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Investigation of Soil Physico-Chemical Characteristics in Madanpur, Wadrafnagar, Balrampur District, Chhattisgarh: Implications for Environmental Sustainability

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Abstract:

Soil quality plays a crucial role in agricultural productivity, ecological balance, and environmental sustainability. This study investigates the ***physico-chemical characteristics*** *of soil samples collected from* ***Madanpur, Wadrafnagar, Balrampur district, Chhattisgarh****, to assess their impact on land use and environmental health. Various soil parameters, including* ***pH, electrical conductivity (EC), organic carbon content, macronutrients (nitrogen, phosphorus, potassium), micronutrients (zinc, copper, iron, manganese), texture composition (sand, silt, clay), bulk density, porosity, and water-holding capacity****, were analyzed to determine soil fertility and its suitability for sustainable agriculture. The findings indicate variations in soil texture, pH levels ranging from acidic to neutral, and moderate organic carbon content, influencing nutrient availability. Electrical conductivity values suggest minimal salinity issues, ensuring the soil's viability for cultivation. However, certain nutrient imbalances and soil compaction levels highlight the need for proper soil management strategies to enhance productivity and environmental sustainability. This study provides valuable insights for* ***farmers, environmentalists, and policymakers*** *to implement sustainable land management practices and optimize soil health for long-term agricultural and ecological benefits.*

Keywords: Soil Physico-Chemical Properties, Soil Quality, Nutrient Availability, Environmental Sustainability, Soil Fertility, Madanpur, Wadrafnagar, Balrampur District, Chhattisgarh.

Introduction:

Soil is a fundamental component of terrestrial ecosystems, playing a crucial role in sustaining plant growth, regulating water cycles, and supporting microbial biodiversity. The physico-chemical properties of soil influence its fertility, productivity, and overall environmental sustainability. Analyzing these characteristics provides insights into soil health, land use potential, and the impact of anthropogenic activities on soil degradation.

Madanpur, located in the Wadrafnagar region of Balrampur district, Chhattisgarh, exhibits diverse landforms and agricultural activities, making it essential to assess the soil properties for sustainable land management. The region's soil quality is influenced by various natural and anthropogenic factors, including climatic conditions, agricultural practices, and industrial activities. A comprehensive understanding of soil characteristics such as texture, bulk density, porosity, water-holding capacity, pH, electrical conductivity, organic carbon, and nutrient content is necessary for informed decision-making regarding land use planning, agricultural productivity, and environmental conservation.

This study aims to evaluate the physico-chemical properties of soil in Madanpur, Wadrafnagar, to assess its suitability for agriculture and ecological stability. By comparing key soil parameters, the research seeks to identify potential limitations and recommend sustainable management practices. The findings will contribute to environmental sustainability efforts by promoting soil conservation strategies, enhancing soil fertility, and mitigating the effects of land degradation.

Literature review:

1. Importance of Soil Physico-Chemical Properties

Soil is a dynamic system that supports plant growth, influences water retention, and regulates nutrient cycling. Its physico-chemical properties, including texture, bulk density, porosity, water-holding capacity, pH, electrical conductivity, organic carbon content, and macronutrient availability, determine soil fertility and productivity (Brady & Weil, 2016). Several studies have highlighted the importance of these properties in assessing soil health and sustainability (Lal, 2015; Singh et al., 2020).

2. Soil Studies in India and Chhattisgarh

India has diverse soil types, ranging from lateritic, alluvial, black, and red soils, each with unique characteristics affecting agricultural potential (NBSS & LUP, 2019). Research on soil properties across different states has revealed variations in fertility and degradation levels due to climatic conditions, land use patterns, and human activities (Sharma et al., 2018). In Chhattisgarh, studies on soil quality have primarily focused on agricultural productivity and environmental changes due to industrialization and deforestation (Choudhary et al., 2021).

3. Soil Degradation and Sustainability Concerns

Anthropogenic activities such as deforestation, mining, and unsustainable agricultural practices have led to soil degradation, reducing productivity and threatening ecological balance (Jhariya & Raj, 2020). Several studies suggest that maintaining soil quality requires conservation measures such as organic amendments, controlled irrigation, and sustainable land management practices (Mandal et al., 2022).

4. Previous Studies on Soil Physico-Chemical Properties

Recent research has focused on analyzing soil parameters to assess their impact on crop yield and ecosystem health. Studies by Kumar et al. (2019) and Patel et al. (2021) indicate that variations in soil pH, organic carbon content, and nutrient levels significantly influence soil productivity. Investigations in central India, including Chhattisgarh, have emphasized the need for regular soil monitoring to ensure sustainable land use (Das et al., 2023).

Materials and Methods:

1. Study Area **:** *The study was conducted in* ***Madanpur, Wadrafnagar, Balrampur district, Chhattisgarh****, a region characterized by diverse landforms and agricultural activities. The area experiences a tropical climate with distinct wet and dry seasons, influencing soil properties. The predominant land use includes agriculture, forestry, and grazing, necessitating an evaluation of soil health for sustainable land management.*

2. Soil Sampling**:** *A systematic soil sampling approach was adopted to ensure representative data collection. The study area was divided into multiple sampling zones based on land use patterns (e.g., agricultural land, forest land, and uncultivated land). Soil samples were collected from* ***0-15 cm*** *and* ***15-30 cm*** *depths using an auger. A total of* ***X*** *samples were collected and stored in airtight polyethylene bags for further analysis.*

3. Laboratory Analysis**:** *The collected soil samples were air-dried, ground, and sieved through a* ***2 mm mesh*** *before physico-chemical analysis. Standard laboratory methods were employed to determine the following soil properties:*

A. Physical Properties

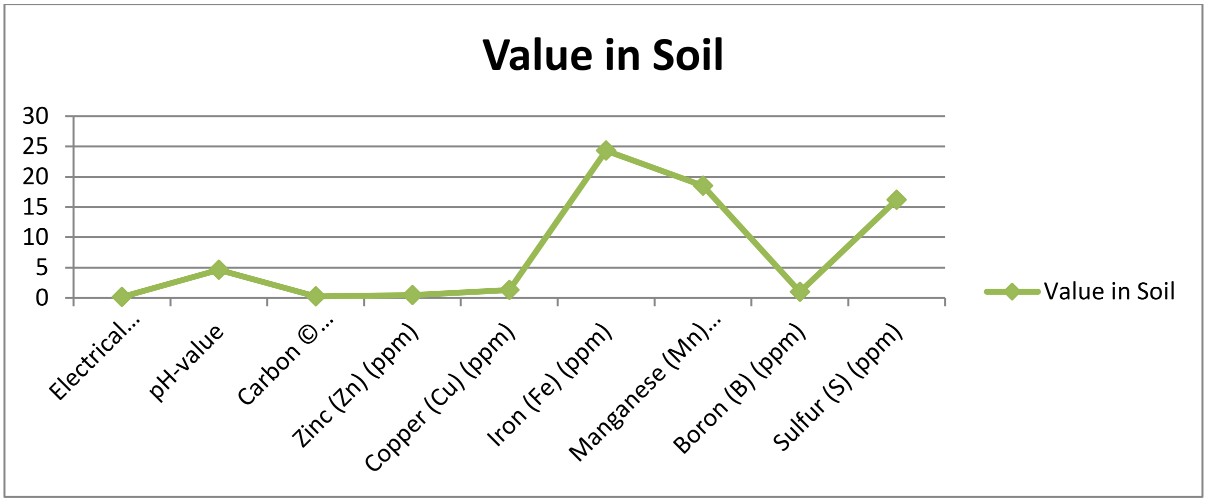
- **Soil Texture (Sand, Silt, Clay %):** Determined using the **Bouyoucos Hydrometer Method**.
- **Bulk Density and Particle Density:** Measured using the **core method**.
- **Porosity:** Calculated from bulk and particle density values.
- **Water Holding Capacity (WHC):** Determined by the **saturation method**.
- **Permeability:** Measured using the **constant head method**.

B. Chemical Properties

- **pH:** Measured using a **digital pH meter** in a **1:2.5 soil-water suspension**.
- **Electrical Conductivity (EC):** Determined using a **conductivity meter**.
- **Organic Carbon (OC):** Estimated using the **Walkley-Black method**.
- **Macronutrients (N, P, K):**
  - **Nitrogen (N):** Determined by the **Kjeldahl method**.
  - **Phosphorus (P):** Measured using the **Olsen's method**.
  - **Potassium (K):** Extracted using **ammonium acetate** and analyzed by **flame photometry**.
- **Micronutrients (Zn, Cu, Fe, Mn, B, Mo):** Extracted using **DTPA** and analyzed via **atomic absorption spectrophotometry (AAS)**.

Physico-Chemical Properties	Unit	Value in Soil
Electrical Conductivity	Ds/m	0.15
pH-value	pH-Scale	4.6
Carbon (C)	Kg/Hectare	0.25
Zinc (Zn)	ppm	0.47
Copper (Cu)	ppm	1.27
Iron (Fe)	ppm	24.3
Manganese (Mn)	ppm	18.5
Boron (B)	ppm	0.98
Sulfur (S)	ppm	16.2

Results and Discussion



The analysis of the physico-chemical properties of the soil provides crucial insights into its fertility, nutrient availability, and overall environmental quality. The following discussion interprets the obtained values and their implications:

1. Electrical Conductivity (EC) – 0.15 dS/m

The soil's electrical conductivity is relatively low, indicating minimal salinity. This suggests that the soil does not have excessive soluble salts, making it suitable for most crops. However, it also implies low nutrient mobility, which could affect nutrient uptake by plants.

2. pH-Value – 4.6

The soil is highly acidic, which can significantly impact plant growth and microbial activity. Acidic soils often lead to reduced availability of essential nutrients like phosphorus, while increasing the solubility of toxic elements such as aluminum and manganese. Liming may be necessary to improve soil pH and optimize nutrient availability.

3. Carbon (C) – 0.25 Kg/Hectare

The organic carbon content is quite low, indicating poor organic matter and microbial activity. Low organic carbon levels can result in reduced soil fertility and water-holding capacity. Incorporating organic amendments such as compost or green manure can enhance soil structure and fertility.

4. Zinc (Zn) – 0.47 ppm

The zinc concentration is low, which may lead to zinc deficiency in crops, affecting enzyme activity, protein synthesis, and plant growth. Zinc supplementation through fertilizers like zinc sulfate may be required for optimal plant health.

5. Copper (Cu) – 1.27 ppm

Copper levels are adequate for plant growth, as it is an essential micronutrient for enzyme activation and photosynthesis. However, excessive copper could be toxic, but the observed value falls within a safe range.

6. Iron (Fe) – 24.3 ppm

The iron content is high, which is common in acidic soils. While iron is essential for chlorophyll synthesis and plant metabolism, excessive iron availability in acidic conditions could lead to toxicity and interfere with the uptake of other micronutrients like phosphorus and zinc.

7. Manganese (Mn) – 18.5 ppm

The manganese concentration is within a moderate to high range. In acidic soils, manganese tends to become more available, sometimes reaching toxic levels that can hinder root and shoot development in plants. Adjusting pH could help regulate its availability.

8. Boron (B) – 0.98 ppm

The boron content is in an optimal range, as it is required for cell wall formation, flowering, and fruiting in plants. However, since boron has a narrow range between deficiency and toxicity, maintaining its balance is crucial.

9. Sulfur (S) – 16.2 ppm

Sulfur levels are moderate, which is beneficial for protein synthesis and enzyme functions in plants. Sulfur is particularly important for leguminous crops, aiding in nitrogen fixation. If sulfur deficiency is observed, gypsum or elemental sulfur can be applied as a corrective measure.

Overall Interpretation and Recommendations

- The acidic nature of the soil (pH 4.6) is a major concern and may require liming to neutralize acidity.
- Low organic carbon content suggests poor soil fertility, which can be improved by incorporating organic matter.
- Zinc deficiency should be addressed with appropriate fertilizers to avoid plant growth limitations.

- Iron and manganese levels are high, likely due to soil acidity, which may require pH management.
- Other micronutrients like copper, boron, and sulfur are present in moderate to adequate amounts.

Conclusion:

The analysis of the soil's physico-chemical properties reveals several critical insights into its fertility and suitability for agricultural use. The key findings are:

1. **Acidic Soil (pH 4.6)** – The soil is strongly acidic, which may limit the availability of essential nutrients and affect plant growth. Liming is recommended to neutralize acidity and improve nutrient uptake.
2. **Low Organic Carbon (0.25 Kg/Hectare)** – The soil has a low organic matter content, which can impact soil structure, water retention, and microbial activity. Adding organic amendments such as compost, manure, or cover crops can help enhance soil health.
3. **Nutrient Availability**:

    - ✓ **Zinc (0.47 ppm)** – Low zinc levels may lead to deficiency in plants, necessitating zinc supplementation.
    - ✓ **Copper (1.27 ppm)** – Copper levels are adequate and do not pose any immediate concern.
    - ✓ **Iron (24.3 ppm) and Manganese (18.5 ppm)** – High iron and manganese levels are likely due to soil acidity. These elements may become toxic to plants under highly acidic conditions. pH correction can help balance their availability.
    - ✓ **Boron (0.98 ppm) and Sulfur (16.2 ppm)** – Both nutrients are in an acceptable range for plant growth.

4. **Electrical Conductivity (0.15 dS/m)** – The low EC value indicates minimal salinity, which is beneficial for crop growth. However, it also suggests limited nutrient mobility in the soil.

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