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Comparative Study of Physicochemical Characteristics of Surface and Subsurface Soils in the Kudargarh Region, Chhattisgarh

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ABSTRACT

This study investigates the physicochemical properties of surface and subsurface soil samples collected from three different locations in the Kudargarh region of Chhattisgarh: Kudargarh Center, Kudargarh (500 meters), and Indarpur (1 kilometer). The parameters analyzed include pH, electrical conductivity (EC), organic carbon content, and concentrations of essential macronutrients (Nitrogen, Phosphorus, and Potassium) and micronutrients (Sulphur, Boron, Zinc, Iron, Manganese, and Copper). Results indicate notable variations between surface and subsurface soils across all sites. Surface soils generally exhibited higher organic carbon and nitrogen content, indicating greater biological activity and organic matter accumulation at the topsoil layer. Subsurface samples, in contrast, showed increased electrical conductivity and variable trends in micronutrient availability. The pH levels ranged from slightly acidic to near neutral across all depths. Notably, elevated concentrations of Zinc and Copper were observed at Indarpur's surface level, possibly due to localized environmental or anthropogenic factors. This comparative analysis enhances understanding of soil nutrient dynamics with depth and distance, providing valuable insight for site-specific soil management, sustainable agriculture, and conservation practices in the Kudargarh region

Keywords: Soil Physicochemical Properties, Surface and Subsurface Soil, Kudargarh Region, Organic Carbon, Soil Acidity (pH), Electrical Conductivity (EC).

1. Introduction:

Soil is a fundamental natural resource that sustains plant growth, regulates water flow, stores nutrients, and supports diverse ecosystems. The productivity and ecological health of any region largely depend on the physical and chemical characteristics of its soils. Variations in soil properties such as pH, electrical conductivity (EC), organic carbon, and nutrient content not only reflect natural processes like weathering and organic matter decomposition but also indicate anthropogenic influences such as agricultural practices and land-use changes.

The Kudargarh region, located in the Surguja division of Chhattisgarh, is known for its hilly terrain, religious significance, and agricultural activity. However, there is limited scientific literature focusing on the detailed characterization of soils in this area, particularly with respect to variations between surface and subsurface layers. Understanding these vertical variations is crucial for effective land use planning, nutrient management, and soil conservation efforts.

This study aims to conduct a comparative analysis of physicochemical properties of soils collected from surface and subsurface layers at three distinct locations within a 1 km radius in the Kudargarh region—namely, Kudargarh Center, Kudargarh (500 meters), and Indarpur (1 kilometer). By assessing key parameters such as pH, EC, organic carbon percentage, macronutrients (N, P, K), and micronutrients (S, B, Zn, Fe, Mn, Cu), the study seeks to uncover patterns that could aid in understanding soil fertility, guiding sustainable agricultural practices, and supporting regional soil health initiatives.

2. Literature Review

Soil physicochemical properties are essential indicators of soil health and fertility, influencing agricultural productivity and ecological sustainability. Various studies have shown that these properties vary significantly with depth, topography, climate, and land use (Brady & Weil, 2016). Parameters such as pH, electrical conductivity (EC), organic carbon, and nutrient concentrations (N, P, K, and micronutrients) are commonly used to assess soil quality.

pH and Electrical Conductivity:

Soil pH influences nutrient availability, microbial activity, and overall plant growth. Acidic or alkaline soils can significantly hinder nutrient uptake (Alloway, 2008). EC is an indicator of soil salinity and the presence of soluble salts, which can affect crop productivity and soil structure (Rhoades & Corwin, 1990).

Organic Carbon and Macronutrients (NPK):

Organic carbon plays a critical role in soil structure, water retention, and nutrient cycling. It is often found in higher concentrations in surface soils due to the accumulation of plant residues and microbial activity (Lal, 2004). Nitrogen, phosphorus, and potassium are essential macronutrients whose distribution is affected by biological uptake, leaching, and fertilizer application (Tandon, 2005).

Micronutrients (S, B, Zn, Fe, Mn, Cu):

Micronutrients are required in small quantities but are vital for plant metabolism and enzyme function. Their availability is often influenced by soil pH, organic matter content, and mineral composition (Fageria, Baligar, & Clark, 2002). Deficiencies or toxicities of micronutrients like zinc, boron, and copper are common in Indian soils, particularly in regions with intensive agriculture (Shukla et al., 2014).

Regional Studies in Chhattisgarh and India:

Previous soil studies in various parts of Chhattisgarh and Central India have revealed significant spatial and vertical variations in soil properties. For instance, Sahu and Singh (2012) reported that subsurface soils often exhibit lower organic carbon and nitrogen content but higher EC, which may be attributed to reduced microbial activity and nutrient leaching. Similarly, research by Chhonkar et al. (2007) highlighted that micronutrient variability is closely linked with soil depth and texture.

Despite such studies, limited work has been done specifically in the Kudargarh region, which possesses unique topographical and cultural features. Therefore, a comparative assessment of surface and subsurface soils in this area is essential to fill this knowledge gap and to support informed land and nutrient management decisions.

3. Materials and Methods

Study Area Description

The study was conducted in the Kudargarh region of Surguja district, Chhattisgarh, India, an area characterized by forested hills, undulating topography, and moderate agricultural activity. Soil samples were collected from three georeferenced locations:

- **Kudargarh (Center):** 23.51618º N, 82.750146º E
- **Kudargarh (500 meters):** 23.49855º N, 82.75343º E
- **Indarpur (1 km):** 23.482524º N, 82.767073º E

Each location reflects different proximities from the Kudargarh center, representing a transect of spatial variation for comparison.

Sample Collection

Soil samples were collected from two depths at each location:

- **Surface soil** (0–15 cm)
- **Subsurface soil** (15–30 cm)

At each site and depth, **composite soil samples** were prepared by mixing five subsamples taken randomly within a 10-meter radius. A stainlesssteel auger and spade were used to collect the samples. The collected soil was air-dried in shade, crushed using a wooden roller, and sieved through a 2 mm mesh for laboratory analysis (Jackson, 1973; Piper, 1966).

Laboratory Analysis

The following physicochemical parameters were analyzed using standard protocols:

- **Soil pH and Electrical Conductivity (EC):** Measured using a 1:2.5 soil-to-water suspension with a calibrated digital pH meter and conductivity meter (Jackson, 1973).
- **Organic Carbon (%):** Estimated by the Walkley and Black (1934) chromic acid wet oxidation method.
- **Available Nitrogen (kg/ha):** Determined by the alkaline permanganate method (Subbiah &Asija, 1956).
- **Available Phosphorus (kg/ha):** Analyzed using the Olsen method for neutral to alkaline soils (Olsen et al., 1954).
- **Available Potassium (kg/ha):** Measured using a flame photometer after extraction with neutral normal ammonium acetate (Tandon, 2005).
- **Sulphur (ppm):** Estimated by turbidimetric method after extraction with 0.15% $CaCl_2$.

- **Micronutrients – Boron (B), Zinc (Zn), Iron (Fe), Manganese (Mn), and Copper (Cu):** Extracted using DTPA (Diethylenetriaminepentaacetic acid) and analyzed using Atomic Absorption Spectrophotometry (Lindsay & Norvell, 1978).

Data Presentation and Analysis

All laboratory data were tabulated to compare spatial (location-wise) and vertical (depth-wise) variations. Descriptive statistics were used to observe trends and differences. The variation in nutrient concentrations and physicochemical properties between surface and subsurface soils was the basis for interpretation of soil fertility and quality in the study area.

4. Results and Discussion

This study analyzed surface and subsurface soil samples from three locations in the Kudargarh region: Kudargarh (Center), Kudargarh (500 meters), and Indarpur (1 km). The results reflect variation in pH, electrical conductivity, macronutrients (N, P, K), organic carbon, and micronutrients (S, B, Zn, Fe, Mn, Cu). The spatial and depth-wise differences are discussed below:

1. Soil pH

- The pH values ranged from **5.9 to 6.6**, indicating **slightly acidic to moderately acidic** conditions.
- Surface soils were more acidic than subsurface at all three sites.
    - Indarpur (surface): 5.9 (most acidic)
    - Kudargarh (center depth): 6.6 (least acidic)
- Soil acidity can influence nutrient availability and microbial activity. Slightly acidic conditions are favorable for most crops, though extremely low pH can hinder phosphorus availability (Brady & Weil, 2008).

2. Electrical Conductivity (EC)

- EC ranged from **0.14 to 0.35 dS/m**, falling within the **normal range** for non-saline soils.
- Higher EC values were observed at **depth** at all sites.
    - Kudargarh (center): 0.35 dS/m (depth) vs. 0.18 dS/m (surface)
    - Indarpur (surface): 0.14 dS/m (lowest)
- Slight increase in subsurface EC may indicate leaching of salts from the surface (Gupta, 2004).

3. Organic Carbon (%)

- Organic carbon ranged from **0.25% to 0.48%**.
- Surface soils generally showed higher organic carbon than subsurface layers.
    - Kudargarh (500m surface): 0.48%
    - Kudargarh (500m depth): 0.25%
- This decrease with depth is expected, as organic matter accumulates from litter and root biomass at the surface (Walkley & Black, 1934).

4. Available Nitrogen (kg/ha)

- Nitrogen content ranged from **202 to 346.2 kg/ha**.
- Highest at **Kudargarh (500m depth): 346.2 kg/ha**, possibly due to nitrogen mineralization.
- Surface soils showed generally moderate levels (~202–216.4 kg/ha).
- Nitrogen is mobile in soil, and its accumulation in the subsoil suggests slower leaching or higher microbial activity at depth.

5. Available Phosphorus (kg/ha)

- Phosphorus ranged from **12.54 to 16.13 kg/ha**.
- Highest at **Indarpur surface (16.13 kg/ha)**, lowest at **Kudargarh 500m (12.54 kg/ha)**.
- Phosphorus availability tends to decrease with depth and acidity. However, minimal depth-wise variation here suggests good P retention and moderate mobility.

6. Available Potassium (kg/ha)

- Potassium content ranged from **151.54 to 222.1 kg/ha**.
- Surface soil at **Kudargarh 500m** had the highest potassium (222.1 kg/ha).
- Subsurface at **Kudargarh 500m** had the lowest (151.54 kg/ha).
- This variation may be due to crop uptake from surface layers or clay mineral leaching.

7. Sulphur (ppm)

- Sulphur values varied between **11.25 to 18.75 ppm**.
- Highest in **Kudargarh 500m surface (18.75 ppm)**, lowest in **Indarpur surface (11.25 ppm)**.
- Depth trend not consistent, suggesting variable retention or anthropogenic sources like fertilizers.

8. Boron (ppm)

- Boron levels ranged from **4.32 to 10.35 ppm**.
- Subsurface soils had **higher B** concentrations, with highest at **Kudargarh 500m depth (10.35 ppm)**.
- Boron can be more mobile in acidic soils, explaining higher levels in deeper layers.

9. Zinc (ppm)

- Zinc values ranged from **0.38 to 5.67 ppm**.
- **Surface at Indarpur** had the highest Zn (5.58 ppm), but **depth Zn dropped drastically to 0.38 ppm**, possibly due to Zn fixation or leaching.
- Zinc availability is also sensitive to pH and organic matter content.

10. Iron (ppm)

- Iron ranged from **41.52 to 55.42 ppm**, relatively high across all sites.
- Maximum Fe in **Kudargarh center surface (55.42 ppm)** and **Indarpur surface (55.18 ppm)**.
- Slight reduction with depth is expected due to reduced organic activity and oxidation processes.

11. Manganese (ppm)

- Manganese ranged from **27.52 to 36.46 ppm**.
- Surface at **Kudargarh center** had the highest Mn (36.46 ppm), likely due to oxidized forms at the aerated surface.
- Depth differences were relatively small.

12. Copper (ppm)

- Copper values showed extreme variability, from **2.218 to 10.878 ppm**.
- **Indarpur surface** had a strikingly high Cu value (10.878 ppm), which may suggest anthropogenic input or localized mineralization.
- Depth Cu was consistently lower, suggesting surface retention.

General Trends and Interpretation

- **Depth Effect:** Organic carbon, pH, and phosphorus were generally higher at the surface, while nitrogen and some micronutrients like boron were higher in subsoil.
- **Location Variation:**Indarpur (1 km) showed the most nutrient-rich surface profile (high P, Zn, Cu), while Kudargarh (center) had balanced fertility with moderate levels across all parameters.
- **Soil Fertility Status:** Overall, soils in this region appear **moderately fertile**, with no indications of salinity or severe nutrient deficiency. However, **micronutrient variability** (especially Cu and Zn) calls for site-specific management.

5. Conclusion:

The present study has provided a comparative assessment of the physicochemical characteristics of both surface and subsurface soils in the Kudargarh region of Chhattisgarh, India. The findings reveal considerable spatial and vertical variations in soil properties, which have significant implications for land management, agriculture, and environmental sustainability in the region.

1. Soil Acidity and pH Stability

- The soils across all locations are slightly to moderately acidic, with pH values ranging from **5.9 to 6.6**.
- Subsurface soils were found to be **less acidic** than surface soils, likely due to reduced organic acid accumulation and microbial activity at depth.
- The moderate acidity is generally favorable for most crops, but localized soil amendments (e.g., liming) may enhance phosphorus and micronutrient availability in more acidic zones like **Indarpur surface (pH 5.9)**.

2. Salinity Status (Electrical Conductivity)

- EC values were consistently **below 0.40 dS/m**, indicating **non-saline conditions** ideal for plant growth.
- Slightly elevated EC in subsurface soils (e.g., 0.35 dS/m at Kudargarh center depth) suggests minor salt accumulation likely due to downward leaching from surface layers.

3. Organic Carbon Content

- Surface soils demonstrated higher **organic carbon percentages** (0.44–0.48%) compared to subsurface soils (0.25–0.4%).
- This pattern is consistent with global soil behavior, as surface layers are more influenced by plant litter and root residues.
- The organic carbon content is **moderate**, but organic matter management practices (e.g., compost, cover cropping) can be used to further enhance soil fertility.

4. Macro-Nutrients (N, P, K)

- **Nitrogen (N)** levels ranged from **202 to 346.2 kg/ha**, with higher levels at depth in some cases (e.g., Kudargarh 500m depth).
    - This unusual increase in subsurface nitrogen may be attributed to **nitrate leaching** or **mineralization** processes.
- **Phosphorus (P)** values were relatively stable across depths, ranging from **12.54 to 16.13 kg/ha**, indicating **moderate availability**.
    - The highest P was observed in **Indarpur surface**, consistent with organic matter and microbial activity influence.
- **Potassium (K)** values varied more broadly from **151.54 to 222.1 kg/ha**, showing **good availability** overall.
    - The highest value was in **Kudargarh 500m surface**, suggesting higher clay content or fertilizer residue.

5. Secondary and Micronutrients

- **Sulphur (S)** levels ranged from **11.25 to 18.75 ppm**, with surface soils having slightly higher values in some sites.
- **Boron (B)** was significantly higher in subsurface layers (e.g., **10.35 ppm at Kudargarh 500m depth**), potentially due to **leaching** or deeper retention.
- **Zinc (Zn)** showed significant site-specific variation, ranging from **0.38 to 5.67 ppm**, with Indarpur surface having the **highest Zn (5.58 ppm)**, suggesting mineralization or previous fertilization.
- **Iron (Fe)** and **Manganese (Mn)** were abundant across all sites, with Fe between **41.52 and 55.42 ppm**, and Mn between **27.52 and 36.46 ppm**.
    - These values indicate **no deficiency**, but care should be taken in managing pH to avoid immobilization.
- **Copper (Cu)** showed **the widest variation**, ranging from **2.218 to 10.878 ppm**, with Indarpur surface exhibiting extremely high Cu content.
    - This anomaly may be due to localized geochemical enrichment or anthropogenic sources like pesticides or industrial residue.

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