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# SOIL QUALITY INDICATORS ASSESSMENT UNDER DIFFERENT LAND USE TYPES IN HARIDWAR, UTTARAKHAND, INDIA

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## ABSTRACT

**Assessing soil quality indicators under different land use types offers valuable insights into how human activities affect soil health and fertility. A few soil quality indicators (pH, EC, OC, essential macro and micronutrients) were evaluated across four land use types (soils near sugar mills, forest soil, industrial areas soil, and agricultural soil) from Haridwar district of Uttarakhand, India. The study was carried out from November 2023 to October 2024 and soil samples were gathered monthly from various sampling sites from depths of 0 cm to 30 cm using a random sampling method and analysed using standard procedures. The results showed that pH values across the different land use types ranged from 7.53 to 8.4, and EC values were found to be low in all land use types (0.13 ds m$^{-1}$ to 0.35 ds m$^{-1}$). The percentage of OC was highest in agricultural soils at 1.15%, forest soils (1.1%), and soils near sugar mills (1.05%), showing that these areas have better organic matter availability compared to industrial areas (0.37%). Availability of N and P was highest in forest soils (329.82 kg ha$^{-1}$, 75.28 kg ha$^{-1}$ respectively) and lowest in soils of industrial area (200.58 kg ha$^{-1}$, 10.3 kg ha$^{-1}$ respectively). Available K (478.2 kg ha$^{-1}$), Ca (576.9 kg ha$^{-1}$), Mg (19.14 kg ha$^{-1}$), and S (13.7 kg ha$^{-1}$) were recorded highest in soils near the sugar mill. Conversely, industrial and agricultural soil had the lowest potassium content (108.6 kg ha$^{-1}$; and 105.5 kg ha$^{-1}$ respectively). Ca content was also high in soils near industrial areas (513.3 kg ha$^{-1}$) reflecting the impact of sugar mill waste and industrial effluents and other local factors. Copper (3.25 ppm) and zinc (2.96 ppm) were observed highest in soils near sugar mill, and lowest in soils near industrial areas (0.86 ppm and 1.33 ppm individually). Agricultural soil was found to have the highest Fe (7.89 ppm) and Mn (5.55 ppm), while soils near industrial areas had the lowest Fe (0.98 ppm) and Mn (0.6 ppm). Boron was recorded highest in forest soils (5.25 ppm) and lowest in soils of industrial areas (0.47 ppm). The study revealed that forest soils had the highest levels of OC, N, P, and micronutrients, indicating healthy soil conditions. In contrast, the industrial area exhibited poor soil quality, characterized by low OC, macronutrient, and micronutrient levels, likely due to industrial pollution, contamination, and soil degradation.**

**(Key words: Haridwar, Land use, Soil health, Soil quality indicators, Sustainable land management, Uttarakhand)**

## INTRODUCTION

Land use changes significantly influence soil quality and ecosystem health. Haridwar, located in the state of Uttarakhand, India, is characterized by a variety of land use patterns, including industrial, agricultural, and forest areas. The purpose of this research was to assess the soil quality indicators under different land use types to understand the impact of human activities on soil fertility and sustainability. Soil quality indicators such as pH, organic carbon content, macro and micronutrients are commonly used to evaluate soil health. Understanding these indicators in the context of land use is crucial for managing soil resources and promoting sustainable land management practices. Soil quality is integral to ecosystem health, agricultural productivity, and environmental sustainability. Soil is a dynamic medium that supports plant growth, water filtration, nutrient cycling, and carbon sequestration (Lal, 2004).

The concept of soil quality incorporates various physical, chemical, and biological properties that influence soil functions. Land use types significantly alter these properties, and an understanding of how different land uses affect soil quality is vital for land management practices. Irrigating with wastewater gradually increases the concentration of pollutants through accumulation. When these accumulated pollutants are absorbed by plant tissues, they significantly affect plants, animals, mankind as well the whole ecosystems (Kumar *et al*., 2019; Sarwar *et al*., 2019). Soil fertility assessment is crucial for maintaining the balance of soil nutrients, as it helps to determine the amount of nutrients needed to achieve higher crop yields, while also lowering cultivation costs and minimizing environmental pollution. Moreover, soil analysis data can be used to recommend the type and amount of fertilizer applications

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and other amendments to increase crop productivity. This study, therefore, focused on the soil fertility status across different land use systems in Haridwar district of Uttarakhand, India.

# MATERIALS AND METHODS

### Study Area

Haridwar, situated in the northern state of Uttarakhand, India, is a region with diverse landscapes, including agricultural land, forest areas, and urban settlements. The district is known for its religious significance and its proximity to the Ganges River, which significantly influences the local ecosystem and agricultural practices. The study area spans various land use types including agricultural, forest, and industrial areas. Four sampling sites were selected (1) land near Laksar sugar mill (2) forest area, (3) Bahadarabad industrial area, (4) agricultural land.

### Soil sampling and analysis

Soil samples were collected at a depth of 0-15 cm at multiple locations within each land use type to ensure representative data. The study was conducted across four distinct land use types in Haridwar. Soil samples were gathered monthly from various sampling sites between November 2023 and September 2024. At each land use system, five composite samples were collected from depths of 0 cm to 30 cm using a random sampling method. Seven subsamples were taken from each site. The samples were then analysed according to standard procedures for each parameter. After air-drying, the samples were ground and sieved through a 2 mm sieve. The analysis included pH using a pH meter, electrical conductivity with an EC meter, soil organic carbon through the Walkley and Black (1934) method, available nitrogen by the Kjeldahl distillation method (Bremner and Mulvaney, 1982), available phosphorus by Bray and Kurtz (1945), potassium, calcium, and magnesium following Jackson (1973), sulphur by Black (1965), micronutrients by Lindsay and Norvel (1978) method, and boron using the method of Wolf (1974).

# RESULTS AND DISCUSSION

The soil properties at different land-use types were analysed, and variations in pH, electrical conductivity (EC), organic carbon (OC), macronutrients (N, P, K, Ca, Mg, and S), and micronutrients (Cu, Fe, Mn, Zn, and B) were observed.

### Soil pH and Electrical Conductivity (EC)

The pH values across the different land use types ranged from 7.53 to 8.4, indicating neutral to slightly alkaline conditions. The land near the sugar mill had a pH of 7.53, the forest area had a pH of 7.7, the industrial area had the highest pH of 8.4, and the agricultural land had a pH of 7.93. The relatively higher pH in the industrial area suggests that industrial activities may contribute to soil alkalinity, possibly due to air pollution or the deposition of alkaline substances. Soil pH, accumulation of organic contents, electrical conductivity and valency of ions affects the availability of soil nutrients to plants (Jiang *et al*., 2009).

Electrical conductivity (EC), a measure of soil salinity, was lowest in the forest area (0.13 ds $m^{-1}$), suggesting minimal salinization in this natural ecosystem. The land near the sugar mill exhibited a slightly higher EC of 0.35 ds $m^{-1}$, indicating that the land near the sugar mill might be more prone to salinization, possibly due to anthropogenic influences like industrial activity and fertilization practices. The industrial area had a moderate EC of 0.25 ds $m^{-1}$, indicating moderate salinization, likely due to industrial effluents. The agricultural land had the lowest EC of 0.12 ds $m^{-1}$, which indicates minimal salinity and a favourable environment for plant growth.

### Organic Carbon (OC)

Organic carbon (OC) content, a key indicator of soil fertility and microbial activity, varied across land use types. The agricultural soil had the highest OC content at 1.15%, forest area 1.1% and land near the sugar mill (1.05%), showing that these areas have better organic matter availability compared to industrial areas (0.37%). The lower OC in the industrial area can be attributed to soil degradation and contamination caused by industrial activities. Organic carbon is vital for soil fertility as it enhances nutrient availability and water retention (Lal, 2016).

### Macronutrients

Among the macronutrients, nitrogen (N) was highest in the forest area (329.82 kg $ha^{-1}$), followed by agricultural land (287.29 kg $ha^{-1}$), and land near the sugar mill (236.42 kg $ha^{-1}$). The industrial area had the lowest nitrogen content (200.58 kg $ha^{-1}$). This disparity reflects the greater organic matter and vegetation in forest ecosystems that contribute to nitrogen cycling. Phosphorus (P) levels were highest in the forest area (75.28 kg $ha^{-1}$), reflecting nutrient-rich conditions, while the land near the sugar mill had 26.88 kg $ha^{-1}$, agricultural land 15.16 kg $ha^{-1}$ and the industrial area had the lowest phosphorus content (10.3 kg $ha^{-1}$), possibly due to contamination and poor soil management. Potassium (K) was highest in the soil near the sugar mill (478.2 kg $ha^{-1}$), suggesting that sugar mill activities may contribute to potassium retention in the soil. The forest soil was found to have a moderate value of potassium (311.2 kg $ha^{-1}$) Conversely, the industrial land and agricultural land had the lowest potassium content (108.6 kg $ha^{-1}$, 105.5 kg $ha^{-1}$ respectively). Calcium (Ca) level was also highest in the land near the sugar mill (576.9 kg $ha^{-1}$), followed by industrial land, reflecting the impact of sugar mill waste and industrial effluents and other local factors. Magnesium (Mg) level was also highest in the land near the sugar mill (19.14 kg $ha^{-1}$); followed by agricultural soil (18.07 kg $ha^{-1}$), forest soil (17.29 kg $ha^{-1}$) and industrial land (16.48 kg $ha^{-1}$). Sulphur (S) was highest in the soils near the sugar mill (13.7 kg $ha^{-1}$) than in other land use types (industrial land 3.0 kg $ha^{-1}$, agricultural soil 2.6 kg $ha^{-1}$ and forest soil 2.6 kg $ha^{-1}$). Calcium and magnesium levels were also elevated in the land near the sugar mill, while sulphur content did not exhibit significant variation across land types.

**Micronutrients:**

The levels of micronutrients varied significantly across the land use types. Copper (Cu) content was highest in the soil near sugar mill area (3.25 ppm), likely due to some activities associated with sugar processing and lowest in the industrial area soil (0.86 ppm). Forest soil and agricultural soil had moderate copper ( 1.4 ppm and 1.95 ppm respectively). Iron (Fe) content was relatively high in the agricultural soil (7.89 ppm), soil near sugar mill area (6.67 ppm) and forest area soil (6.33 ppm), indicating a healthy soil environment, while it was low in the industrial area (0.98 ppm). Manganese (Mn) levels were highest in the soil of agricultural land (5.55 ppm) and lowest in the industrial area (0.6 ppm) and sugar mill area (1.11 ppm), reflecting the negative impact of industrial pollution on soil health. The level of Mn was found to be moderate in soils of forest area (2.35 ppm). Zinc (Zn) and boron (B) levels were highest in the forest area (3.3 ppm and 5.25 ppm, respectively), indicating that forest soils may accumulate more micronutrients than those influenced by industrial and agricultural activities, which is consistent with the natural nutrient cycling in forest ecosystems. The increase in the available micronutrients might be due to the decomposition of organic matter (Kaur *et al*., 2023). In contrast, the industrial area had the lowest zinc (1.33 ppm) and boron (0.47 ppm) concentrations. However, soil near sugar mill was also found to have high Zn content (2.96 ppm), but a low level of boron (0.87 ppm). On the other hand, agricultural soil had moderate levels of Zn (1.76 ppm) and B (1.61 ppm).

The results revealed that soil quality varied significantly under different land use types in Haridwar, Uttarakhand. The forest soils had the highest levels of organic carbon (OC), N, P, and micronutrients, suggesting healthy soil conditions, and a more fertile and balanced ecosystem. In contrast, the industrial area exhibited poor soil quality, characterized by low OC, macronutrient, and micronutrient levels, likely due to industrial pollution, contamination, and soil degradation. The soil health of any area can be restored by adding a certain amount of essential nutrients and using appropriate cropping strategies (Sharma *et al*., 2024). The agricultural soil demonstrated relatively better soil quality than the industrial area but had lower nutrient levels compared to the forest area soil. Agricultural land generally exhibited higher nitrogen and potassium levels, highlighting the importance of fertilization in sustaining soil fertility.

The soil from the fields near sugar mill showed mixed results, with higher levels of potassium, calcium, sulphur and copper but lower organic carbon and micronutrient levels. The higher levels of potassium, sulphur, calcium and copper might be linked to anthropogenic influences like use of chemical fertilizers and sugar mill waste discharge. To enhance soil health and productivity in Haridwar, it is recommended to adopt sustainable land use practices such as organic farming, agroforestry, and industrial waste management. The findings emphasize the need for land-use management strategies that balance nutrient input and minimize contamination, particularly in industrial areas. Additionally, constant supervising of agricultural land near dumping sites is essential to protect public health, as the transfer of pollutants into vegetables can pose health risks. It is also important to raise awareness among farmers about the proper use of wastewater for irrigation to ensure they apply the correct quantities in their fields (Bhardwaj *et al*., 2020). The soil nutrient imbalances indicate the need for specific fertilization and soil management approaches to recover soil mineral availability and helthier plant growth. The integration of legumes and crop rotation may help ease some of these challenges and promote long-term soil fertility as well as a better ecosystem ( Rani, 2025). Therefore, regular monitoring of soil quality indicators is essential for understanding the long-term impacts of land use on soil health.

**Table 1. Values of pH, EC and OC under different land use types**

| Land Use Types | pH | EC (ds $m^{-1}$) | OC (%) |
|---|---|---|---|
| Sugar mill area | 7.53 | 0.35 | 1.05 |
| Forest area | 7.7 | 0.13 | 1.1 |
| Industrial area | 8.4 | 0.25 | 0.37 |
| Agricultural soil | 7.93 | 0.12 | 1.15 |

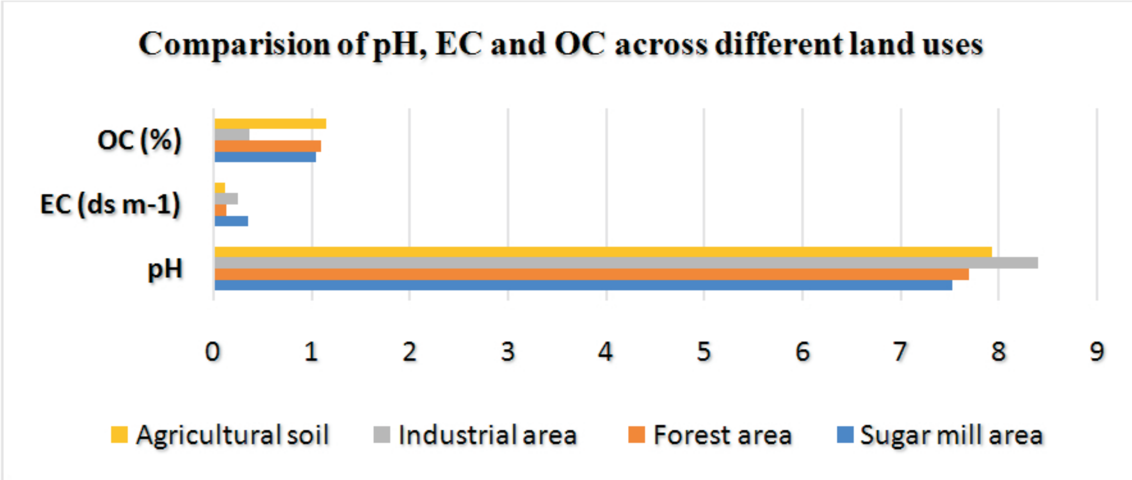


**Figure 1. Levels of soil pH, EC and OC under different land use types**

**Table 2. Values of macronutrients under different different land use types**

| Land Use Types | N (kg ha$^{-1}$) | P (kg ha$^{-1}$) | K (kg ha$^{-1}$) | Ca (kg ha$^{-1}$) | Mg (kg ha$^{-1}$) | S (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Sugar mill area | 236.42 | 26.88 | 478.2 | 576.9 | 19.14 | 13.7 |
| Forest area | 329.82 | 75.28 | 311.2 | 351.4 | 17.29 | 2.6 |
| Industrial area | 200.58 | 10.3 | 108.6 | 513.3 | 16.48 | 3.8 |
| Agricultural soil | 287.29 | 15.16 | 105.5 | 240.6 | 18.07 | 2.7 |

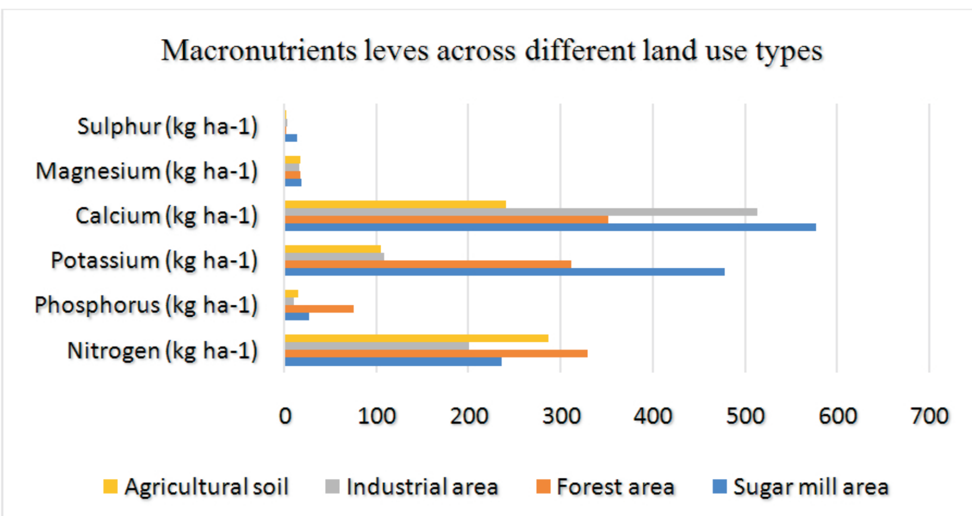


**Figure 2. Availability of macronutrients under different land use types**

**Table 3. Values of micronutrients under different land use types**

| Land Use Types | Cu (ppm) | Fe (ppm) | Mn(ppm) | Zn(ppm) | B (ppm) |
|---|---|---|---|---|---|
| Sugar mill area | 3.25 | 6.67 | 1.11 | 2.96 | 0.87 |
| Forest area | 1.4 | 6.33 | 2.35 | 3.3 | 5.25 |
| Industrial area | 0.86 | 0.98 | 0.6 | 1.33 | 0.47 |
| Agricultural soil | 1.95 | 7.89 | 5.55 | 1.76 | 1.61 |

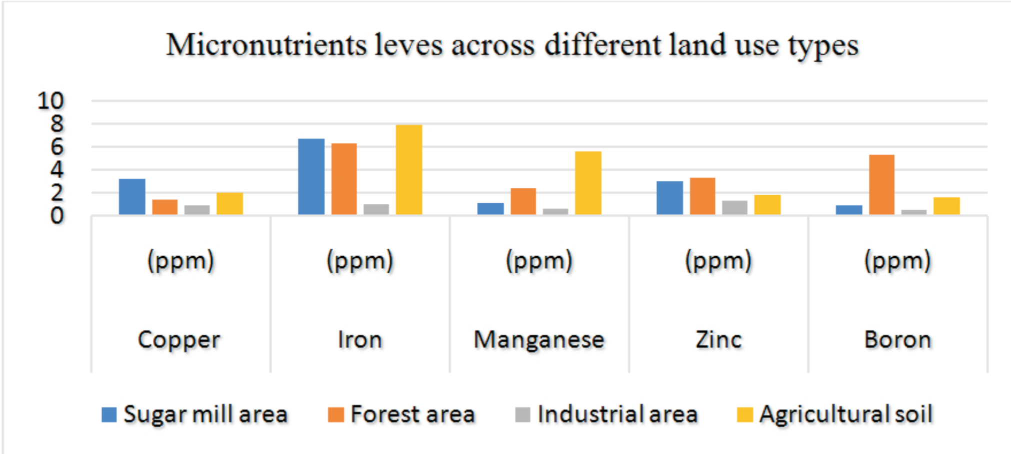


**Figure 3. Availability of micronutrients under different land use types**

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