IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.414 ⧖ Peer-reviewed & Refereed journal ⧖ Vol. 13, Issue 11, November 2025

DOI: 10.17148/IJIREEICE.2025.131143

Physico-Chemical Characterization of Soil in the Vicinity of Banki Dam and Ghaghi Waterfall, Surguja District, Chhattisgarh, India

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Abstract: This study presents a detailed physico-chemical characterization of soils collected from the vicinity of Banki Dam and Ghaghi Waterfall in the Surguja district of Chhattisgarh, India, with the aim of assessing their agricultural potential and fertility status. Soil samples from multiple locations were analyzed for key parameters including texture (sand, silt, clay), pH, electrical conductivity (EC), organic carbon content, major nutrients (N, P, K), micronutrients, cation exchange capacity (CEC), and bulk density. The results revealed notable variations in soil texture and structure, affecting water retention and drainage properties. Soil pH was found to range from slightly acidic to neutral, generally favorable for a wide range of crops, while EC values indicated low to moderate salinity in certain areas. Organic carbon levels were sufficient to maintain soil fertility, though some deficiencies in nitrogen and phosphorus were observed. The findings underscore the need for site-specific soil management practices, including targeted fertilizer application and organic amendments, to optimize crop productivity and maintain soil health. These insights provide valuable guidance for farmers, researchers, and land managers to support sustainable agriculture and long-term soil conservation in the region.

Keywords: Soil texture, pH, electrical conductivity (EC), organic carbon, nutrient status, Banki Dam, Ghaghi Waterfall, Surguja district, soil fertility, sustainable agriculture.

1. INTRODUCTION

- Soil is a fundamental component of the ecosystem, serving as a primary source of nutrients essential for plant growth and overall development. The fertility and quality of soil have a direct impact on crop yield, productivity, and quality. The Surguja district of Chhattisgarh, particularly the areas surrounding Banki Dam and Ghaghi Waterfall, possesses significant agricultural importance due to its diverse cropping patterns and favorable climatic conditions. Therefore, understanding the physicochemical properties of the soil in this region is crucial for enhancing sustainable agricultural practices and maintaining soil health.
- The present study area lies in the Ambikapur region of Surguja district, Chhattisgarh, India. Banki Dam **(located at approximately 23.12046° N latitude and 83.26432° E longitude)** is one of the important reservoirs in the region and serves as a major source of water for irrigation and local ecosystems. Ghaghi Waterfall, situated near Mainpat hill station **(approximately 22.83° N latitude and 83.31° E longitude),** represents a prominent natural site known for its scenic and ecological significance. The straight-line distance between Banki Dam and Ghaghi Waterfall is about **32 km**, indicating that both sites fall within the same physiographic zone of the Surguja plateau. Their proximity provides an ideal setting for comparative environmental and geospatial studies focusing on soil, water, and landscape characteristics of the Ambikapur–Mainpat region. indicating that both sites fall within the same physiographic zone of the Surguja plateau. Their proximity provides an ideal setting for comparative environmental and geospatial studies focusing on soil, water, and landscape characteristics of the Ambikapur–Mainpat region.
- The present study aims to evaluate the physico-chemical characteristics of soil samples collected from the vicinity of Banki Dam and Ghaghi Waterfall in Surguja district, Chhattisgarh. The investigation focuses on parameters such as soil texture, pH, electrical conductivity, organic carbon content, and the levels of key nutrients—nitrogen,

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phosphorus, and potassium. The outcomes of this study will provide valuable insights into the soil's fertility status and help in formulating better land management and crop cultivation strategies in the region.

2. LITERATURE REVIEW

Understanding the physico-chemical characteristics of soil is essential for evaluating its fertility, productivity, and overall environmental health. Numerous studies have emphasized the significance of analyzing soil properties to promote sustainable agricultural practices and ecological balance. In the context of the Surguja district of Chhattisgarh, research on soils in specific localities, such as the areas surrounding Banki Dam and Ghaghi Waterfall, provides valuable insights into their nutrient status, texture, pH, organic carbon content, and other essential parameters. This section presents an overview of previous studies related to the physico-chemical characteristics of soils in this region, highlighting factors that influence soil fertility and suitability for agriculture, and underlining the importance of targeted soil management for sustainable land use.

1. **Prasad, Mr., & Maurya, Dr., et al. (2025)** carried out a comprehensive study of soil samples collected from the Lafri region in Surguja district, Chhattisgarh. Their research highlighted that factors such as soil pH, electrical conductivity (EC), organic carbon content, and nutrient levels are key indicators of soil fertility and are essential for promoting sustainable agricultural practices. The study emphasizes the significance of understanding site-specific soil properties to enhance crop productivity and implement effective land management measures. [1]
2. **Prasad, Maurya and Srivastava (2025)** reported that environmental dust and sand conditions have a significant effect on microwave and millimetre-wave communication systems by increasing signal attenuation and scattering. Previous studies frequently employ Mie Scattering Theory to calculate scattering and absorption when particulate dimensions are comparable to the wavelength of the transmitted wave. To represent the composite dielectric behavior of dust-laden media, Effective Medium Approximations such as the Maxwell–Garnett and Bruggeman models have also been applied in related research. For high-density particulate environments, the Radiative Transfer Equation (RTE) is widely used to account for multiple scattering interactions within the medium. In addition, several empirical and semi-empirical attenuation models based on visibility, dust concentration and particle density have been proposed to provide practical estimates of signal loss in real field conditions. Experimental techniques such as Vector Network Analyzer (VNA) measurements, Point-to-Point Analyzer (PPA), Infinite Sample Method, and Two-Point Dielectric Method are often referenced in the literature for model validation. Most studies conclude that attenuation increases with both operating frequency and particle concentration, with millimetre-wave bands above 30 GHz being particularly more susceptible. Furthermore, coal dust exhibits greater dielectric loss compared to sand, making its impact on electromagnetic wave propagation especially critical in mining regions such as Surguja.
3. **Prasad et al. (2025)** carried out a comparative study on the physico-chemical properties of surface and subsurface soils in Lakhanpur, Surguja district, Chhattisgarh. Soil samples from different sites were analyzed for texture, pH, EC, organic carbon, major nutrients (N, P, K), micronutrients, CEC, and bulk density. The results showed noticeable variation in soil texture, affecting water-holding capacity and drainage. Soil pH ranged from slightly acidic to neutral, suitable for most crops, while EC indicated moderate salinity in some areas. Organic carbon content was generally sufficient, though deficiencies in nitrogen and phosphorus were identified. The study suggests the need for targeted soil management and fertilizer application to improve soil fertility and support sustainable agricultural productivity.[4]
4. **Kumar, S. & Maurya, Dr. (2025)** carried out a comparative analysis of agricultural soils from Ajirma, Raghunathpur, and Mainpat in the Surguja division and reported notable differences in their physico-chemical characteristics, especially pH, organic carbon, and nitrogen levels. Among the study sites, soils from Mainpat displayed comparatively balanced fertility, whereas those from Ajirma and Raghunathpur showed nutrient deficiencies and higher acidity. The study emphasized the need for location-specific soil management strategies, including liming to regulate soil pH, incorporation of organic matter to improve carbon levels, and appropriate fertilization programs, to improve soil health and promote sustainable agricultural productivity in the region.[6]
5. **Srivastava and Mishra (2004)** conducted an experimental study to determine the real (ε_1) and imaginary (ε_2) components of the complex dielectric constant (ε) of sand, silt, and clay at 9.967 GHz under controlled laboratory conditions. Using the infinite sample method, the authors investigated how varying moisture content affects the dielectric behavior of these soil types. Their findings showed that both ε_1 and ε_2 exhibited a gradual increase with rising moisture levels up to a specific transition point, after which a rapid increase was observed. This behavior indicates that moisture significantly influences the dielectric properties of soils, and the rate of change becomes more pronounced once the soil approaches saturation.[7]

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3. MATERIAL AND METHODS

3.1 Study Area Description:

The present study was undertaken in the regions surrounding Banki Dam and Ghaghi Waterfall, situated in Surguja district of Chhattisgarh, India. The landscape of the area is marked by gently rolling relief, dense natural vegetation, and moderate agricultural utilization. The region experiences a subtropical climate with well-defined seasonal transitions, which play a crucial role in shaping soil formation processes, moisture conditions, and nutrient behavior.

To assess spatial differences in soil physico-chemical attributes, five carefully chosen and georeferenced sampling sites were established at varying distances from the two major geomorphological features. The sampling locations, along with their approximate geographic coordinates, are presented below:

- Sample 1 – Ghaghi Waterfall, Mainpat (approximately 22.82° N, 83.28° E)
- Sample 2 – Kumharta area near Ghaghi Waterfall (approximately 22.80° N, 83.30° E)
- Sample 3 – Ghaghi Waterfall (within 1 km radius) (positioned within the coordinate range of Samples 1 and 2)
- Sample 4 – Khairbar, adjacent to Banki Dam (approximately 23.1164° N, 83.1961° E)
- Sample 5 – Khairbar, 1 km from Banki Dam (lying within the approximate range of 23.11–23.13° N and 83.18–83.21° E)

Collectively, these sites form a spatial transect that enables systematic comparison of soil characteristics across the study area. This sampling layout provides a scientific foundation for evaluating variations in soil fertility, nutrient status, and environmental influences within the landscapes surrounding the two physiographic landmarks.

3.2 Soil Sample Collection:

To evaluate vertical variations in soil health, samples were collected from two depths at each site:

- **Surface layer:** 0–15 cm
- **Subsurface layer:** 15–30 cm

At every location, **five subsamples were collected randomly within a radius of approximately 10 meters** and combined to form a single composite sample. This method improves representativeness and reduces localized bias.
A stainless-steel auger and spade were used for sampling to prevent chemical contamination.

3.3 Sample Preparation:

Freshly collected soil samples were:

1. **Air-dried at room temperature in the shade** to avoid alteration of chemical composition due to heat.
2. **Gently crushed using a wooden roller**, avoiding metallic tools that could react with soil components.
3. **Sieved through a 2 mm mesh** to ensure uniform grain size and remove stones and plant debris.

The processed samples were then stored in airtight polyethylene bags and labeled for laboratory analysis.

3.4 Physico-Chemical Analysis:

Standard laboratory procedures were followed as described in modern soil analysis methodologies (e.g., Singh 2023; Verma & Paul 2023; Pansu & Gautheyrou 2006). The parameters analyzed included:

3.4.1 Soil Texture

Particle size distribution (sand, silt, and clay) was determined using **the hydrometer/sieve method**, which enables classification of soil according to USDA textural standards.

3.4.2 Soil pH and Electrical Conductivity (EC)

- **pH** was measured in a 1:2.5 soil–water suspension using a digital pH meter.
- **EC** was determined using a conductivity meter, providing an indication of soluble salt concentration.

3.4.3 Organic Carbon

Organic carbon was analyzed using a **wet oxidation method**, which estimates the amount of organic matter affecting soil fertility and microbial activity.

3.4.4 Macronutrients

- **Available Nitrogen (N)**
- **Available Phosphorus (P)**
- **Available Potassium/Potash (K)**

These were determined following standard chemical extraction and titration/spectrophotometric procedures commonly used in soil fertility evaluation.

3.4.5 Cation Exchange Capacity (CEC)

CEC was measured to assess the soil's capacity to retain and exchange essential nutrients, influencing nutrient availability for crop growth.

3.5 Data Interpretation:

The obtained results were statistically analyzed and compared between surface and subsurface layers to understand depth-

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wise variations. Spatial differences between sites were also evaluated to interpret the influence of local geography, vegetation, and agricultural practices on soil quality.

- **The physico-chemical parameters of surface soil samples collected from both sites, Banki Dam and Ghaghi Waterfall, are presented together in Table 1 for comparative analysis.**

Parameters	Sample 1 Ghaghi Waterfall Mainpat	Sample 2 Kumharta Ghaghi Waterfall	Sample 3 Ghaghi Waterfall 1 kM	Sample 4 Khairbar Banki Dam	Sample 5 khairbar Banki Dam 1 km
Ph	6.42	6.49	6.52	6.29	6.41
Electric Conductivity	0.45	0.10	0.18	0.25	0.17
Organic carbon	0.85	0.88	0.90	0.60	0.58
Nitrogen	303.00	308.00	311.00	227.00	220.00
Phosphorus	15.40	16.80	17.20	20.00	12.00
Potash	305.00	306.00	310.00	298.00	295.00
Zinc	0.3	0.3	0.3	0.2	0.3
Copper	0.1	0.1	0.1	0.2	0.2
Iron	1.4	1.0	1.4	0.6	1.0
Boron	0.2	0.2	0.2	0.2	0.2
manganese	0.6	0.6	0.6	0.9	0.9

- **The physico-chemical parameters of soil samples collected from 15–30 cm depth at both sites, Banki Dam and Ghaghi Waterfall, are presented together in Table 2 for comparative analysis.**

Parameter	Sample 1 Ghaghi Waterfall Mainpat	Sample 2 Kumharta Ghaghi Warerfall	Sample3 Ghaghi Warerfall 1 km	Sample 4 Khairbar Banki Dam	Sample 5 Khairbar Banki Dam 1 km
pH	6.23	6.40	6.20	6.34	6.46
Electric Conductivity	0.14	0.19	0.40	0.22	0.25
Organic carbon	0.54	0.90	0.55	0.62	0.55
Nitrogen	219.00	312.00	215.00	231.00	212.00
Phosphorus	18.20	19.00	19.00	19.00	13.50
Potash	260.00	308.00	265.00	301.00	300.00
Zinc	0.1	0.2	0.2	0.2	0.3
Copper	0.1	0.1	0.1	0.1	0.2
Iron	0.8	1.1	1.4	1.7	1.0
Boron	0.2	0.2	0.2	0.2	0.2
manganese	0.5	0.6	0.7	0.8	0.9

4. RESULT AND DISCUSSION

In the present investigation on Physico-Chemical Characterization of Soil in the Vicinity of Banki Dam and Ghaghi Waterfall, Surguja District, Chhattisgarh, surface (0–15 cm) and subsurface (15–30 cm) soil samples were collected from five sampling locations: Ghaghi Waterfall (Mainpat), Kumharta – Ghaghi region, Ghaghi Waterfall (1 km), Khairbar – Banki Dam, and Khairbar – Banki Dam (1 km). The analytical results focus on major soil attributes such as pH, electrical conductivity (EC), organic carbon, macronutrients (nitrogen, phosphorus, potassium), and important micronutrients including sulfur (S), boron (B), zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu).
The findings demonstrate considerable spatial as well as depth-wise variability in soil fertility and chemical properties across the study area. Differences in nutrient concentrations and soil reactions between surface and subsurface layers may be attributed to variations in land management practices, organic matter accumulation, terrain characteristics, and proximity to natural water bodies. Detailed interpretation of parameter-wise variations recorded for each location and soil depth is discussed in the subsequent sections.

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4.1 Soil pH:

Surface Soil (0–15 cm)

The pH values of surface soil samples collected from the five locations ranged from **6.29 to 6.52**, indicating that the soils of the study area fall within the **slightly acidic category**. The highest pH (6.52) was recorded at **Ghaghi Waterfall – 1 km,** while the lowest (6.29) occurred at **Khairbar Banki Dam.**

The Ghaghi region (Samples 1–3) exhibited slightly higher pH values compared to the Banki Dam sites, suggesting the possible influence of **higher organic matter accumulation, natural vegetation cover, and leaching patterns** in the hilly Mainpat region. The near-neutral soil reaction observed in most samples is favorable for the availability of major nutrients and supports good agricultural potential.

Subsurface Soil (15–30 cm)

In subsurface soil samples, pH values ranged from **6.20 to 6.46**, also indicating a slightly acidic soil environment. The lowest value (6.20) was observed at **Ghaghi Waterfall – Mainpat,** while the highest pH (6.46) was recorded at **Khairbar Banki Dam – 1 km.**

A comparison of surface and subsurface data reveals that **most locations show a marginal decrease in pH with soil depth**, which may be attributed to reduced organic matter content, lower microbial activity, and downward leaching of basic cations in deeper layers. This trend is consistent with typical soil formation processes observed in humid and forest-influenced landscapes.

Overall Interpretation

The results demonstrate that soils in both the Ghaghi Waterfall and Banki Dam regions maintain **a slightly acidic reaction**, suitable for the availability of essential nutrients such as nitrogen, phosphorus, and micronutrients. Minor spatial differences in pH could be associated with **topography, vegetation cover, parent material, and land use practices** around both study zones.

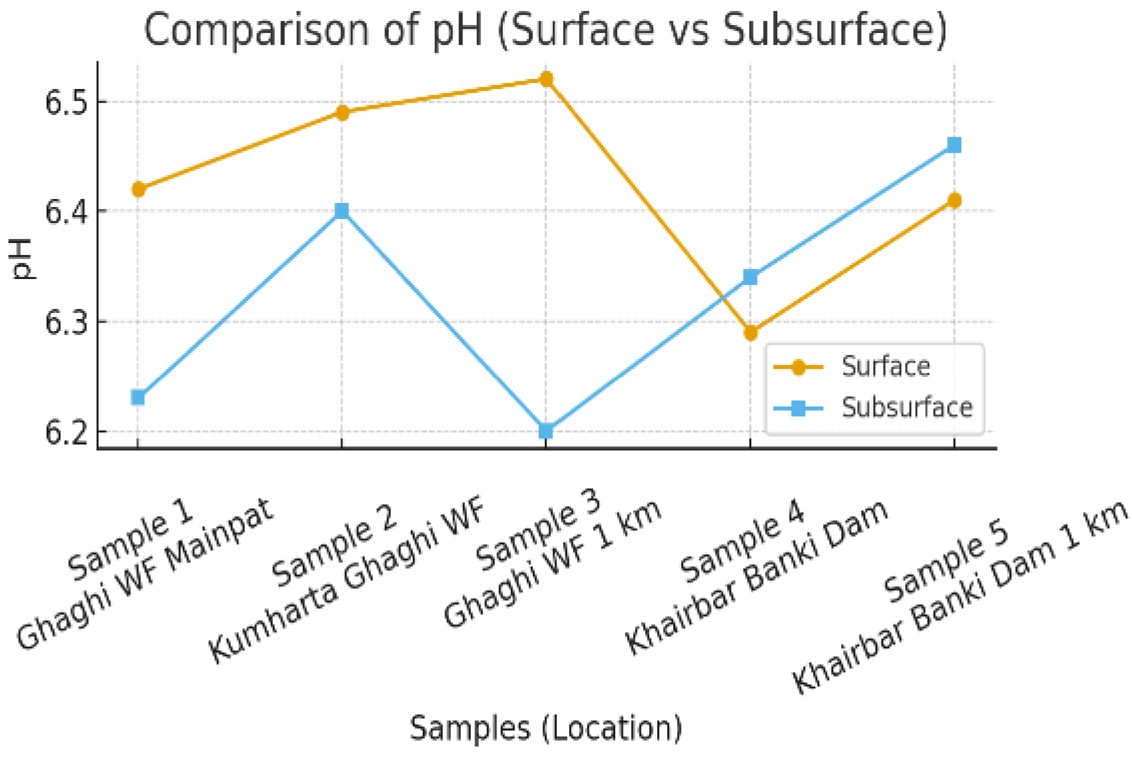

Figure-1: Comparative plot of pH for surface and subsurface samples across five Sampling locations.

Discussion: The mean ph is similar between surface and subsurface samples (surface mean = 6.43, subsurface mean = 6.33). Biggest sample-wise difference observed at Sample 3 Ghaghi WF 1 km (surface − subsurface = 0.320). Trace element differences may be controlled by redox status, leaching, or parent material variability. The comparison between surface and sub-surface levels of pH shows variations influenced by soil depth, organic matter content, leaching, and site-specific environmental conditions. Generally, surface soils tend to show slightly higher biological activity and nutrient availability, whereas sub-surface soils may reflect long-term mineral accumulation or depletion depending on the parameter.

DOI: 10.17148/IJIREEICE.2025.131143

4.2 Electrical Conductivity (EC):

Surface Soil (0–15 cm)

Electrical conductivity in the surface soil samples ranged from **0.10 to 0.45 dS m⁻¹**. The highest EC value (0.45 dS m⁻¹) was recorded at **Ghaghi Waterfall – Mainpat,** while the lowest (0.10 dS m⁻¹) was observed at **Kumharta – Ghaghi region.** Samples from the Banki Dam area exhibited moderate values (0.17–0.25 dS m⁻¹).

These values indicate that the soils are **non-saline in nature**, suggesting that soluble salt accumulation in the surface horizons is minimal. The slightly higher conductivity near Ghaghi Mainpat could be linked to greater organic matter decomposition and weathering effects associated with the elevated terrain and natural vegetation.

Subsurface Soil (15–30 cm)

In subsurface soils, EC values ranged from **0.14 to 0.40 dS m⁻¹**, with the maximum at **Ghaghi Waterfall (1 km)** and the minimum at **Ghaghi Waterfall – Mainpat.** EC values at the Banki Dam sites remained within a narrow range (0.22–0.25 dS m⁻¹).

Comparison of depths shows that **several locations exhibited slightly higher conductivity in the subsurface layer**, which may be attributed to the downward movement and accumulation of soluble ions through leaching processes. Reduced biological activity and lower organic matter at deeper depths may also contribute to this pattern.

Overall Interpretation

The results confirm that soils in both Ghaghi Waterfall and Banki Dam regions fall within the **low-salinity category**, suitable for crop cultivation without risk of salt-induced stress. Spatial differences in EC are influenced by topography, rainfall-driven leaching, soil texture, and organic matter distribution across the study area.

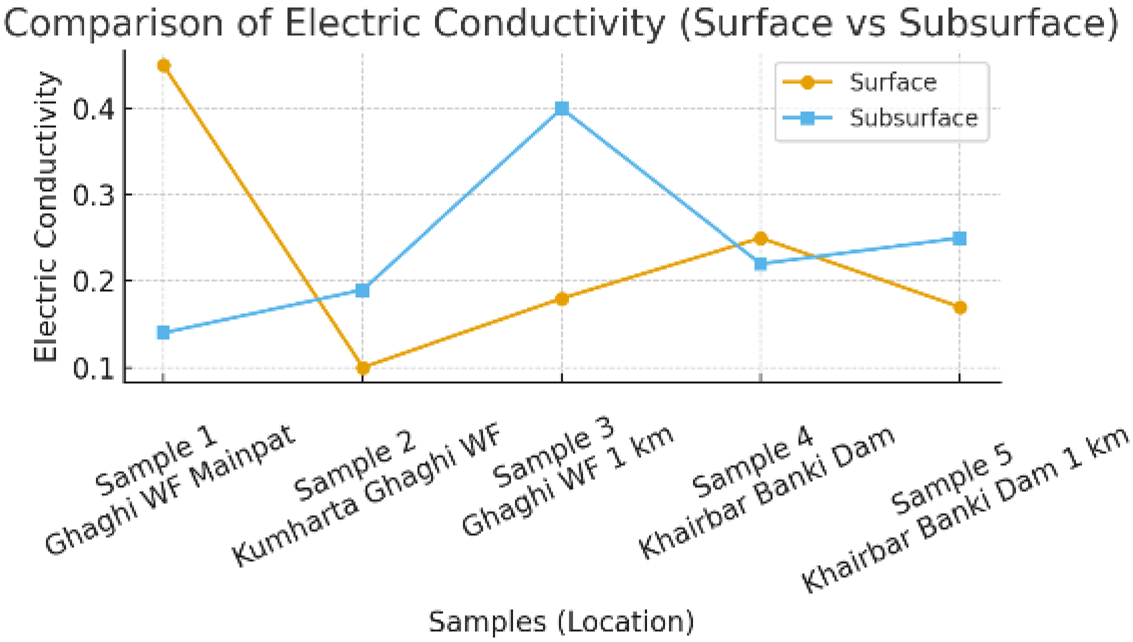

Figure-2: Comparative plot of Electric Conductivity for surface and subsurface samples across five sampling locations.

Discussion: The mean electric conductivity is similar between surface and subsurface samples (surface mean = 0.23, subsurface mean = 0.24). Biggest sample-wise difference observed at Sample 1 Ghaghi WF Mainpat ((surface − subsurface = 0.310). Differences in EC could indicate variations in soluble salts or moisture content between depths.

4.3 Organic Carbon (%):

The present study titled **"Physico-Chemical Characterization of Soil in the Vicinity of Banki Dam and Ghaghi Waterfall, Surguja District, Chhattisgarh, India"** investigates the organic carbon content in both surface and sub-surface soils collected from five different sampling sites.

For the **surface soil**, the organic carbon content ranged from **0.58% to 0.90%**, with the highest value observed at **Ghaghi Waterfall (1 km)** (0.90%) and the lowest near **Banki Dam (1 km)** (0.58%). Higher organic carbon in surface soil reflects greater accumulation of plant residues and enhanced microbial activity, contributing to better soil fertility.

In the **sub-surface soil**, the organic carbon values were comparatively lower, ranging from **0.54% to 0.90%**, showing reduced organic deposition and lower decomposition rates at depth.

Overall, the results show that **surface soil is richer in organic carbon compared to sub-surface soil** across all sampling locations, indicating better nutrient status and fertility in the upper soil horizon of the study area. These observations are

DOI: 10.17148/IJIREEICE.2025.131143

significant for evaluating soil quality and supporting sustainable agricultural and land-use planning around **Banki Dam and Ghaghi Waterfall in Surguja district**.

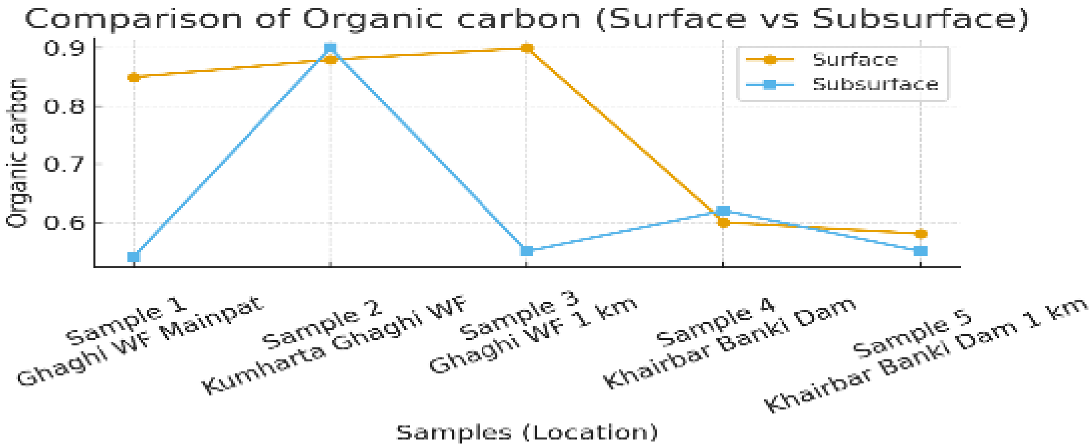

Figure-3: Comparative plot of Organic carbon for surface and subsurface samples across five sampling locations.

Discussion: The mean organic carbon is higher in the surface samples (surface mean = 0.76, subsurface mean = 0.63). Biggest sample-wise difference observed at Sample 3 Ghaghi WF 1 km (surface − subsurface = 0.350). This may reflect variations due to surface organic matter accumulation or agricultural inputs which typically influence nutrient concentrations at the surface.

4.4 Available Nitrogen (kg/ha):

The present investigation assessed the available nitrogen content in both surface and sub-surface soils collected from five sampling sites in the study region.

Surface Soil

In the surface soil, available nitrogen ranged from 220.00 to 311.00 kg/ha. The highest nitrogen content was recorded at Ghaghi Waterfall (1 km) with 311.00 kg/ha, while the lowest value (220.00 kg/ha) was observed near Banki Dam (1 km). The relatively higher nitrogen content in surface soil indicates increased biological activity and the presence of decomposing organic matter, which contributes to nitrogen mineralization and nutrient enrichment in the upper soil layer.

Sub-surface Soil

In the sub-surface samples, available nitrogen values ranged from 212.00 to 312.00 kg/ha. Unlike the general trend of lower nitrogen in deeper layers, one site—Kumharta Ghaghi Waterfall, recorded the highest value of 312.00 kg/ha, slightly higher than its surface counterpart. However, overall, most sub-surface samples exhibited marginally lower nitrogen levels compared to surface soil, likely due to reduced organic residue deposition and microbial processes at depth.

Overall Interpretation

Comparison of both layers indicates that:

- Surface soil generally contains higher available nitrogen, reflecting better fertility, nutrient cycling, and organic matter content.
- Sub-surface soil shows slightly lower nitrogen levels, consistent with limited biomass decomposition and nutrient accumulation at deeper depths.

These results support the observation that the soils of the Ghaghi Waterfall and Banki Dam region possess moderate nitrogen levels, which are important for sustaining agricultural productivity. The findings further contribute to understanding soil fertility status in the study area as part of the physico-chemical characterization study.

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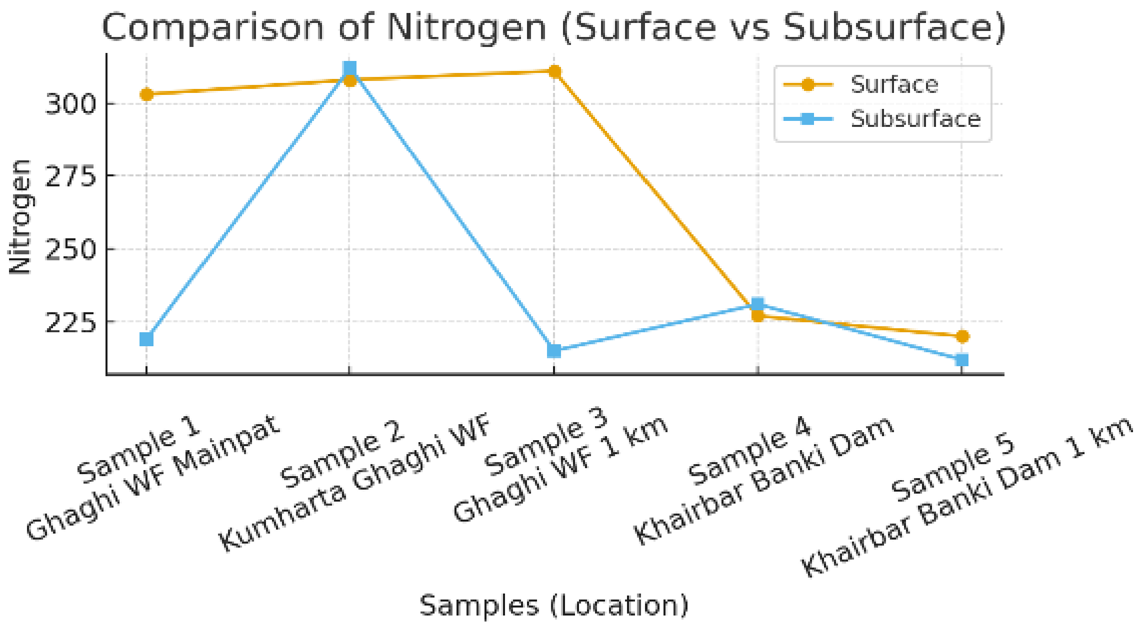

Figure-4: Comparative plot of Nitrogen for surface and subsurface samples across five sampling locations.

Discussion: The mean nitrogen is higher in the surface samples (surface mean = 273.80, subsurface mean = 237.80). Biggest sample-wise difference observed at Sample 3 Ghaghi WF 1 km (surface − subsurface = 96.000). This may reflect variations due to surface organic matter accumulation or agricultural inputs which typically influence nutrient concentrations at the surface.

4.5 Available Phosphorus (kg/ha):

The study evaluated the available phosphorus content in both surface and sub-surface soil layers from five sampling sites located around Ghaghi Waterfall and Banki Dam.

Surface Soil

In the surface soil samples, the available phosphorus ranged from 12.00 to 20.00 kg/ha. The highest phosphorus concentration (20.00 kg/ha) was recorded near Banki Dam, while the lowest value (12.00 kg/ha) was observed at Banki Dam (1 km). The relatively lower phosphorus content in some sites may be attributed to phosphorus fixation by soil minerals and reduced mobility of phosphate ions in the soil.

Sub-surface Soil

In the sub-surface layer, phosphorus values ranged from 13.50 to 19.00 kg/ha, with the highest concentration (19.00 kg/ha) recorded at multiple locations, including Ghaghi Waterfall (1 km), Kumharta Ghaghi Waterfall, and Banki Dam. Compared to the surface soil, the sub-surface samples displayed slightly higher phosphorus levels at most locations, which may be due to downward movement of phosphorus over time or limited plant uptake at deeper depths.

Overall Interpretation

A comparison of both soil depths indicates that:

- Surface soil generally showed moderate phosphorus availability, consistent with plant uptake and upper-layer nutrient cycling.
- Sub-surface soils exhibited slightly higher phosphorus levels at several sites, possibly due to reduced root extraction and vertical nutrient transport.

These findings suggest that the soils of the Banki Dam and Ghaghi Waterfall region contain moderate phosphorus levels, contributing to an improved understanding of soil fertility and supporting effective land-use planning and agricultural management in Surguja district.

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

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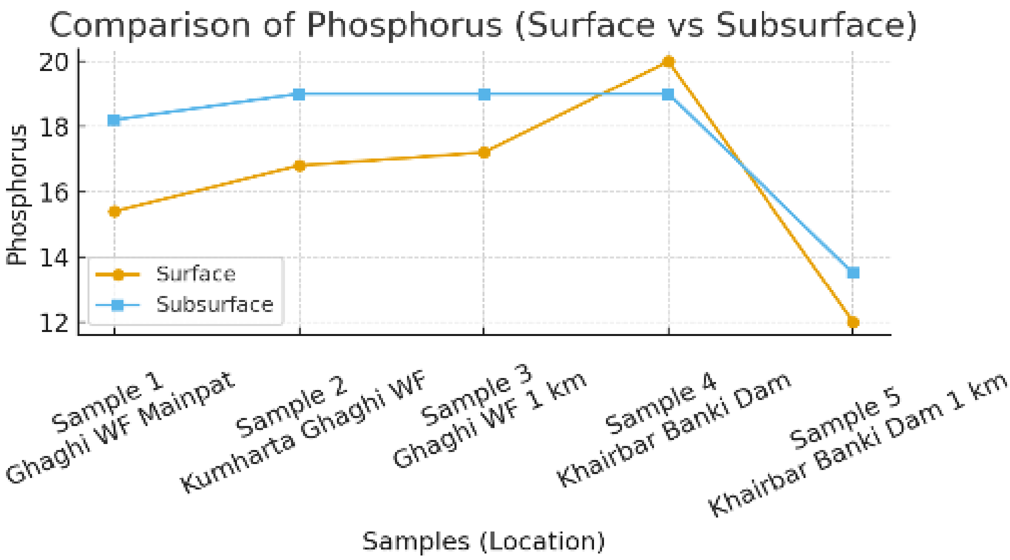

Figure-5: Comparative plot of Phosphorus for surface and subsurface samples across five sampling locations.

Discussion: The mean phosphorus is lower in the subsurface samples (surface mean = 16.28, subsurface mean = 17.74). Biggest sample-wise difference observed at Sample 1 Ghaghi WF Mainpat (surface − subsurface = -2.800). This may reflect variations due to surface organic matter accumulation or agricultural inputs which typically influence nutrient concentrations at the surface.

4.6 Available Potash (kg/ha):

Soil analysis clearly shows that the concentration of available potash varies among the collected samples and between surface and subsurface layers. In the surface soil, potash values ranged from 295 to 310 kg/ha. The maximum potash level was observed at Ghaghi Waterfall (Sample 3: 310 kg/ha), while the lowest value was found at Khairbar Banki Dam (Sample 5: 295 kg/ha). In contrast, the subsurface soil samples showed potash levels between 260 and 308 kg/ha, with Sample 2 (Kumharta Ghaghi Waterfall: 308 kg/ha) exhibiting the highest and Sample 1 (Ghaghi Waterfall Mainpat: 260 kg/ha) showing the lowest concentration. A comparative observation indicates that surface soils generally contain more potash than subsurface soils. This may be due to higher biological activity, greater organic matter accumulation, and more active nutrient cycling in the upper soil horizon. The recorded potash concentration in both layers falls within the medium to high nutrient range, indicating that the soils in the vicinity of Banki Dam and Ghaghi Waterfall are adequately rich in potash, which is beneficial for crop production and soil fertility maintenance in the Surguja region. These results provide a clear understanding of potash distribution in the study area and can be useful for planning appropriate soil nutrient management strategies.

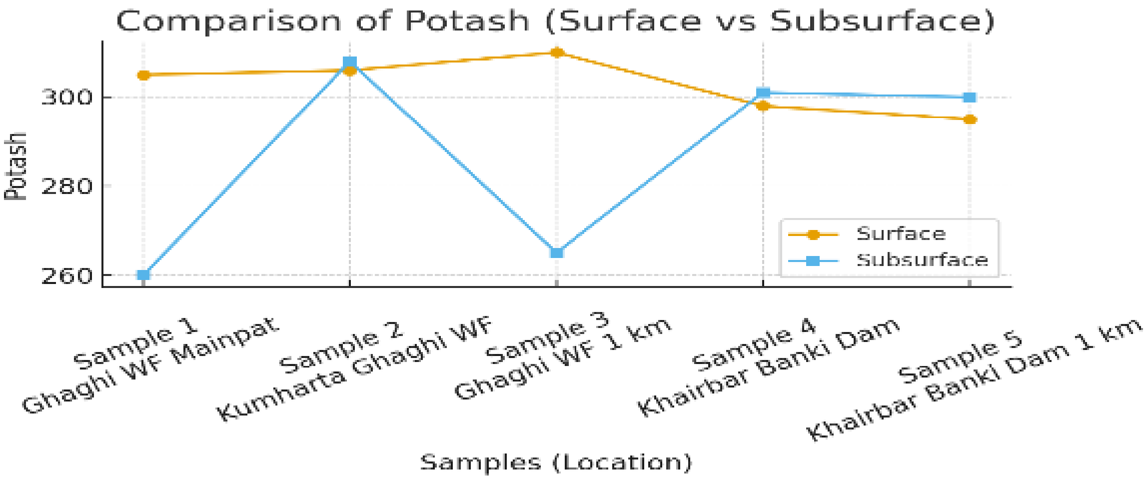

Figure-6: Comparative plot of Potash for surface and subsurface samples across five sampling locations.

Discussion: The mean potash is higher in the surface samples (surface mean = 302.80, subsurface mean = 286.80). Biggest sample-wise difference observed at Sample 1 Ghaghi WF Mainpat (surface − subsurface = 45.000). This may reflect variations due to surface organic matter accumulation or agricultural inputs which typically influence nutrient concentrations at the surface.

4.7 Boron (mg/kg):

The analysis of boron content in the soil samples collected from the vicinity of Banki Dam and Ghaghi Waterfall shows uniform values across all sampling locations. In both surface and subsurface soils, the boron concentration was recorded as 0.2 mg/kg for all five samples, including **Ghaghi Waterfall Mainpat, Kumharta Ghaghi Waterfall, Ghaghi Waterfall 1 km, Khairbar Banki Dam, and Khairbar Banki Dam 1 km.** This uniformity indicates that boron distribution in the study area is stable and not significantly affected by geographical location or soil depth. Since the recorded concentration falls within the acceptable range for agricultural soils, the region does not show any signs of boron deficiency or toxicity. Such balanced boron levels are beneficial for normal plant physiological processes, including cell wall formation, reproductive development, and metabolic functions.

Overall, the findings suggest that the soils in the surroundings of Banki Dam and Ghaghi Waterfall possess adequate and consistent boron availability, contributing positively to soil fertility and supporting agricultural productivity in the Surguja district of Chhattisgarh.

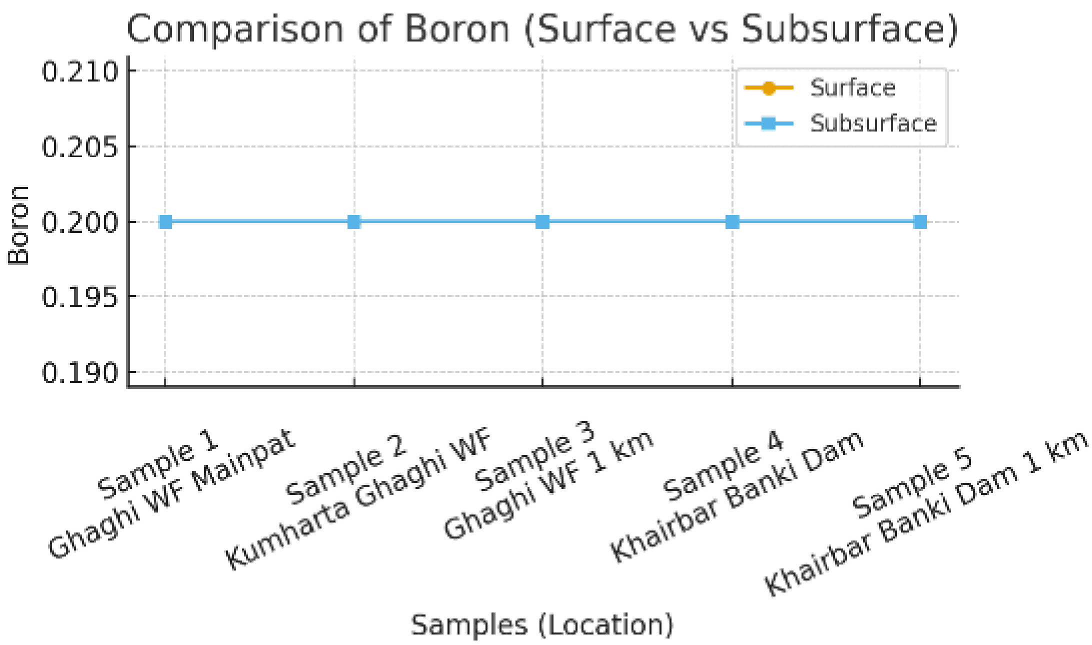

Figure-7: Comparative plot of Boron for surface and subsurface samples across five sampling locations.

The mean boron is similar between surface and subsurface samples (surface mean = 0.20, subsurface mean = 0.20). Biggest sample-wise difference observed at Sample 1
Ghaghi WF Mainpat (surface − subsurface = 0.000). Trace element differences may be controlled by redox status, leaching, or parent material variability.

4.8 Zinc (mg/kg):

- **Surface soil samples showed zinc values between 0.2 and 0.3 mg/kg.** Most locations recorded 0.3 mg/kg, except Khairbar Banki Dam (Sample 4), which showed 0.2 mg/kg.
- **Subsurface soil samples also showed low zinc content, ranging from 0.2 to 0.3 mg/kg.** Only Sample 5 (Khairbar Banki Dam 1 km) showed a slightly higher value of 0.3 mg/kg, while all others recorded 0.2 mg/kg.
- **Zinc availability was generally low in both soil depths,** indicating that the region may have limited natural zinc reserves.
- **Only minor spatial variability was observed,** suggesting that zinc distribution is fairly uniform across the study area.
- **Low zinc levels may be influenced by soil properties such as pH, organic matter, and leaching,** which can reduce micronutrient retention in soil.
- **Zinc is essential for critical plant functions,** including enzyme activation and protein synthesis; therefore, low zinc availability may restrict optimal crop performance.

ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.414 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 11, November 2025
DOI: 10.17148/IJIREEICE.2025.131143

- **The study indicates the need for proper micronutrient management, such as fertilizer supplementation,** to maintain soil fertility and support long-term agricultural productivity.
- **Overall, soils around Banki Dam and Ghaghi Waterfall exhibit marginal zinc levels,** highlighting the importance of periodic monitoring and nutrient management in the Surguja district.

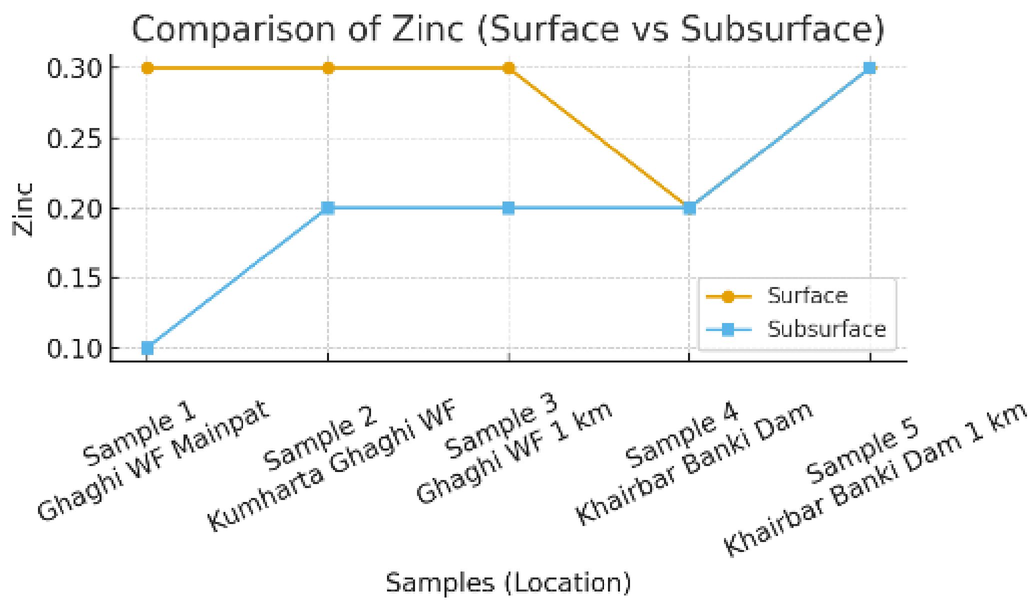

Figure-8: Comparative plot of Zinc for surface and subsurface samples across five sampling locations.

Discussion: The mean zinc is higher in the surface samples (surface mean = 0.28, subsurface mean = 0.20). Biggest sample-wise difference observed at Sample 1 Ghaghi WF Mainpat (surface − subsurface = 0.200). Trace element differences may be controlled by redox status, leaching or parent material variability.

4.9. Iron (mg/kg):
In the present study, the concentration of iron (Fe) in soil samples collected from the areas surrounding Banki Dam and Ghaghi Waterfall in Surguja district shows noticeable spatial variation. For surface soil, iron content ranged from 0.6 to 1.4 mg/kg, with the highest concentration observed at Ghaghi Waterfall (Sample 1 and Sample 3, both 1.4 mg/kg) while the lowest value was recorded at Khairbar Banki Dam (Sample 4, 0.6 mg/kg). This indicates that the waterfall region possesses slightly higher iron availability, possibly due to natural mineral leaching from upstream rocks and constant water flow, which may contribute to nutrient enrichment in the topsoil. In comparison, subsurface soil samples exhibited iron content ranging from 0.8 to 1.7 mg/kg, with the highest value found near the Banki Dam area (Sample 4, 1.7 mg/kg). This suggests that iron tends to accumulate at deeper layers, particularly in the dam region where reduced surface runoff and slower soil movement may enhance mineral deposition.
Overall, the study reveals that both sites exhibit moderate iron concentration, with subsurface soils showing slightly higher values. These variations may be attributed to differences in geomorphology, soil formation processes, and local hydrological conditions. The findings reflect typical nutrient distribution patterns in the soils of the Surguja district, and the iron levels remain within normal ranges suitable for agricultural practices in the region.

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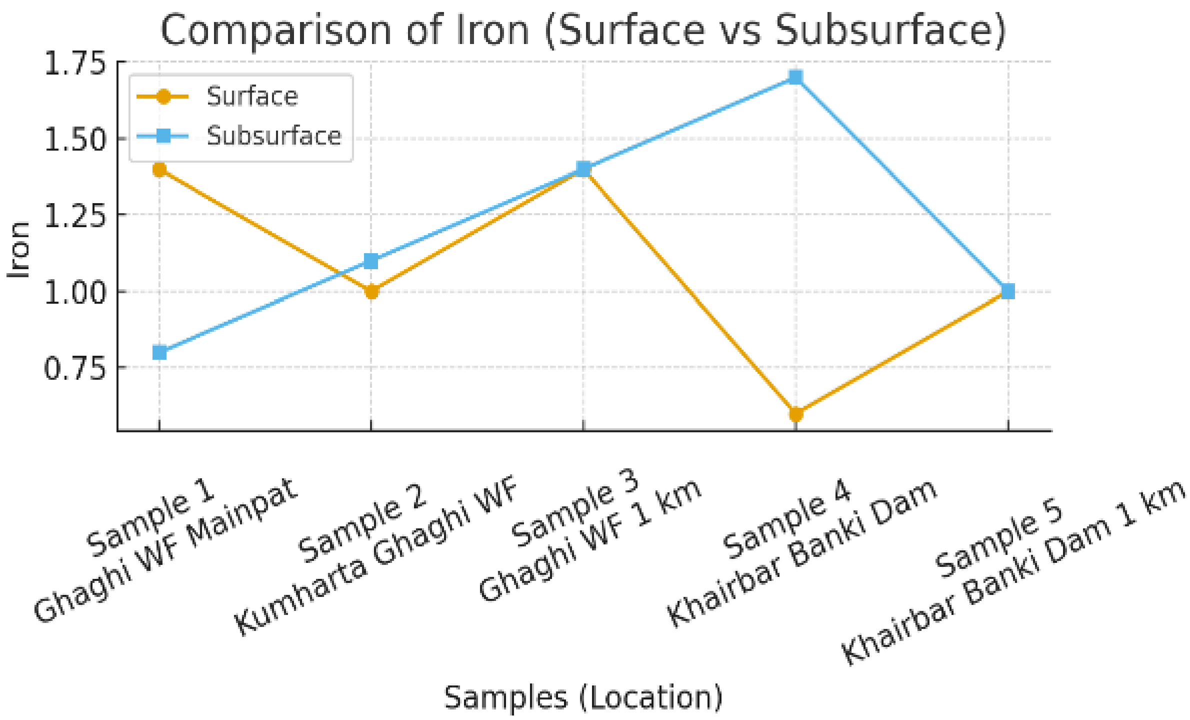

Figure-9: Comparative plot of Iron for surface and subsurface samples across five sampling locations.

The mean iron is lower in the subsurface samples (surface mean = 1.08, subsurface mean = 1.20). Biggest sample-wise difference observed at sample 4 Khairbar Banki Dam (surface-subsurface = -1.100). Trace element differences may be controlled by redox status, leaching, or parent material variability.

4.10 Manganese (mg/kg):

Manganese content in the soil showed small variation between sampling sites. In surface soil, values ranged from 0.6 to 0.9 mg/kg, with lower levels at Ghaghi Waterfall (0.6 mg/kg) and higher concentrations at Banki Dam (0.9 mg/kg). In subsurface soil, manganese ranged from 0.5 to 0.9 mg/kg, again with higher values in the dam area compared to the waterfall region. The slightly higher manganese levels at Banki Dam may be due to sediment accumulation and weaker soil erosion, allowing minerals to remain in the soil. In contrast, the Ghaghi Waterfall area experiences continuous water flow, which may lead to nutrient leaching and slightly lower manganese values. Overall, manganese levels in the study area fall within normal ranges, indicating that the soils are sufficiently supplied with this micronutrient for agricultural use.

4.11 Copper (mg/kg):

The copper (Cu) concentration in soils collected from the vicinity of Banki Dam and Ghaghi Waterfall shows small numerical variation between the two sampling depths.

- In surface soils, copper values ranged from 0.1 to 0.2 mg/kg.
  - The Ghaghi Waterfall sites (Samples 1, 2, and 3) recorded lower Cu levels of 0.1 mg/kg.
  - Higher concentrations of 0.2 mg/kg were observed in the Banki Dam region (Samples 4 and 5).
- In subsurface soils, copper concentration varied between 0.1 and 0.2 mg/kg.
  - Ghaghi Waterfall samples showed consistent values of 0.1 mg/kg,
  - while the highest value (0.2 mg/kg) was recorded at Khairbar Banki Dam (Sample 5).

Overall, both surface and subsurface soils exhibit low but comparable copper levels, with slightly higher values in the dam region.

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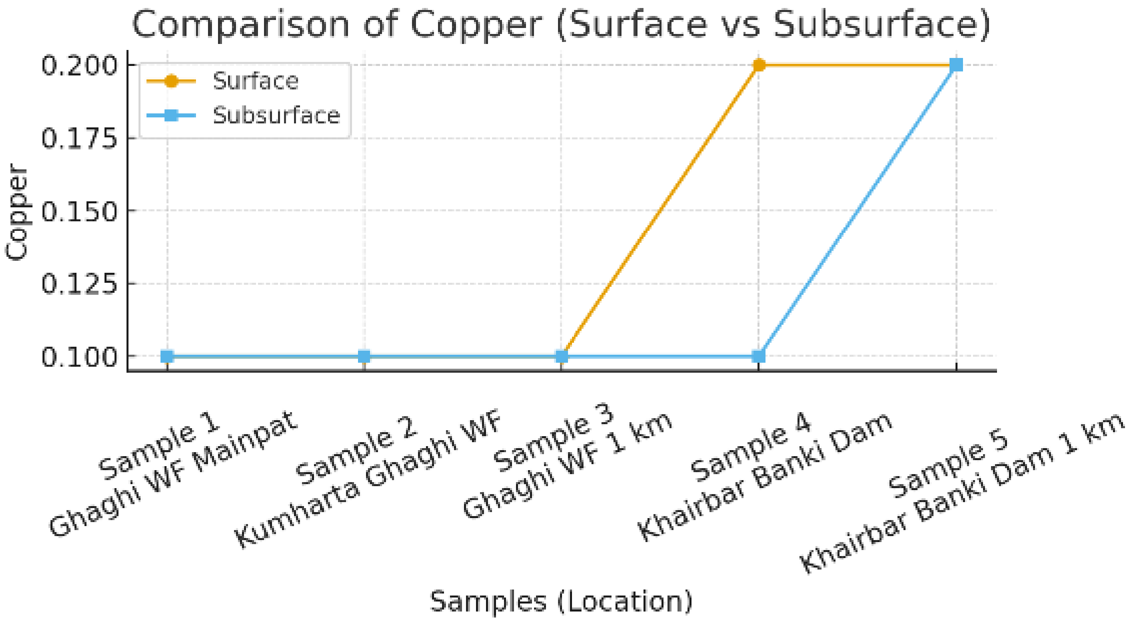

Figure-11: Comparative plot of copper for surface and subsurface samples across five sampling locations.

Discussion: The mean copper is higher in the surface samples (surface mean = 0.14, subsurface mean = 0.12). Biggest sample-wise differences observed at sample 4 Khair Banki Dam (surface − subsurface = 0.100). Trace element differences may be controlled by redox status, leaching, or parent material variability.
The results indicate that copper availability in the study area is influenced by topographic and hydrological factors.

- The higher Cu concentration at Banki Dam may be attributed to sediment deposition and reduced nutrient loss, which allow essential micronutrients such as copper to accumulate in the soil.
- In contrast, the Ghaghi Waterfall region experiences continuous water runoff, which can promote nutrient leaching, resulting in lower Cu levels in both soil layers.
- The similarity between surface and subsurface copper values suggests that vertical mobility of copper is limited, likely due to soil binding and stable mineral forms.
- Despite the variations, all measured values fall within the normal range for agricultural soils, indicating that copper availability in the region is adequate for plant growth and does not present deficiency-related constraints.

This trend aligns with typical micronutrient distribution patterns in forested and high-rainfall landscapes, where runoff and soil transport play a key role in nutrient balance.

5.CONCLUSION

The present study provides a comprehensive physico-chemical characterization of soils collected from the surrounding areas of Banki Dam and Ghaghi Waterfall in the Surguja district of Chhattisgarh. Analysis of surface (0-15cm) and subsurface(15-30cm) soil samples indicate noticeable spatial and vertical variations in soil properties, influenced by local geology, vegetation, and site conditions. Soil pH values ranged from slightly acidic to neutral in both layers, representing a favourable range for nutrients availability and crop growth. Electrical conductivity remained low across samples, indicating negligible salinity hazards. Organic carbon content was comparatively higher in surface soils, suggesting better biological activity, organic matter accumulation, and nutrient cycling in the upper horizons. Major nutrients also displayed meaningful variability. Nitrogen and phosphorus levels were generally adequate but relatively lower in subsurface layers, while potash concentrations fell within medium to high fertility categories, highlighting the agricultural suitability of the region. Micronutrients such as iron, zinc, manganese, and boron exhibited site-specific variations, which may be controlled by redox conditions, leaching, mineral composition, and soil-forming processes.
Overall, the findings confirm that the soils in the study area possess favorable fertility characteristics and hold significant potential for sustainable agricultural utilization. However, differences observed between sampling locations and soil depths emphasize the need for site-specific nutrient management strategies, including appropriate fertilizer scheduling and the incorporation of organic amendments to sustain long-term soil health. The study contributes useful baseline information for farmers, land managers, and policy planners to support efficient resource utilization, soil conservation, and improved crop productivity in the Surguja region.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

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REFERENCES

[1]. Prasad, Mr & Maurya, Dr & Toppo, Mr & Dubey, Miss. (2025). Study of Physio-Chemical Analysis of Soil Taken from Lafri, Area of Surguja District of Chhattisgarh, India. International Journal of Research Publication and Reviews. 6. 3775-2781. 10.55248/gengpi.6.0725.25152.

[2]. Mr. Govind Prasad, Dr. M.K. Maurya, Dr. S.K. Srivastava, "Modeling and Theoretical Study of Microwave and Millimetre-Wave Propagation under Dusty Conditions in the Coalfield Region of Surguja District, Chhattisgarh," International Advanced Research Journal in Science, Engineering and Technology (IARJSET), DOI: 10.17148/IARJSET.2025.1211024

[3]. Prasad, G., Maurya, M. K., Chaudhary, P., Chakradhar, G., & Anshumala. (2025). Physio chemical characterization and suitability assessment of water from Ramgarh (Sitabengra) area located in Surguja district, Chhattisgarh, India. Saraswati Mahavidyalaya, Ambikapur, Chhattisgarh, India. [Unpublished manuscript].

[4]. Prasad, G., Maurya, M. K., Nayak, R. K., & Chaudhary, M. (2025). Comparative study of physico-chemical properties of surface and subsurface soils from Lakhanpur, Surguja District, Chhattisgarh, India. [Unpublished manuscript].

[5]. Yadav, S., Maurya, M. K., & Prakash, U. (2025). Solar mass and dark energy dependence characteristics study of black holes and their role in galaxy formation and cosmic evolution. Department of Physics, Rajeev Gandhi Government P.G. College, Ambikapur, Chhattisgarh, India. [Unpublished manuscript].

[6]. Kumar, Suresh & Maurya, Dr. (2025). Comperative Study Of Physical And Chemical Properties Of Agriculture Soil In Raghunathpur Area, MainpatAndAjirmaOfSurguja Division. International Journal of Research Publication and Reviews. 6. 7813-7820. 10.55248/gengpi.6.0625.2269.

[7]. Srivastava, S.K., Mishra, G.P. Study of the characteristics of the soil of Chhattisgarh at X band frequency. Sadhana 29, 343–347 (2004). https://doi.org/10.1007/BF02703685

[8]. Maurya, Manish Kumar, et al. "MULCHING: ENHANCING SOIL ENVIRONMENT." ADVANCES IN AGRICULTURAL & ENVIRONMENTAL SUSTAINABILITY: 28

[9]. Kumar, M., Kushwaha, R., Maurya, M. K., Singh, G., & Kumari, R. (2017). Knowledge, awareness and attitude regarding biomedical waste management among medical students in a tertiary health care centre: A cross sectional study. Indian J. Res. Med. Sci, 6, 611-614.

[10]. Maurya, Mukesh Kumar, et al. "Study on genetic variability and seed quality of groundnut (Arachis hypogaea L.) genotypes." International Journal of Emerging Technology and Advanced Engineering 4.6 (2014): 818-823.

[11]. Maurya, M. K., et al. "Study of characteristic properties of electromagnetic radiation in the presence of earth's atmosphere." spectrum 9 (2024): 17.

[12]. Maurya, M. K., and Harleen Babra. "Dielectric Dependence Characteristic Study Of Sugarcane Vegetation At C-Band MW Frequency and Comparison With Debye-Cole Dual Dispersion Model."

[13]. Prasad, G., Maurya, M. K., Nayak, R. K., & Chaudhary, M. (2025). Comparative study of physico-chemical properties of surface and subsurface soils from Lakhanpur, Surguja District, Chhattisgarh, India. [Unpublished manuscript].

[14]. Swati Shrivastava, S. S., & Kanungo, V. K. (2013). Physico-chemical analysis of soils in Surguja district Chattishgarh, India.

[15]. Verma, U. S., Jatav, G. K., & Bhagat, R. K. (2013). Evaluation of soil fertility status in Inceptisol of Malkharauda block in Janjgir district of Chhattisgarh. An Asian Journal of Soil Science, 8(1), 103-109.

[16]. Mahla, H. K., Tiwari, A. L. O. K., & Devdas, D. E. E. P. I. K. A. (2014). Evaluation of soil fertility status in red and yellow soil of Navagarh block in Janjgir-Champa district of Chhattisgarh. International Journal of Agricultural Sciences, 10(2), 550-557.

[17]. Rajak, M., Patel, K. S., Jaiswal, N. K., Patel, R. K., Bontempi, E., Yubero, E., ... & Martín-Ramos, P. (2023). Urban soil quality of Raipur, Chhattisgarh, India. Environmental Quality Management, 32(3), 287-299.

[18]. *SAHU, K. D., & VISHWAVIDYALAYA, I. G. K. EVALUATION OF SOIL FERTILITY IN SOILS OF JAIJAIPUR BLOCK IN DISTRICT JANJGIR-CHAMPA OF CHHATTISGARH*

[19]. Kevat, T. K., Chowdhury, T., Bhambri, M. C., & Gupta, S. B. Changes in physico-chemical properties of soil as influenced by conservation agriculture in rice based cropping system of Chhattisgarh.

