ranged from 2.10 to 7.70 cmol (P^+) kg^{-1}, with a mean of 2.85 cmol (P^+) kg^{-1} (Table 2).

Reddy et al. (2012) andVasundhara et al. (2020) showed an approximate nearby result. Sample No. 24 was found to contain the least amount of magnesium. However, Sample No. 4 had the highest amount of exchangeable magnesium, measuring 7.70 cmol (P^+) kg^{-1}. It was discovered that the exchangeable magnesium content had an S.D. and C.V. value of 1.40 and 28.48%, respectively. The entire sample was determined to fall within the adequate category for exchangeable calibration. The information is displayed in Table 2. The range of sulphur content in soils of Kukra block varied from 10.11 to 26.25 kg ha^{-1} with a mean value of 15.73 $kgha^{-1}$ (Table 2). Sample No 35 had the least content of available sulphur while the highest content of available sulphur was found in another edge of Sample No. 9, 16 and 33. The S.D. and C.V. values for available S in soils of Kukra block region soil were 3.92 and 24.91% respectively. Similar results were also shown bySingh et al. (2021). 100% of the collected soil samples were found in the high range of available sulphur (Table 3). The spatial variability mapsof Ca, Mg, and S areshown in Figure 6.

3.4. Soil nutrient index value (NIV)

The accessible primary nutrients (N, P, K and S) and their corresponding Nutrient Index Value (NIV), the Kukra block soils had low available nitrogen, medium phosphorus and potassium, and low sulphur nutrient index values. NIVs for N, P, K, and S were determined to be 1.65, 2.31, 1.74, and 1.11 after analysis. Three categories of soil fertility- low, medium, and high-were used to determine the NIV of the soils in various regions. According to Singh et al. (2018), the soil's fertility level was classified as low, medium, or high if the NIV was less than 1.67, 1.67–2.33, or more than 2.33 (Figure 5).

3.5. Network analysis

Figure 7 provided the value of the correlation matrix with soil propertiesof soils of the Kukra block of the Muzaffarnagar district. The colour band (based on 'r' values) in the network among different soil physico-chemical properties depicted the strength of association (Figure 7). The broader lines indicate a strong correlation (both positive and negative) and narrow lines suggest a weak correlation. A significant negative correlation between Bulk density with porosity, and a non-significant negative correlation with parameters like sulphur, EC, Ca and organic carbon. The pH of the soil was shown to have a non-significant positive association with the EC and nitrogen contents of the soil. Available nitrogen and organic carbon were shown to be closely correlated, which might be because ammoniacal nitrogen and the humus complex in the soil were closely related. Nitrogen and organic carbon exhibit a strong and positive association. The EC exhibits a non-significant negative association with clay and a non-significant positive correlation with sand. The accessible phosphorus exhibits a non-significant positive correlation with porosity and a non-significant positive correlation with particle density. The figure displays a negative and non-significant correlation between the available calcium and magnesium, silt, and particle density and clay, as well as a non-significant and positive correlation and. There was a non-significant and negative correlation between the available sulphur and EC and OC.

3.6. Principal component analysis of soil parameters

The outcomes PCA using KMO statistical method indicated that the analyzed15 soil properties were successfully accounted for by the three major components whose Eigenvalues were more than 1.5 which accounts for 49.85% variation in the soil parameters (Table 4), Scree plot showed the Eigenvalues (Figure 8), the first three components, namely PCA1 (21.7%), PCA2 (14.6%) and

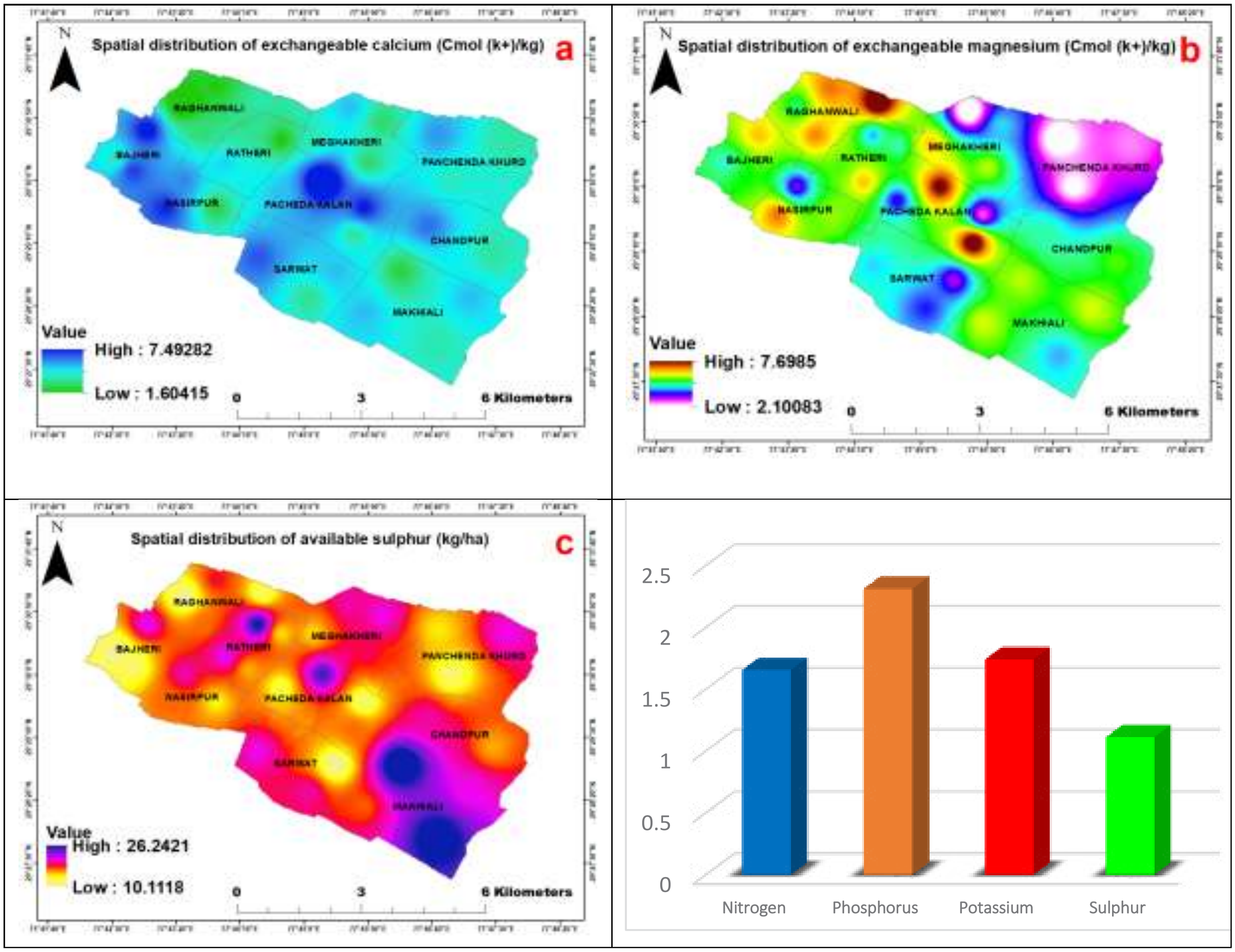

Figure 6: Spatial variability maps of Ca, Mg, S and Nutrient index of Kukra block of Muzaffarnagar district

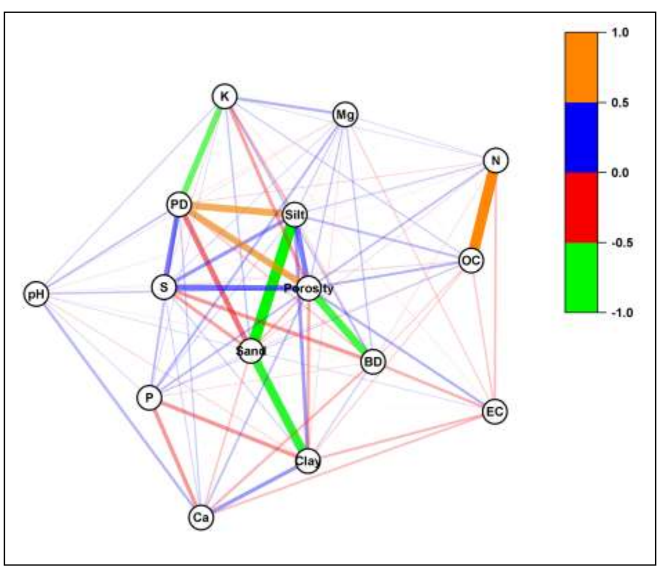

Figure 7: Network analysis between soil physico-chemical properties

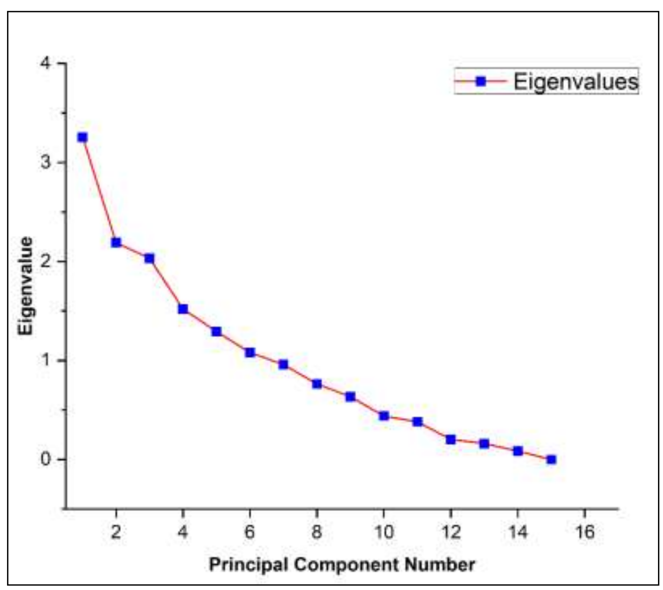

Figure 8: Scree plot showing the eigenvalues

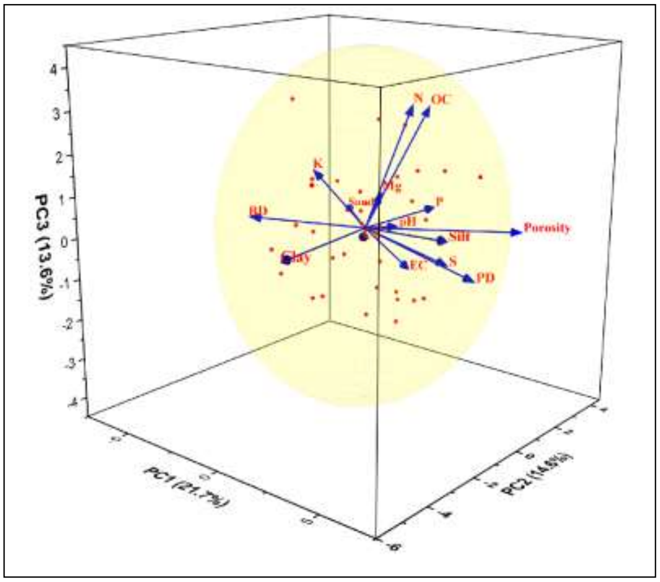

Figure 9: 3D PCA-Biplot showing soil physico-chemical properties of study area

PCA3 (13.6%). From the factor loading matrix of the soil parameters, it was seen that silt, clay, pH, OC, PD, porosity, available N, P, S, Ca and Mg had a positive factor on PCA1, whereas sand, BD and available K had a negative factor on PCA1. The common PCA1 component that had compositions bearing a strong relationship with the inherited mechanical components was given the name of the 'Inherent Potentiality Factor'. The sand, PD, porosity, pH, OC, available N, P, Mg and S had positive factors on PCA2, whereas, Silt, Clay, BD, available K and Ca had negative loaded on PCA2. The weak positive and negative loaded on PCA3. The PCA biplot in Figure 9 shows both the PCA scores of samples and the loading of variables.

Table 4: Principal component analysis of soil physico-chemical analysis of Kukra block of Muzaffarnagar

Parameters	PCA1	PCA2	PCA3
Eigenvalue	3.256	2.191	2.033
Variance (%)	21.705	14.604	13.550
Cumulative (%)	21.705	36.309	49.859
Sand (%)	-0.414	0.378	-0.102
Silt (%)	0.454	-0.134	0.094
Clay (%)	0.158	-0.568	0.066
Bulk density (g cm^{-3})	-0.238	-0.318	0.097
Particle density (g cm^{-3})	0.429	0.055	-0.180
Porosity (%)	0.398	0.374	-0.041
Soil reaction (pH)	0.038	0.134	-0.025
Electrical conductivity (dS m^{-1})	0.023	0.216	-0.292
Organic carbon (%)	0.110	0.208	0.596
Available Nitrogen (kg ha^{-1})	0.087	0.143	0.612
Available Phosphorus (kg ha^{-1})	0.045	0.332	0.021
Available Potassium (kg ha^{-1})	-0.225	-0.021	0.260
Available Calcium (Cmol(k+)/kg)	0.135	-0.168	0.034
Available Magnesium (Cmol(k+)/kg)	0.025	0.056	0.180
Available Sulphur (kg ha^{-1})	0.323	0.048	-0.126

4. CONCLUSION

The present study was aimed to evaluate the soil fertility status of the Kukra block in Muzaffarnagar district, thereby enabling local farmers to utilise these recommendations for assessing their soil conditions and improving crop yields over time.

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