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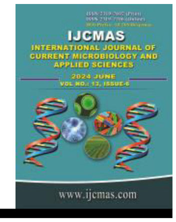

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Assessment of Physio-chemical Properties on Alluvial Soils of North-Western District of Uttar Pradesh, India

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A B S T R A C T

Maintaining agricultural productivity and environmental health is essential for that optimized soil management practices, targeted fertilization, efficient irrigation, and strategic crop rotation are required. This can be achieved by examining the physical and chemical attributes of soil. The physical aspects like soil texture, structure, porosity, and water retention capacity are critical for supporting plant growth, managing water infiltration, and preventing erosion. The chemical attributes such as pH levels, nutrient availability, cation exchange capacity, and salinity affect how nutrients are accessed and retained by plants. Studying soil properties is vital for maintaining soil health, ensuring food security, and protecting ecological systems. For the same objective, part of Shamli-a north-western district of Uttar Pradesh was selected and soil samples from surface and sub-surface regions were taken for laboratory analysis of the required attributes. The results shows that soil of the region is alkaline with sandy loam texture. To find linear correlations—that is, if an increase in one variable is linked to a reduction in another—between the various physio-chemical qualities, the Pearson's co-relation among them was examined. Understanding that between soil's physical and chemical properties is vital for comprehending soil health and its functionality. These properties interplay to influence soil fertility, structure, and plant support capabilities. For example, soil texture and structure affect water retention and drainage, impacting nutrient availability. Likewise, chemical properties like pH and nutrient content can influence soil structure by affecting aggregate stability. Investigating these correlations allows researchers and farmers to develop improved soil management practices, enhancing agricultural productivity, promoting sustainable land use, and reducing environmental degradation. It is seen that the fertility of the region is not satisfactory implying poor soil health conditions.

Introduction

Soil is a natural resource that allows crops to thrive and feed the entire country. With the rapid expansion in human population, increased crop output should be available to support the growing population. Soil is a source of nutrients that plants need to meet their nutritional requirements and continue to grow and develop, hence a sufficient quantity of nutrients should be present. Natural sources of nutrition and the addition of various fertilizers are used to meet nutritional requirements. Soil nutrients are the ingredients that enable plant growth and crop productivity, therefore maintaining adequate nutrient concentrations helps ensure long-term yields (Arevalo-Gardini, *et al.,* 2015).

The concentration of nutrients in the soil varies between plots in an area and within a field. This type of soil analysis is required to determine specific nutrient concentrations in different plots of the same field or distinct plots. Soil analysis in a specific region is mostly accomplished through a sampling technique in which a field is divided into plots and soil samples are collected from each plot and sent to laboratories for examination. Plant nutrients exist in separate forms in soil and are in a dynamic equilibrium condition. Essential nutrient is required lifetime for the survival of the plant. It is closely related to plant metabolism and biological processes. To be considered an essential nutrient, an element must meet D.I. Arnon and P.R. Stout's essentiality criterion (1939). Plant growth necessitates the consumption of 17 key elements. The two types of nutrients found in soil are called macronutrients and micronutrients. Macronutrients such carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur must be consumed in greater amounts. As primary nutrients, nitrogen, phosphorous, and potassium are highly sought after by plants and their deficiency has far-reaching effects (Edem and Ndaeyo, 2009; Colombo, *et al.,* 2014). Due to their low requirements and specific deficiencies, calcium, magnesium, and sulphur are considered secondary nutrients. Micronutrients are just as vital as macronutrients, however they are less necessary for plants. Among them are Nickel, Iron, Manganese, Zinc, Copper, Boron, Molybdenum, and Chlorine. Sodium, silicon, cobalt, selenium, chromium, and vanadium are among the elements that are beneficial. Structural elements include carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulphur. Among the elements that activate enzymes are manganese, zinc, calcium, magnesium, and potassium. Iron, manganese, copper, and molybdenum are examples of redox reagents. Magnesium, calcium, and potassium are transporters and regulators. Conversely, micronutrients such as Fe, Mn, Zn, and Cu are only found abundantly in an acidic environment. Sometimes these nutrients surpass the dangerous threshold, and when they reach high enough quantities, they damage plants. Cropping strategies and fertilizer use can potentially alter the status of micronutrients. In the top soil, the amount of organic matter varies from 3 to 5% by weight, which is a very small amount. Organic matter acts as a storehouse for nutrients in soil. Apart from these organic materials, organic matter is what gives surface soils their ideal structure, promotes a greater percentage of bigger particles, and improves the soil's ability to hold water and breathe (Bassirani, et al., 2011; Bhanwaria, et al., 2011).

The assessment of physio-chemical properties of soils is pivotal in understanding soil health, fertility, and suitability for agriculture. In the north-western district of Uttar Pradesh, alluvial soils is dominant due to their inherent fertility and favourable physical characteristics. Previous studies have highlighted the importance of evaluating soil attributes such as texture, structure, pH, organic matter content, and nutrient availability to optimize crop production and sustainable land management (Singh *et al.,* 2020; Sharma & Kumar, 2018). The dynamic interaction between physical and chemical properties of these soils can significantly influence water retention, nutrient dynamics, and overall soil productivity (Kumar *et al.,* 2019). Understanding these relationships helps in formulating better soil management practices and enhancing agricultural outputs. This study aims to systematically evaluate the physio-chemical properties of alluvial soils in this region, providing a comprehensive understanding that can inform local farming practices and soil conservation strategies.

Understanding the physical properties of soil is crucial for comprehending its capacity to support plant growth, manage water resources, and maintain environmental sustainability. Soil physical properties, such as texture, structure, density, porosity, and water-holding capacity, directly affect root development, water infiltration, and nutrient availability. These characteristics influence agricultural productivity and ecological balance, making their study essential for effective soil management (Hillel, 2008; Brady & Weil, 2017). Recent research has underscored the importance of these properties in various soil functions, including aeration, water movement, and microbial activity, which are vital for sustaining plant health and crop yields (Lal & Shukla, 2004; Moraru, *et al.,* 2020). For example, the proportions of sand, silt, and clay in the soil affect drainage and water retention, which in turn affect crop choice and irrigation techniques (Blanco-Canqui & Lal, 2008). For example, the proportions of sand, silt, and clay in the soil affect drainage and water retention, which in turn affect crop choice and irrigation techniques (Blanco-Canqui & Lal, 2008). This study aims to delve into the physical properties of soil, providing a comprehensive analysis that can inform better agricultural practices and soil conservation efforts. Understanding the chemical properties of soil is fundamental to enhancing soil fertility, optimizing plant growth, and maintaining sustainable agricultural practices.

The chemical qualities of soil, such as pH, organic matter levels, cation exchange capacity (CEC), and nutrient content, are important factors that affect soil health and nutrient availability. These characteristics affect the uptake of nutrients by plants, microbial activity, and nutrient cycling, among other soil processes (Brady & Weil, 2017; Havlin *et al.,* 2014). Current research highlights how important soil pH is for influencing microbial populations and nutrient availability and solubility (Sparks, 2003). Additionally, the cation exchange capacity is vital for retaining essential nutrients and maintaining soil fertility over time (Rengel, 2015). Organic matter, another key component, enhances soil structure, water retention, and provides a reservoir of nutrients for plant growth (Weil & Brady, 2016). The objectives of this research work is to study the amount of macro and micro nutrient from the collected soil samples and their physical attributes then to determine co-relation among them to understand proper nutrient management.

Materials and Methods

Study area and sampling

The Shamli district, which is situated at an elevation of 254 meters (833 feet) above mean sea level (MSL) and latitudes of 290 44′ north and 770 310′ east, is where the soil samples are gathered. The area have semi-arid to sub-tropical climate. Soil samples from KVK, Shamli was collected on 19th January, 2021. A "V" shaped hole was bored to take samples. Surface contaminated debris was removed using a spade or khurpi. After that, the samples were allowed to air dry in a room for five to six days. Afterwards, the samples are separated using an 80 mm mesh screen and the aggregates are smashed using a long hammer in the soil processing laboratory. Following that, materials were divided into distinct polythene packets with markings for various depths and plot numbers. These packets were then examined in a laboratory for a variety of physio-chemical characteristics.

Sample processing and laboratory analysis

After using a long hammer to break up the aggregates, samples were sorted using an 80 mm mesh sieve. Estimations are made of the following: pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium, Ca, Mg, Fe, Mn, Cu, and Zn; hydraulic conductivity; infiltration rate; bulk density; particle density; porosity; aggregate stability; and so on. Bulk density is the ratio of weight of oven dry soil and volume of soil expressed as Mg m-3. Particle density is estimated using pycnometer, consider only the volume of soil solids. Porosity percentage is calculated as % porosity = (1- Bulk density/particle density) x100 and ranges from 30-60%. Towards 60% indicates clay soil and towards 30% for more % of sand.

The hydrometer method is used to study the soil texture using principle of Stoke’s law. Aggregate stability estimated by wet sieving apparatus that indicates the soil structure. Organic carbon is analysed by Walkey and Black method, Nitrogen by Kjheldal apparatus, Phosphorous by spectrometer and potassium, sodium by flame photometer. AAS used to estimate the different micro-nutrients present in the samples. Sodium adsorption ratio is used to measures the relative concentration of sodium to calcium and magnesium ions in soil. A high SAR value indicates a high sodium content relative to calcium and magnesium, which can lead to soil dispersion, reduced permeability, and poor soil structure. This condition, known as sodicity, negatively impacts water infiltration, root penetration, and ultimately plant growth. It is evaluated by taking ratio of total Na ions by square root of average of Mg and Ca ions.

Exchangeable sodium percentage is also estimated which is indicator of soil sodicity, representing the proportion of sodium ions relative to the total cation exchange capacity of the soil. High ESP levels can lead to detrimental soil conditions, such as poor structure, reduced permeability, and impaired water infiltration. These adverse effects are due to the dispersive nature of sodium, which causes soil particles to repel each other, leading to compaction and reduced aeration. Consequently, high ESP can severely limit plant growth by restricting root development and nutrient uptake. Monitoring and managing ESP is essential for maintaining soil health, particularly in irrigated agricultural systems where sodium accumulation is a risk.

Pearson co-relation

Studying Pearson correlation is vital because it measures the strength and direction of the linear relationship between two continuous variables, yielding a numerical value from -1 to +1. Pearson correlation helps identify linear associations, indicating whether an increase in one variable is associated with an increase or decrease in another.

$$\text{Correlation coefficient } (X, Y) = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

Where, r = correlation coefficient, x is x- variables, $\bar{x}$is the mean of x values, y is y- variables and $\bar{y}$ is mean of y values.

Results and Discussion

Physical attributes of collected soil samples

- Textural class: 14 samples have sandy loam and 01 is in the sandy clay loam textural group. Proportion of sand ranges 62 to 82 % with an average of 72 %, silt fractions from 3 to 23 % with an average of 13 %, and clay fractions from 12 to 26 % with an average of 19 %. The ratio of silt to clay in all plots exceeds the threshold level of 0.4.
- Bulk Density: Soil BD varies from 1.30 to 1.46 Mg/m^3.at surface layer and 1.43-1.74 Mg/m3 at the subsurface. The average value lies 1.38-1.58 Mg/m^3.
- Particle density: values varies between 2.31-2.51 Mg/m^3.In surface, the PD of sandy loam soil ranges 2.18-2.45 Mg m-3 and at subsurface it varies between 2.32-2.70 Mg/m^3. Thus, the surface soil has a lower PD than subsurface soil.
- Porosity: Surface soil porosity ranged from 35.78 to 44.41 %, while subsurface soil porosity ranged from 30.54 to 46.58 %.
- Aggregate Stability: Aggregate stability (water stable aggregates) ranged from 18.10 to 21.86 % at the surface and 12.34 to 17.00 % below the surface.
- The Hydraulic conductivity: ranges between 4.58 and 7.48 cm hr-1. Plot no 2 had the highest HC (7.48 cm/hr), whereas plot no 4 had the lowest (4.58 cm/hr).
- Rate of Infiltration: The maximum IR (8.83 cm/hr) was in plot number 2, whereas the least IR (5.40 cm/hr) reported on plot no 4. The average IR is 7.11 cm/hr.

Chemical attributes of collected soil samples

Macro-nutrients

- pH: The pH lies between 7.44 to 8.03 at the surface and 7.64 to 8.40 at sub-surface.
- EC: The electrical conductivity ranges 0.13 to 0.23 dS/m at surface layer whereas 0.18 to 0.27 dS/m1 at sub-surface layer.
- OC: The organic carbon percentage lies between 0.39-0.84 % at surface and 0.24 to 0.51 % at sub-surface layers.
- N: Nitrogen proportion ranges 184.70-305.10 kg/ha and 116.51-211.04 kg/ha.
- P: phosphorous ranges 19.56-25.98 kg/ha and 17.31-23.73 kg/ha
- K: potassium values 294.77-391.52 kg/ha and 230.92-323.36 kg/ha.
- Ca: soil exchangeable calcium ranges 1.83-4.23 and 1.92-4.14 meq/L soil.
- Mg: soil exchangeable magnesium ranges 1.01-2.21 and 0.97-2.08 meq/L soil.
- Na: samples' exchangeable sodium lies 5.74-8.35 and 3.98-7.85 meq/L soil.
- Ca/Mg ratio: the ratio lies 1.80-1.91 whereas the Mg/K ratio lies 1.18 to 3.15.

Micro-nutrients

- DTPA-extractable Cu ranges 0.319-1.682 and 0.267-1.312 mg/kg soil.
- Zn value ranges 1.07-2.16 mg/kgsoil and 0.58-1.52 mg/kg soil.
- Available iron lies between 8.24-12.91 mg/kg soil and 6.95-10.56 mg/kg soil.
- Mn in soil lies 13.50-23.53 mg/kg and 11.57-20.63 mg/kg.

Table.1 Correlation of different Physio-Chemical properties of soil samples

Attributes	pH	EC	N	P	K	OC	Cu	Fe	Mn	Zn	SAR	ESP
Sand%	0.247	0.349	0.041	0.236	-0.296	-0.190	-0.047	-0.097	0.178	-0.031	0.336	0.335
Silt%	0.290	0.050	-0.167	-0.067	-0.042	-0.219	0.242	-0.019	-0.303	-0.173	-0.227	-0.224
Clay%	-0.217	0.096	-0.066	-0.007	-0.216	-0.082	0.142	-0.538	-0.221	-0.053	0.017	0.013
BD	-0.218	-0.327	-0.352	-0.544	0.035	-0.190	0.235	0.328	-0.011	-0.408	0.125	0.124
PD	-0.064	-0.383	-0.613	-0.601	-0.384	-0.489	0.322	0.355	-0.120	-0.470	-0.173	-0.169
Porosity	0.157	0.395	0.104	0.258	-0.047	-0.114	-0.085	-0.027	0.020	0.060	0.435	0.433
IR	-0.008	-0.107	0.170	0.160	0.093	0.149	-0.030	0.274	0.190	0.029	0.103	0.105
HC	-0.009	-0.108	0.178	0.159	0.094	0.147	-0.031	0.275	0.189	0.030	0.102	0.108
Aggregate stability	-0.163	-0.343	-0.175	-0.245	-0.196	-0.048	-0.206	-0.081	0.049	-0.042	0.356	0.352

Table.2 Classification of Shamli soil on the basis of Nutrient Index

S No	Name of Nutrient	Percent sample			Nutrient Index		Fertility Status class
		Low	Medium	High	Observed	Proposed	
1	Nitrogen Surface	100	Nil	Nil	1.27	<1.67	Low
	Subsurface	100	Nil	Nil	1.00		Low
2	Phosphorus Surface	Nil	100	Nil	2.40	1.67-2.33	medium
	Subsurface	Nil	100	0	2.00		medium
3	Potassium Surface	Nil	100	Nil	3.00	1.67-2.33	medium
	Subsurface	16.67	83.33	Nil	2.46		medium

Figure.1 Map of the Shamli area

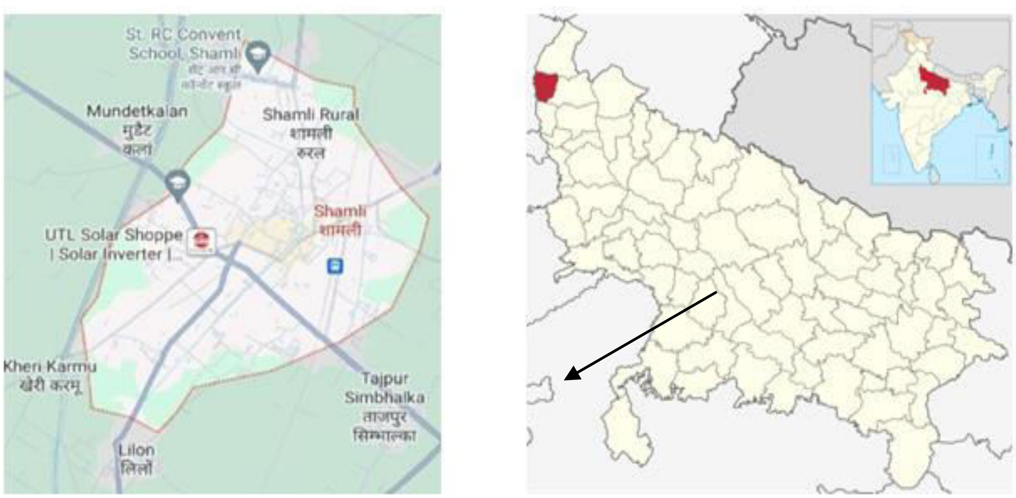


Figure.2 Box plot soil properties in surface soil

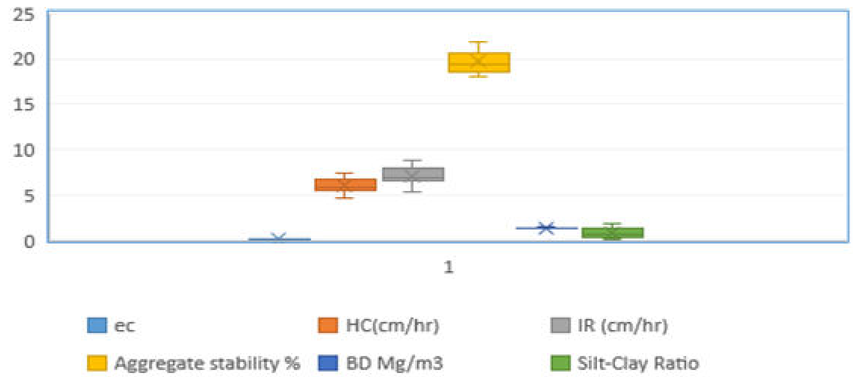


Figure.3 Scatter plot of silt and clay in surface soil (%)

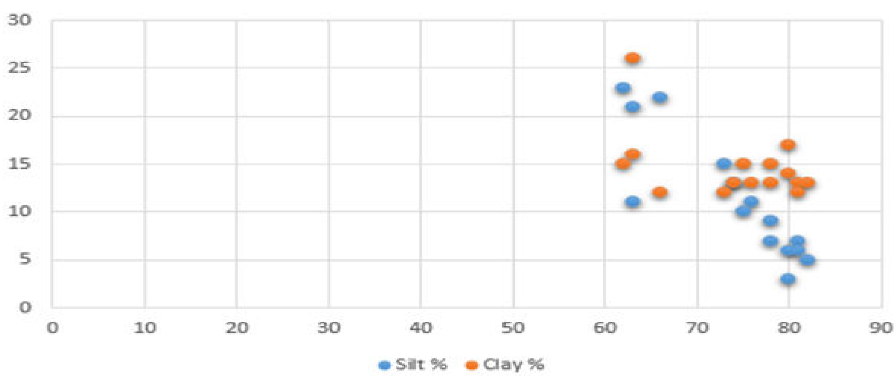
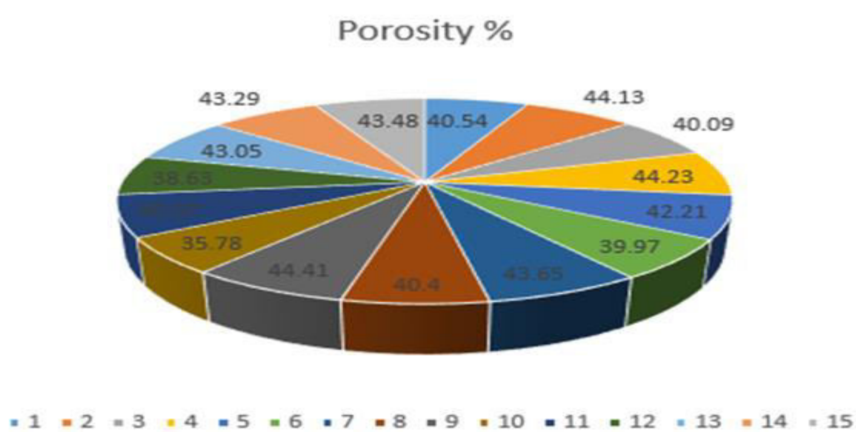


Figure.4 Pie chart of porosity % values of the surface soil



Pearson's co-relation among different attributes

The pH is significantly and positively correlated with manganese (0.226), non-significantly and negatively correlated with electrical conductivity (-0.037), positively correlated with nitrogen (0.220), phosphorus (0.310), organic carbon (0.190), Cu (0.362), and negatively correlated with potassium (-0.251), Zn (-0.096), and Fe (-0.110). Additionally, there were positive correlations between EC and P (0.516), K (0.286), O.C. (0.213), N (0.465), Fe (0.074), Zn (0.690), SAR (0.388), and ESP (0.386), as well as negative correlations with Cu (-0.170) and Mn (-0.429).O.C and nitrogen have a significant and positive relationship (0.931).

It was shown that potassium had negative relationships with copper (0.312), iron (-0.258), manganese (-0.263), and SAR and ESP that did not achieve statistical significance. Conversely, potassium had positive relationships with zinc (0.558) and organic carbon (0.660). Cu exhibits a statistically significant negative association (-0.504) with Zn and a statistically significant positive relationship (0.146) with Mn, Fe, SAR, and ESP. Zn and iron showed a negative association (-0.089), while ESP and SAR showed positive correlations (0.479 and 0.473), respectively. There was an inverse relationship between manganese and zinc (-0.365), SAR (-0.092), and ESP (-0.089). Zinc exhibited a favourable relationship with both SAR and ESP, whereas SAR had a strong and positive association with ESP (0.909). The pH of the soil has a negative correlation with clay (-0.217), bulk density (-0.218), particle density (-0.064), porosity (-0.064), infiltration rate (-0.008), hydraulic conductivity (-0.009), and water stable aggregate (-0.163), but a positive correlation with sand (0.247) and silt (0.290).

In contrast to negative correlations for BD (-0.327), P.D. (-0.383), infiltration rate (-0.107), hydraulic conductivity (-0.108), and water stable aggregate (-0.343), positive correlations were found for clay (0.096), porosity (0.395), sand (0.349), and silt (0.050).It was demonstrated that there were substantial and unfavourable relationships between soil organic carbon and sand (-0.190), P.D. (-0.489), BD (-0.190), porosity (-0.114), silt (-0.219), clay (-0.082), and water stable aggregate (-0.048). There is a positive but non-significant correlation between OC and hydraulic conductivity (0.147) and infiltration rate (0.149). Sand has non-significant positive correlations with infiltration rate (0.190), clay (0.232), Porosity (0.925), H.C. (0.189), silt (-0.319), and P.D. (-0.493), negative correlations with BD (-0.158), and non-significant positive correlations with sand (-0.319). In terms of HC (-0.291), IR (-0.291), B.D (-0.238), P.D (-0.088), porosity (0.100), and aggregate stability (0.264), clay was found to have a negative connection. There is a positive and significant association between infiltration rate (0.130), HC (0.130), aggregate stability (0.180), and P.D (0.285); nevertheless, there is a negative and significant relationship between B.D and porosity (-0.036).

Therefore, fertility status of the region is low in terms of nutrient content thus require proper nutrient management procedures to enrich soil health and soil quality.

It's obvious that the soils under study are a fragile bionetwork with various boundaries that could compromise soil health and crop development and productivity. According to a research of physio-chemical properties, the soils of KVK Shamli are not suitable for crop growth without the use of various management measures. According on the findings, the following limitations have been discovered. Water scarcity in the root zone is a possibility because soil hydraulic conductivity and infiltration are somewhat quick due to low bulk density and more macro pores in the soil, especially in summer crops. The physical qualities of the soil in the study region were insufficient for growing crops in a satisfactory manner without the use of management measures (Xu, *et al.,* 2013; Musinguzi, *et al.,* 2016). The majority of soils have poor fertility, as measured by the nutrient index, due to low nitrogen and organic carbon availability, as well as medium phosphorus and potassium. As a result, rigorous management is required to ensure soil health and productivity. To improve the fertility of KVK soil, some of the management strategies indicated below can be used alone or in combination. Because agricultural soil is prone to erosion, which can alter chemical configuration, regular soil testing is recommended for future soil fertility management. The management proposal based on the findings would be to raise the levels of organic matter in the soils by adding good quality farmyard manure, mulching, compost, incorporating crop wastes and adding balanced fertilizers. Fertilizers with an INM approach should be used to boost nutrient availability and promote nutrient uptake. To prevent soil erosion, agronomical measures must be implemented, as well as some measures such as the construction of a cemented channel and the use of diversion. Soil management strategies to manage hydraulic conductivity and infiltration rate are essential to achieve soil health and higher sustainable yields.

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Author Contributions

Arunima Chakraborty: Investigation, formal analysis, writing—original draft. Yogesh Kumar Kataria: Validation, methodology, writing—reviewing. Satendra Kumar:—Formal analysis, writing—review and editing. Adesh Singh: Investigation, writing—reviewing. S. P. Singh: Resources, investigation writing—reviewing. R. K. Naresh: Validation, formal analysis, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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