International Journal of Science, Strategic Management and Technology
Volume **02** Issue **07** July- **2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

A Comparative Study on Soil Quality Dynamics in Saharanpur District, Uttar Pradesh

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https://doi.org/ 10.55041/ijsmt.v2i7.002

Cite this Article: Patel, P. (2026). A Comparative Study on Soil Quality Dynamics in Saharanpur District, Uttar Pradesh. International Journal of Science, Strategic Management and Technology, *02*(7). https://doi.org/10.55041/ijsmt.v2i7.002

ABSTRACT

Soil quality is a fundamental determinant of agricultural productivity, environmental sustainability, and ecosystem health. In an agriculturally important district such as Saharanpur, Uttar Pradesh, soil characteristics have undergone significant changes due to intensive cultivation, excessive fertilizer application, irrigation practices, urban expansion, and changing climatic conditions. Continuous monitoring of soil quality is therefore essential for maintaining crop productivity and ensuring sustainable land management. The present study comparatively evaluates the soil quality dynamics of selected agricultural regions of Saharanpur District by examining important physicochemical parameters, including soil pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), available phosphorus (P), and available potassium (K). The study primarily relies on comparative analysis of published scientific literature, government soil health records, and regional agricultural reports to assess spatial variations in soil fertility.

The comparative assessment indicates that the district exhibits considerable variability in soil properties due to differences in land use, irrigation intensity, cropping patterns, and management practices. While several regions maintain moderate to high fertility owing to fertile alluvial deposits, continuous cultivation without balanced nutrient replenishment has resulted in declining organic carbon content and nutrient imbalances in many agricultural fields. The study also identifies localized increases in soil salinity and alkalinity associated with irrigation practices and improper drainage. Comparison with previous studies demonstrates a gradual decline in soil health indicators over the past decade, highlighting the necessity for improved soil conservation strategies.

The study contributes valuable scientific information for researchers, agricultural planners, and policymakers working towards sustainable soil resource management.

Keywords: Soil Quality, Saharanpur District, Soil Fertility, Organic Carbon, Nutrient Dynamics, Soil Health, Sustainable Agriculture, Physicochemical Properties.

Introduction

Soil is one of the most valuable natural resources and forms the foundation of terrestrial ecosystems. It serves as the primary medium for plant growth by supplying essential nutrients, water, oxygen, and physical support to crops. In addition to sustaining agricultural production, soil regulates the hydrological cycle, stores carbon, supports biodiversity, and acts as a natural filter for pollutants. The quality of soil directly influences crop productivity, food security, environmental sustainability, and the economic well-being of farming communities. As agricultural practices become increasingly intensive to meet the demands of a growing population, maintaining soil health has become a major scientific and environmental concern.

Soil quality refers to the capacity of soil to perform its ecological and agricultural functions while maintaining environmental quality and supporting plant and animal health. It is determined by a combination of physical, chemical, and biological properties. Important indicators of soil quality include soil texture, pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), available phosphorus (P), available potassium (K), moisture content, microbial activity, and bulk density. These parameters collectively determine the fertility, productivity, and long-term sustainability of agricultural soils. Variations in these properties occur naturally because of differences in parent material, topography, and climate, but they are also significantly influenced by human activities such as fertilizer application, irrigation, crop rotation, pesticide use, and land-use changes.

Saharanpur District, situated in the north-western part of Uttar Pradesh, represents one of the agriculturally productive regions of the Indo-Gangetic Plains. The district is characterized by fertile alluvial soils deposited by rivers such as the Yamuna and Hindon and their tributaries. Agriculture forms the backbone of the district's economy, with major crops including sugarcane, wheat, rice, maize, mustard, and fodder crops. The favorable climatic conditions, extensive irrigation network, and fertile soils have contributed significantly to agricultural development. Nevertheless, continuous cultivation, intensive cropping systems, increasing dependence on synthetic fertilizers, and irregular irrigation practices have gradually altered the physicochemical characteristics of soils in several parts of the district. Comparative assessment of soil quality provides valuable insights into differences among agricultural regions, cropping systems, and management practices. By comparing key soil quality indicators across different locations and with findings from earlier studies, researchers can identify trends in soil degradation, nutrient depletion, and environmental stress. These comparisons also help evaluate the effectiveness of government initiatives such as the Soil Health Card Scheme and promote evidence-based agricultural decision-making.

3. Previous Research Studies (Literature Review)

Soil quality assessment has become an important area of agricultural and environmental research because it provides valuable information about soil fertility, nutrient availability, crop productivity, and long-term sustainability. Several researchers have evaluated the physicochemical properties of soils in different parts of India, particularly in the Indo-Gangetic Plains, where intensive agriculture has significantly influenced soil health. Previous studies indicate that continuous cultivation, excessive use of chemical fertilizers, declining organic matter, and improper irrigation practices have altered the physical and chemical characteristics of agricultural soils.

One of the most significant studies related to Saharanpur District was conducted by **Ashok et al. (2017)**, who evaluated the nutrient status of wheat-growing soils collected from farmers' fields. Their findings revealed that most soils were **low to medium in organic carbon (approximately 0.50%)**,

low in available nitrogen (about 193 kg ha^{-1}), while phosphorus and potassium were generally within the medium range. The authors emphasized the importance of **soil-test-based fertilizer recommendations** and regular nutrient monitoring to improve wheat productivity and maintain soil fertility.

A later regional assessment of soil fertility in Saharanpur also reported considerable spatial variability in organic carbon soil, nitrogen, and available nutrients across irrigated agricultural lands. The study concluded that although the district possesses fertile alluvial soils, continuous cultivation without sufficient organic matter addition has gradually reduced soil fertility in intensively cultivated areas. The researchers recommended integrated nutrient management and balanced fertilizer application for sustaining crop yields.

Saxena (2021) investigated the relationship between soil quality and agricultural productivity in Saharanpur District. The study reported that increasing dependence on chemical fertilizers, intensive sugarcane cultivation, and declining organic matter have adversely affected soil quality. However, fields receiving organic manure and balanced fertilization maintained comparatively better soil structure, nutrient availability, and productivity. The research emphasized the importance of conservation-oriented agricultural practices for sustaining long-term soil health.

Table 1. Summary of Previous Research Studies

Author(s)	**Year**	**Study Area**	**Major Findings**
Ashok et al.	2017	Saharanpur	Low organic carbon and nitrogen; medi phosphorus and potassium; recommended s test-based fertilizer application.
Saxena	2021	Saharanpur	Intensive cultivation reduced soil quali balanced fertilization improved productivity.
Regional Soil Fertility Assessment	2019	Saharanpur	Significant variation in soil fertility acr irrigated agricultural lands.
Recent Comparat Studies	2024–2025	Indo-Gangetic Plains	Legume and pasture systems maintained super soil quality compared with intensive cropp systems.

4. Methodology

4.1 Research Design

The present study adopts a **comparative descriptive research design** to evaluate soil quality dynamics in Saharanpur District, Uttar Pradesh. The study compares major physicochemical soil properties reported from different agricultural regions within the district and analyzes variations in soil fertility using published scientific literature, government soil health records, and agricultural reports. This approach is appropriate for identifying differences in soil quality across locations and assessing the impact of agricultural practices on soil health. Comparative soil assessment commonly relies on multiple indicators such as pH, EC, organic carbon, and available macronutrients to evaluate overall soil quality.

4.2 Study Area

Saharanpur District is located in the north-western region of Uttar Pradesh between approximately **29°34′–30°21′ N latitude** and **77°09′–78°13′ E longitude**. The district forms part of the fertile Indo-Gangetic Plains and is bordered by Haryana, Uttarakhand, Muzaffarnagar, and Shamli districts.

The region experiences a **sub-tropical climate** with:

- Average annual rainfall: **900–1100 mm**
- Average temperature: **5°C (winter) to 42°C (summer)**
- Dominant soil type: **Alluvial soil**
- Major crops: Sugarcane, wheat, rice, maize, mustard and fodder crops.

These favorable conditions make Saharanpur one of the important agricultural districts of western Uttar Pradesh.

4.3 Data Collection

The present investigation is based on **secondary data analysis**. Information was collected from:

- Peer-reviewed scientific journals
- ICAR research publications
- Government agricultural reports
- Soil Health Card Scheme records
- Published soil fertility studies conducted in Saharanpur District
- Agricultural university publications

The collected information was carefully screened for consistency and reliability before comparative analysis. Earlier studies on Saharanpur wheat-growing soils and recent soil-quality assessment methods provided the principal reference framework.

4.4 Soil Quality Parameters

The comparison was performed using widely accepted indicators of soil quality.

Parameter	Importance
Soil pH	Indicates soil acidity or alkalinity Electrical Conductivity (EC) Measures soluble salt concentration
Organic Carbon (OC)	Indicator of soil fertility and microbial activity Available Nitrogen (N) Essential for vegetative crop growth Available Phosphorus (P) Supports root development and flowering Available Potassium (K) Improves crop quality and disease resistance

These parameters are widely recognized as reliable indicators for evaluating agricultural soil quality in India.

4.5 Comparative Analysis

The collected soil data were grouped according to the reported agricultural locations within Saharanpur District. Each parameter was compared to determine:

- Spatial variation in soil fertility.
- Nutrient deficiency patterns.
- Changes in organic carbon levels.
- Variability in pH and salinity.
- Influence of intensive agricultural practices on soil quality.

The values were interpreted using standard soil fertility classifications recommended by ICAR and related agronomic guidelines.

4.6 Statistical Analysis

The comparative analysis employed descriptive statistical techniques including:

- Mean
- Percentage variation

- Comparative tables
- Graphical representation
- Trend interpretation

Since the study is based on published datasets rather than new laboratory experiments, inferential statistical tests were not applied. Instead, differences among soil quality indicators were interpreted through comparative evaluation of reported values.

4.7 Research Workflow

The study followed the following sequence:

1. Selection of Saharanpur District as the study area.
2. Collection of published soil quality data.
3. Selection of key physicochemical parameters.
4. Comparative evaluation of soil fertility indicators.
5. Preparation of tables and graphical representations.
6. Interpretation of results.
7. Identification of impacts on agriculture.
8. Suggestion of suitable remediation measures.

5. Results and Discussion

The comparative evaluation of soil quality in Saharanpur District revealed considerable variation in the major physicochemical properties influencing agricultural productivity. The assessment focused on soil reaction (pH), electrical conductivity (EC), organic carbon (OC), available nitrogen (N), available phosphorus (P), and available potassium (K). These indicators collectively determine soil fertility, nutrient availability, microbial activity, and crop performance.

The reviewed studies indicate that the agricultural soils of Saharanpur are predominantly **alluvial**, possessing naturally moderate fertility. However, long-term intensive cultivation, especially under sugarcane–wheat and rice–wheat cropping systems, has resulted in gradual depletion of soil organic matter and available nitrogen. Similar observations have been reported in recent studies from western Uttar Pradesh.

Table 2. Comparative Soil Quality Indicators

Soil Parameter	**Observed Status in Saharanpur**	**General Optimum Range**	**Interpretation**
pH	7.4–8.2	6.5–7.5	Slightly alkaline
Electrical Conductivity (dS m^{-1})	0.20–0.60	<1.0	Non-saline
Organic Carbon (%)	~0.50	>0.75	Low to Medium
Available Nitrogen (kg ha	~193	280–560	Deficient
Available Phosphorus (ha^{-1})	~11.8	10–25	Medium
Available Potassium (ha^{-1})	~154	120–280	Medium

The results demonstrate that **soil pH** remains slightly alkaline in most cultivated fields. Such conditions are typical of the alluvial soils of western Uttar Pradesh. Although this pH range generally supports crop production, persistent alkalinity may reduce the availability of micronutrients such as zinc and iron, particularly under intensive irrigation.

Electrical conductivity values remained below the critical threshold for salinity, indicating that most agricultural soils are **non-saline**. Nevertheless, isolated pockets with inadequate drainage may experience localized salt accumulation over time.

One of the most significant observations was the **low organic carbon content**, averaging approximately **0.50%**. Organic carbon is widely recognized as one of the most reliable indicators of soil quality because it enhances soil aggregation, microbial activity, nutrient retention, and water-holding capacity. The reduced organic carbon observed in Saharanpur is largely attributed to intensive cultivation, limited incorporation of crop residues, and inadequate application of organic manures.

Available nitrogen showed the greatest deficiency among the major nutrients. The average value of **approximately 193 kg ha^{-1}** falls below the desirable range for intensive crop production. Continuous cultivation of nutrient-demanding crops such as sugarcane and wheat without adequate replenishment contributes significantly to nitrogen depletion. Since nitrogen directly influences vegetative growth and chlorophyll synthesis, insufficient levels may reduce crop productivity and fertilizer-use efficiency.

Available phosphorus was generally found within the **medium fertility category**. Although phosphorus deficiency was not severe, balanced fertilizer management remains essential because excessive phosphorus application can reduce micronutrient availability and increase production costs. Similarly, available potassium values indicated moderate fertility, suggesting that current potassium reserves remain sufficient for many cropping systems, though long-term monitoring is recommended.

Comparison with recent studies conducted elsewhere in the Indo-Gangetic Plains indicates a similar pattern of declining organic carbon and nitrogen under intensive cultivation, while legume-based systems and soils receiving regular organic amendments consistently show better nutrient status. These findings reinforce the importance of sustainable nutrient management practices for maintaining long-term soil health.

6. Comparison Charts and Graphical Representation

Graphical representation helps in understanding variations in soil quality parameters and provides a clear comparison between the observed values in Saharanpur District and the generally recommended ranges for agricultural soils. The charts below summarize the comparative analysis of the major physicochemical properties affecting soil fertility.

Figure 1. Soil pH Comparison

The soil pH of Saharanpur District was found to range between **7.4 and 8.2**, indicating slightly alkaline conditions. Although this range is generally suitable for the cultivation of major crops such as wheat and sugarcane, prolonged alkalinity may reduce the availability of micronutrients, particularly zinc and iron.

Parameter	Observed Value	Recommended Range
Soil pH	7.8 (Average)	6.5–7.5

Figure 2. Organic Carbon Status

Organic carbon is an important indicator of soil fertility because it improves soil structure, water-holding capacity, and microbial activity. The average organic carbon content in Saharanpur soils was approximately **0.50%**, which is below the desirable level for sustainable agriculture.

Parameter	Observed (%)	Recommended (%)
Organic Carbon	0.50	>0.75

Figure 3. Available Macronutrients (NPK)

Nitrogen showed the greatest deficiency, whereas phosphorus and potassium were generally within the medium fertility range.

Nutrient	**Observed (kg ha^{-1})**	**Recommended Range (kg ha^{-1})**
Nitrogen	193	280–560
Phosphorus	11.8	10–25
Potassium	154	120–280

Figure 4. Electrical Conductivity (EC)

Electrical conductivity remained well below the salinity threshold, indicating that most soils are non-saline and suitable for agricultural production.

Parameter	**Observed**	**Critical Limit**
EC (dS m^{-1})	0.40	1.00

Comparative Interpretation

The comparative evaluation highlights that Saharanpur District possesses naturally fertile alluvial soils with favorable pH and electrical conductivity for crop production. However, the relatively low organic carbon content and deficiency of available nitrogen indicate a gradual decline in soil quality under intensive cultivation. Similar trends have been reported in other parts of the Indo-Gangetic Plains, where continuous monocropping and excessive dependence on chemical fertilizers have reduced soil organic matter and nutrient-use efficiency.

The graphical comparison also demonstrates that phosphorus and potassium remain within acceptable limits, suggesting that current fertilization practices are generally adequate for these nutrients. Nevertheless, balanced nutrient management, regular soil testing, and incorporation of organic amendments are essential to maintain long-term soil fertility and prevent future degradation.

7. Impacts and Remediation

The comparative assessment of soil quality in Saharanpur District indicates that although the region continues to possess fertile alluvial soils, continuous agricultural intensification has gradually affected several important soil quality indicators. Declining organic carbon content, nitrogen deficiency, nutrient imbalance, and localized alkalinity have emerged as major concerns that may adversely influence long-term agricultural productivity and environmental sustainability. Appropriate remediation strategies are therefore essential to restore soil fertility and ensure sustainable land management.

7.1 Impacts on Soil Quality and Agriculture

1. Decline in Soil Fertility

The reduction in soil organic carbon and available nitrogen decreases the natural fertility of soil. Organic carbon is essential for maintaining soil structure, nutrient cycling, microbial activity, and moisture retention. Continuous cultivation without adequate replenishment of organic matter accelerates nutrient depletion and reduces the productive capacity of agricultural land.

2. Reduction in Crop Productivity

Nitrogen deficiency directly affects chlorophyll formation, vegetative growth, and grain development. Crops grown in nitrogen-deficient soils often exhibit poor growth, lower biomass production, and reduced yields. Over time, this may increase farmers' dependence on chemical fertilizers and production costs.

3. Soil Degradation

Intensive cultivation combined with excessive application of chemical fertilizers may gradually deteriorate soil structure. Declining soil aggregation increases the risk of compaction, erosion, and reduced water infiltration, ultimately affecting root development and crop performance.

4. Nutrient Imbalance

Although phosphorus and potassium were generally found within acceptable ranges, repeated application of fertilizers without soil-test-based recommendations may create nutrient imbalances. Excessive phosphorus can reduce the availability of important micronutrients such as zinc and iron, while continuous nitrogen depletion further limits crop productivity.

5. Environmental Impacts

Unsustainable agricultural practices may contribute to environmental degradation through nutrient runoff, groundwater contamination, greenhouse gas emissions, and loss of soil biodiversity. Declining soil quality also reduces the soil's capacity for carbon sequestration, thereby influencing climate resilience.

7.2 Remediation Measures

To improve soil quality and maintain sustainable agricultural productivity in Saharanpur District, the following remediation strategies are recommended:

Integrated Nutrient Management (INM)

Application of organic manures, compost, green manure, crop residues, and biofertilizers along with balanced chemical fertilizers can improve nutrient availability while restoring soil organic matter. Integrated nutrient management enhances fertilizer-use efficiency and supports long-term soil fertility.

Regular Soil Testing

Periodic soil analysis should be conducted to determine nutrient status before fertilizer application. Soil-test-based nutrient management prevents excessive fertilizer use, reduces production costs, and minimizes environmental pollution.

Increasing Organic Carbon

Incorporation of farmyard manure (FYM), vermicompost, green manuring, and crop residues can significantly improve organic carbon content. Higher organic matter enhances microbial activity, water retention, nutrient availability, and soil structure.

Crop Rotation and Legume Cultivation

Introducing legumes such as chickpea, lentil, mung bean, and cowpea into existing cropping systems naturally improves soil nitrogen through biological nitrogen fixation. Crop rotation also interrupts pest cycles and improves overall soil health.

Conservation Agriculture

Practices such as minimum tillage, residue retention, cover cropping, and controlled traffic farming help reduce soil erosion, conserve moisture, and improve soil biological activity.

Balanced Fertilizer Application

Fertilizer application should follow Soil Health Card recommendations and Integrated Nutrient Management guidelines. Balanced use of nitrogen, phosphorus, potassium, and micronutrients prevents nutrient imbalance and supports sustainable crop production.

Efficient Irrigation Management

Proper irrigation scheduling, improved drainage systems, and adoption of micro-irrigation techniques can reduce salinity development and improve water-use efficiency.

8. Conclusion

Soil quality plays a vital role in maintaining agricultural productivity, environmental sustainability, and food security. The present comparative study evaluated the major soil quality indicators of Saharanpur District, Uttar Pradesh, including soil pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, and potassium. Based on the comparative assessment of published scientific studies and government reports, the research demonstrates that the district continues to possess fertile alluvial soils suitable for intensive agriculture. However, continuous cultivation, excessive dependence on chemical fertilizers, limited application of organic manures, and intensive irrigation practices have gradually influenced several important soil quality parameters.

The findings indicate that soil pH and electrical conductivity remain within acceptable limits for agricultural production, suggesting that widespread salinity is not currently a major concern. Nevertheless, declining organic carbon content and low available nitrogen represent significant challenges affecting long-term soil fertility. Organic carbon deficiency reduces microbial activity, nutrient retention, and soil structure, while inadequate nitrogen availability limits crop growth and productivity. Phosphorus and potassium levels were generally found within the medium fertility category, indicating comparatively better nutrient status for these elements.

The comparative analysis also highlights considerable spatial variation in soil quality across different agricultural areas of Saharanpur. Differences in cropping systems, irrigation practices, fertilizer application, and land management contribute significantly to variations in soil fertility. These findings emphasize the importance of location-specific soil management rather than adopting uniform fertilizer recommendations across the district.

Sustainable improvement of soil quality requires an integrated approach that combines scientific soil testing, balanced fertilizer application, organic manure incorporation, crop rotation, conservation agriculture, and efficient irrigation management. Government initiatives such as the Soil Health Card Scheme should be strengthened through regular farmer awareness programmes and timely technical support to encourage evidence-based nutrient management.

In conclusion, maintaining soil health is essential for ensuring sustainable agricultural development in Saharanpur District. Adoption of integrated soil management practices can restore declining soil fertility, improve crop productivity, conserve natural resources, and support long-term environmental sustainability. The findings of this study may serve as a useful reference for researchers, agricultural scientists, policymakers, and farmers engaged in soil resource management and sustainable agriculture in western Uttar Pradesh.

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