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Comparative Physico–Chemical Analysis of Soils from Different Sites in Udaipur Area, Surguja District, Chhattisgarh

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Abstract: The present study focuses on the comparative evaluation of physico–chemical characteristics of soils collected from multiple sites within the Udaipur region of Surguja District, Chhattisgarh, India. Both surface (0–15 cm) and subsurface (15–30 cm) samples were analyzed to assess spatial and depth-wise variations in soil properties. The parameters investigated include pH, electrical conductivity (EC), organic carbon (OC), and the available concentrations of key macronutrients—Nitrogen (N), Phosphorus (P), and Potassium (K)—along with essential micronutrients such as Sulphur (S), Zinc (Zn), Iron (Fe), Manganese (Mn), Copper (Cu), and Boron (B).

The findings indicate distinct differences among the sampling sites and between soil layers. Surface soils showed comparatively higher organic carbon and nitrogen levels, reflecting increased biological activity and accumulation of organic matter in the topsoil. In contrast, subsurface samples exhibited relatively higher electrical conductivity and inconsistent trends in micronutrient availability, likely influenced by leaching and soil composition. The soil pH values ranged from slightly acidic to nearly neutral, suggesting favourable conditions for most crop species. Overall, this comparative investigation provides valuable insight into the nutrient dynamics and fertility status of Udaypur soils, serving as a useful reference for sustainable land management and region-specific agricultural planning.

Keywords: Soil analysis; Physico–chemical properties; Nutrient dynamics; Surface and subsurface soil; Soil fertility; Udaipur area; Surguja district; Chhattisgarh; Macronutrients; Micronutrients; Sustainable agriculture; Soil management.

I. INTRODUCTION

1) Soil is a vital natural resource that supports plant growth and maintains ecological balance by serving as a major reservoir of nutrients, water, and microorganisms. The fertility and quality of soil directly influence agricultural productivity, crop yield, and environmental sustainability. Therefore, understanding the physico–chemical properties of soil is essential for assessing soil health and developing sustainable land-use and agricultural practices.

2) The present study focuses on the Udaipur area of Surguja District, located in the northern part of Chhattisgarh, India. Geographically, the study region lies approximately between 23.06° N to 23.12° N latitude **and** 83.20° E to 83.27° E **longitude**. Udaipur is known for its agricultural significance and varied cropping patterns supported by favourable climatic conditions and fertile soils. The region exhibits noticeable diversity in soil texture, topography, and land use, which influences the distribution of essential nutrients and overall soil fertility.

3) This study aims to carry out a comparative physico–chemical analysis of soil samples collected from different sites within the Udaipur region to evaluate spatial and depth-wise variations. The parameters analysed include soil pH, electrical conductivity (EC), organic carbon (OC), and concentrations of major nutrients—Nitrogen (N), Phosphorus (P), and Potassium (K)—along with selected micronutrients. The findings of this research will provide valuable insights into the nutrient dynamics and fertility status of soils in the Udaipur area, aiding in the formulation of effective, site-specific soil management and sustainable agricultural strategies for the Surguja plateau region.

II. LITERATURE REVIEW:

1) Prasad G. and Maurya M. K.et al. (2025), conducted a study on the physico-chemical properties of soil in the Lafri area of Surguja district, Chhattisgarh. Soil is a fundamental resource for agriculture, influencing crop growth, nutrient availability, and overall productivity. In their study, they analyzed parameters such as pH, organic carbon, moisture content, and essential nutrients like nitrogen, phosphorus, and potassium. The study highlighted the spatial variability of soil characteristics due to local climatic and geographical factors and emphasized the importance of such analyses for assessing soil fertility and crop suitability. These findings offer valuable insights for sustainable land management, efficient nutrient application, and enhancing agricultural productivity in the region. [1]
2) Prasad G. and Maurya M. K. et al. (2025), conducted a comparative study on the physico-chemical properties of surface and subsurface soils from Lakhanpur, Surguja district, Chhattisgarh, to assess their suitability for agriculture. Soil samples were analyzed for texture, pH, electrical conductivity, organic carbon, essential nutrients (N, P, K, micronutrients), cation exchange capacity, and bulk density. The study revealed variations in texture and structure affecting water retention and drainage. Soil pH was slightly acidic to neutral, while EC indicated moderate salinity in some areas. Organic carbon was generally adequate, though deficiencies in nitrogen and phosphorus were noted. The authors highlighted the need for targeted soil amendments and improved management practices to enhance fertility and support sustainable agriculture.[2]
3) Srivastava and Mishra (2004) carried out a laboratory-based experiment to measure the real (ε_1) and imaginary (ε_2) parts of the complex dielectric constant (ε) for sand, silt, and clay at a frequency of 9.967 GHz. By applying the infinite sample method, the study examined how different moisture levels affect the dielectric response of these soil types. The results revealed that both ε_1 and ε_2 increased slowly as moisture content rose until a certain threshold, beyond which a sharp rise was recorded. This pattern demonstrates that moisture plays a crucial role in altering the dielectric characteristics of soils, and the rate of increase becomes significantly higher when the soil nears saturation.[3]
4) Kumar, S. and Dr. Maurya (2025) conducted a comparative study of agricultural soils from Ajirma, Raghunathpur, and Mainpat in the Surguja region and noted significant variations in their physico-chemical properties, particularly in pH, organic carbon, and nitrogen content. Among the locations, soils from Mainpat showed relatively balanced fertility, while those from Ajirma and Raghunathpur exhibited nutrient deficiencies and greater acidity. The research highlighted the need for site-specific soil improvement measures, such as applying lime to adjust soil pH, adding organic matter to enhance carbon levels, and implementing suitable fertilization practices to strengthen soil quality and support sustainable agricultural development in the area.
5) Prasad, Maurya and Srivastava (2025) noted that dust and sand in the environment significantly affect microwave and millimetre-wave communication by increasing signal attenuation and scattering. Mie Scattering Theory is commonly used to estimate scattering and absorption when particle size is comparable to the signal wavelength. To explain the overall dielectric response of dust-filled media, studies also apply Effective Medium Approximations such as the Maxwell–Garnett and Bruggeman models. For dense particulate conditions, the Radiative Transfer Equation (RTE) is often used to model multiple scattering effects. Additionally, several empirical and semi-empirical models based on visibility, dust concentration, and particle density provide practical estimates of signal loss in real conditions. Laboratory validation techniques referenced in the literature include Vector Network Analyzer (VNA) testing, Point-to-Point Analyzer (PPA), the Infinite Sample Method, and the Two-Point Dielectric Method. Most studies agree that signal attenuation rises with increasing frequency and particle concentration, with frequencies above 30 GHz being more vulnerable. Coal dust also causes stronger dielectric losses than sand, making its impact particularly important in mining areas like Surguja.

III. MATERIAL AND METHODS:

A. Study Area Description

The present study was conducted in various locations around the Udaipur area of Surguja District, Chhattisgarh, India. The terrain in this region is characterized by gentle undulations, interspersed with patches of natural vegetation and moderate agricultural land-use. The region has a subtropical climate with marked seasonal variations, which significantly influence soil formation, moisture dynamics, and nutrient cycling.

To capture spatial variability in soil physico-chemical properties, we selected five representative sampling sites across the study area. The sites, along with their approximate geographic coordinates, are as follows:

1) Sample 1 – Dandgaon (Udaipur) (approx. 22.95° N, 83.20° E)
2) Sample 2 – Sontarai (Udaipur) (approx. 22.98° N, 83.22° E)

3) Sample 3 – Jhirmiti (Udaipur) (approx. 23.00° N, 83.18° E)
4) Sample 4 – Ramgarh Road (Udaipur) (approx. 23.02° N, 83.15° E)
5) Sample 5 – Udaipur (town/central area) (approx. 23.00° N, 83.20° E)

These five sites form a spatial transect covering varied landscape settings. This sampling framework provides a scientific basis for systematically comparing soil physico-chemical characteristics, assessing fertility status, and evaluating the influence of local topography, vegetation cover, and land-use practices across the Udaipur area.

B. Soil Sample Collection

For assessing the physico-chemical variability of soils across different locations in the Udaipur area of Surguja District, samples were collected from two distinct depths at each sampling point:

- Surface layer (0-15 cm
- Subsurface layer (15–30 cm)

At every site, five subsamples were randomly collected within an approximate radius of 10 meters and thoroughly mixed to prepare a single composite sample. This approach enhances representativeness and minimizes the effect of localized heterogeneity. A stainless-steel auger and spade were used during the entire sampling process to ensure that no external chemical contamination affected the results.

C. Sample Preparation

The freshly collected soil samples were subjected to standard preparation procedures:

1) Air-dried at room temperature in the shade to prevent thermal alteration of chemical properties.
2) Crushed gently using a wooden roller to break aggregates while avoiding any interaction with metallic surfaces.
3) Passed through a 2 mm sieve to obtain uniform particle size and to remove stones, roots, and other debris.

The processed samples were then stored in airtight, properly labeled polyethylene bags for further laboratory examination.

D. Physico-Chemical Analysis

All analytical determinations were carried out using standardized soil testing protocols as outlined by recent methodological references (Singh 2023; Verma & Paul 2023; Pansu & Gautheyrou 2006). The following parameters were examined:

1) Soil Texture

Soil particle size distribution-sand, silt, and clay-was determined using the hydrometer/sieve method, facilitating textural classification based on USDA system guidelines.

2) Soil pH and Electrical Conductivity (EC)

- pH was measured using a digital pH meter in a 1:2.5 soil–water suspension.
- EC was determined using a conductivity meter to assess the concentration of soluble salts in the soil.

3) Organic Carbon

Organic carbon content was quantified using a wet oxidation method, which provides an estimate of soil organic matter and its contribution to fertility and biological activity.

4) Macronutrients

The available macronutrients analysed include:

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

These were assessed through standard extraction and titration/spectrophotometric techniques widely employed in soil fertility studies.

5) Cation Exchange Capacity (CEC)

CEC was evaluated to determine the soil’s ability to adsorb, retain, and exchange essential cations, which plays a crucial role in nutrient availability and overall soil productivity.

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E. Data Interpretation

The generated physico-chemical data were systematically analyzed to compare variations between the surface (0–15 cm) and subsurface (15–30 cm) soil layers across the study area. Statistical evaluation was carried out to identify depth-wise trends and to determine how nutrient distribution changes with soil profile development. Additionally, spatial comparisons among different sampling sites within the Udaipur region of Surguja District were performed to assess the role of local geomorphology, vegetation cover, and land-use or agricultural practices in shaping overall soil quality and fertility status.

Comparative Physico-Chemical Parameters of Surface Soil Samples from Different Locations of Udaipur District:

Parameters	Sample 1 Dandgaon (Udaipur)	Sample 2 Sontarai (Udaipur)	Sample 3 Jhirmiti (Udaipur)	Sample 4 Ramgarh road(udaipur)	Sample 5 Udaipur
Ph	5.49	5.92	5.90	6.44	6.32
Electric Conductivity	0.19	0.30	0.14	0.47	0.26
Organic carbon	0.56	0.75	0.80	0.86	0.61
Nitrogen	217.00	269.00	282.00	305.00	230.00
Phosphorus	14.40	12.50	12.50	15.10	17.80
Potash	286.00	277.00	302.00	301.00	304.00
Zinc	0.2	0.2	0.2	0.2	0.2
Copper	0.1	0.1	0.2	0.1	0.1
Iron	1.2	1.7	1.0	1.5	1.4
Boron	0.2	0.2	0.2	0.2	0.2
Manganese	0.4	0.6	0.4	0.8	0.7
Molybdenum	0.1	0.1	0.1	0.1	0.1

Comparative Physico-Chemical Parameters of Sub-Surface Soil Samples (15–30 cm) from Different Locations of Udaipur District

Parameters	Sample 1 Dandgaon (Udaipur)	Sample 2 Sontarai (Udaipur)	Sample 3 Jhirmiti (Udaipur)	Sample 4 Ramgarh road(udaipur)	Sample 5 Udaipur
Ph	5.55	6.00	5.95	6.40	6.38
Electric Conductivity	0.12	0.30	0.18	0.52	0.19
Organic carbon	0.60	0.81	0.84	0.80	0.60
Nitrogen	228.00	277.00	294.00	295.00	228.00
Phosphorus	15.00	14.00	13.00	14.00	21.00
Potash	297.00	290.00	308.00	290.00	307.00
Zinc	0.2	0.3	0.2	0.2	0.3
Copper	0.1	0.1	0.1	0.2	0.1
Iron	0.4	1.9	1.2	1.4	1.0
Boron	0.2	0.2	0.2	0.2	0.2
Manganese	0.6	0.8	0.6	0.9	0.6
Molybdenum	0.1	0.1	0.1	0.1	0.1

IV. RESULT AND DISCUSSION

In the present investigation titled "Comparative Physico–Chemical Analysis of Soils from Different Sites in Udaipur Area, Surguja District, Chhattisgarh," surface (0–15 cm) and subsurface (15–30 cm) soil samples were collected from five georeferenced locations: Dandgaon, Sontarai, Jhirmiti, Ramgarh Road, and Udaipur. The study focuses on key soil parameters including pH, electrical conductivity (EC), organic carbon, essential macronutrients (nitrogen, phosphorus, and potassium), and important micronutrients such as zinc (Zn), iron (Fe), boron (B), manganese (Mn), and copper (Cu). Molybdenum (Mo) was also assessed to understand trace nutrient availability.

The analytical results reveal noticeable spatial differences among the selected sites as well as distinct depth-wise variations between surface and subsurface soil layers. Variability in nutrient levels and soil chemical properties appears to be influenced by local cultivation practices, organic matter inputs, topographic setting, and environmental conditions across the Udaipur region. These observed variations provide meaningful insights into the fertility status and nutrient dynamics of the soils. A detailed, parameter-wise comparison for each sampling site and soil depth is presented in the following sections.

A. Soil pH

The pH of surface soil samples collected from different sites of the Udaipur area ranged from 5.49 to 6.44, indicating slightly to moderately acidic conditions. The lowest pH was observed at Dandgaon, while the highest values were recorded at Ramgarh Road and Udaipur.

In the sub-surface layer (15–30 cm), pH values ranged from 5.55 to 6.40. Sub-surface soils showed a slight increase in pH compared to surface soils, suggesting reduced acidity with depth. Dandgaon again showed the lowest pH, whereas Ramgarh Road and Udaipur showed relatively higher pH.

Comparative Observation:

Both surface and sub-surface soils from all sites fall within the acidic category. Ramgarh Road and Udaipur soils are comparatively less acidic, while Dandgaon soils exhibit the highest acidity. The small difference between surface and sub-surface pH indicates that soil acidity is fairly uniform throughout the soil profile across the studied sites.

pH

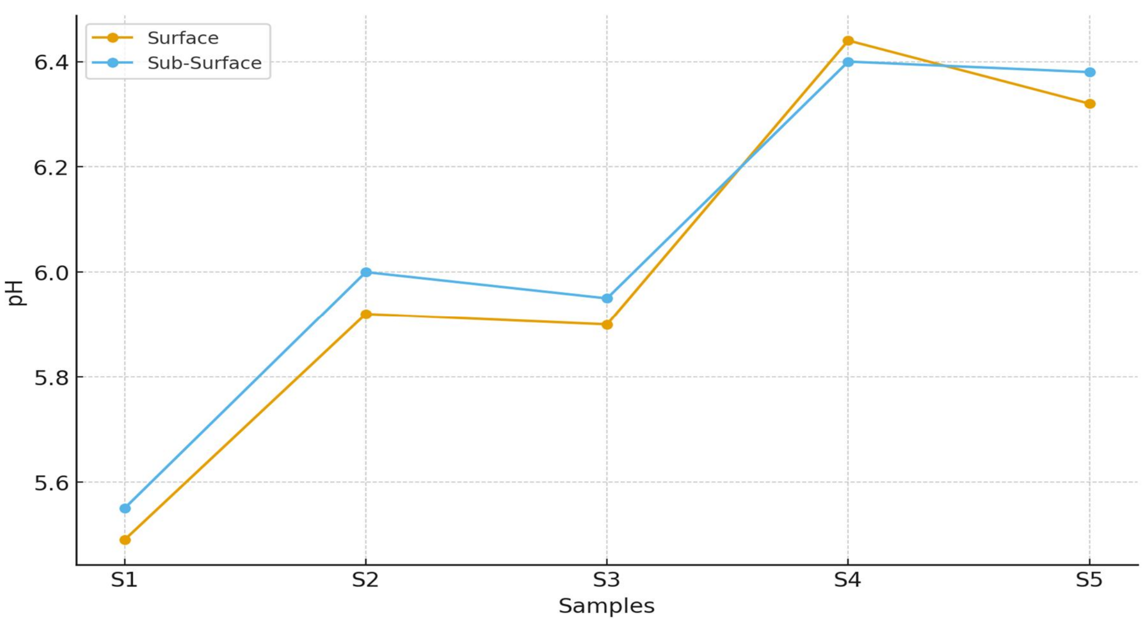

Figure 1: Comparative pH values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For pH, surface values range between 5.49 and 6.44, while sub-surface values range between 5.55 and 6.4. Average surface value = 6.01, and sub-surface average = 6.06. Minor variations among locations indicate spatial heterogeneity in soil profile.

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B. Electrical Conductivity (EC):

1) Surface Soil Samples (0–15 cm)

The electrical conductivity (EC) of surface soil samples collected from five locations of Udaipur district showed noticeable spatial variation. The EC values ranged from 0.14 to 0.47 dS/m, indicating low to moderate salinity in the study area.

Sample 3: Jhirmiti recorded the lowest EC (0.14 dS/m), reflecting minimum soluble salt concentration in the upper soil layer.

Sample 4: Ramgarh Road exhibited the highest EC (0.47 dS/m), suggesting comparatively greater salt accumulation, possibly due to local mineralogy, anthropogenic influence, or reduced leaching.

Other samples- Dandgaon (0.19), Sontarai (0.30), and Udaipur (0.26 dS/m)—fell within the normal EC range for agricultural soils, indicating overall non-saline to slightly saline conditions.

Overall, the variation in surface EC values highlights differences in soil parent material, drainage conditions, and land use practices across the sampling sites.

2) Sub-Surface Soil Samples (15–30 cm)

The EC of sub-surface soils (15–30 cm depth) also showed spatial variability, ranging from 0.12 to 0.52 dS/m across the five sampling locations. The minimum EC (0.12 dS/m) was observed in Dandgaon, indicating a very low concentration of dissolved salts below the surface. The maximum EC (0.52 dS/m) was found at Ramgarh Road, which suggests downward movement and deposition of salts at deeper layers, possibly due to percolation patterns or soil texture. The remaining sites—Sontarai (0.30), Jhirmiti (0.18), and Udaipur (0.19 dS/m)- showed moderate EC values, indicating normal salt distribution in sub-surface profiles.

The overall trend shows that locations with higher EC in surface soil similarly exhibited higher EC in sub-surface layers, which reflects vertical continuity in soil salinity patterns.

EC

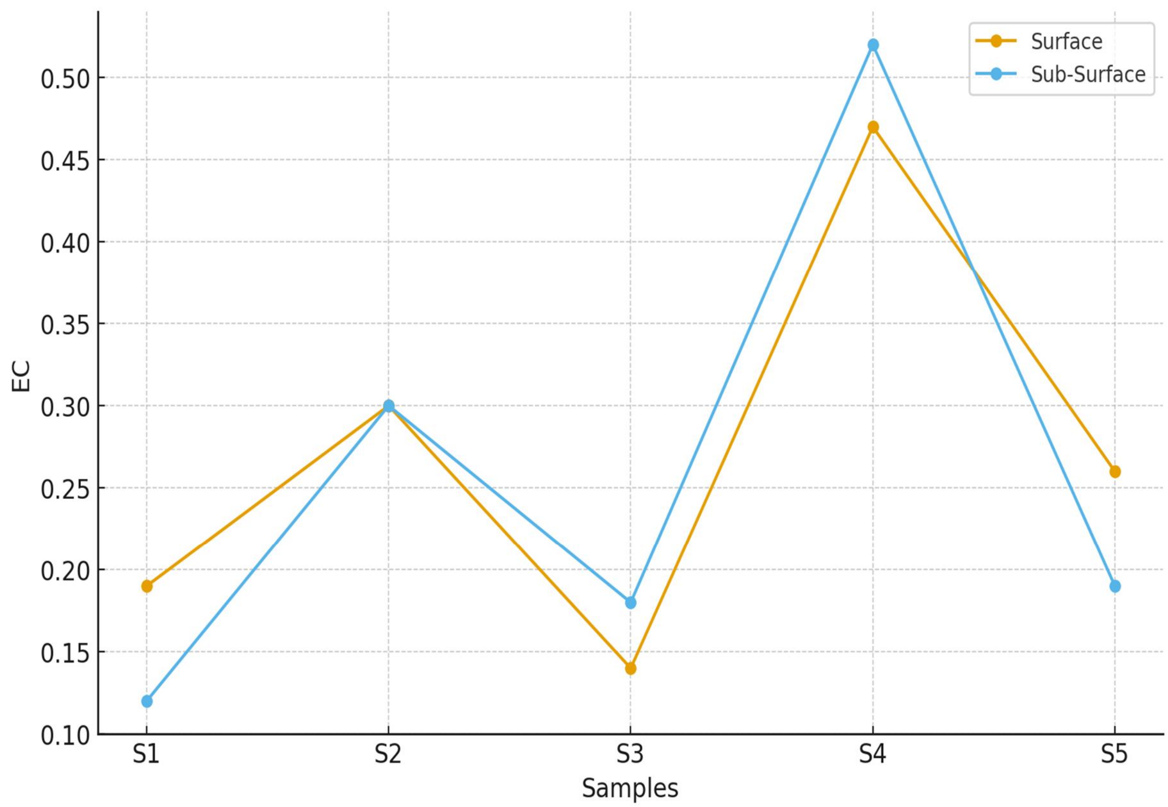

Figure 2: Comparative electrical conductivity (EC) values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For EC, surface values range between 0.14 and 0.47, while sub-surface values range between 0.12 and 0.52. Average surface value = 0.27, and sub-surface average = 0.26. Minor variations among locations indicate spatial heterogeneity in soil profile.

C. Organic Carbon (%)

1) Organic Carbon in Surface Soils (0–15 cm)

The organic carbon content of the surface soils showed noticeable variation across the five sampling locations of the Udaipur area. Values ranged from 0.56% to 0.86%. The lowest organic carbon content was observed at Dandgaon (0.56%), while the highest value was observed at Ramgarh Road (0.86%). Sontarai (0.75%), Jhirmiti (0.80%), and Udaipur (0.61%) exhibited moderate levels of organic carbon. These variations indicate differences in vegetation cover, organic matter decomposition, and land-use intensity among the sites.

2) Organic Carbon in Sub-Surface Soils (15–30 cm)

Sub-surface soil samples also displayed variations in organic carbon content, ranging from 0.60% to 0.84%. The highest value was measured at Jhirmiti (0.84%), followed closely by Sontarai (0.81%). Dandgaon and Udaipur both recorded 0.60%, while Ramgarh Road showed 0.80% organic carbon. As expected, sub-surface soils generally contained slightly lower organic carbon than the surface layer at most sites, which aligns with the natural decline of organic matter with increasing depth.

3) Comparative Assessment

Overall, both surface and sub-surface layers demonstrated moderate organic carbon levels, indicating fairly productive soils across the Udaipur area. Among all sites, Ramgarh Road and Jhirmiti consistently showed higher organic carbon concentrations, suggesting better organic matter accumulation, possibly due to favorable land management or reduced disturbance. The comparative results highlight spatial variability in soil fertility characteristics, which is essential for site-specific soil management and sustainable agricultural planning.

OC

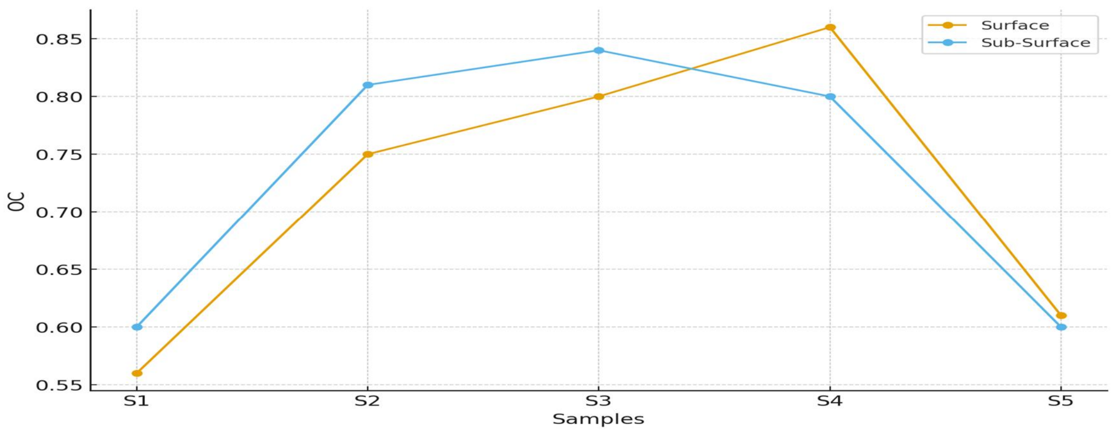

Figure 3: Comparative Organic Carbon values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For OC, surface values range between 0.56 and 0.86, while sub-surface values range between 0.6 and 0.84. Average surface value = 0.72, and sub-surface average = 0.73. Minor variations among locations indicate spatial heterogeneity in soil profile.

D. Available Nitrogen (kg/ha)

In the present study, the available nitrogen content of surface and sub-surface soil samples collected from five locations of the Udaipur area was evaluated to understand spatial and depth-wise variations. In surface soils (0–15 cm), available nitrogen ranged from 217 to 305 kg/ha. The lowest value was recorded at Dandgaon (217 kg/ha), while the highest concentration was observed along Ramgarh Road (305 kg/ha). Sontarai and Jhirmiti showed moderately higher nitrogen levels, measuring 269 kg/ha and 282 kg/ha, respectively.

In sub-surface soils (15–30 cm), nitrogen values showed a slight increase or remained comparable to the surface layer, ranging between 228 and 295 kg/ha. Dandgaon and Udaipur exhibited similar nitrogen content (228 kg/ha), whereas Sontarai and Jhirmiti showed higher levels (277 kg/ha and 294 kg/ha, respectively). The Ramgarh Road site recorded 295 kg/ha, indicating minimal reduction with depth.

Overall, the findings reveal that nitrogen availability varies across locations, with Ramgarh Road consistently exhibiting the highest values, while Dandgaon shows comparatively lower nitrogen content. Minor differences between surface and sub-surface layers suggest moderate vertical mobility of nitrogen within the soil profiles of these sites.

N

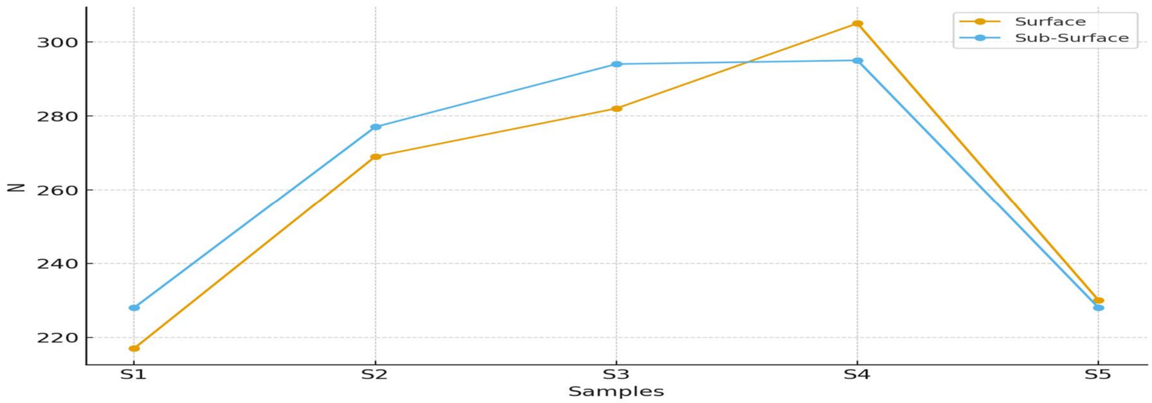

Figure 4: Comparative available nitrogen values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For N, surface values range between 217 and 305, while sub-surface values range between 228 and 295. Average surface value = 260.60, and sub-surface average = 264.40. Minor variations among locations indicate spatial heterogeneity in soil profile.

E. Available Phosphorus (kg/ha)

The available phosphorus content in the surface (0–15 cm) and sub-surface (15–30 cm) soil layers varied notably across the five sampling sites in the Udaipur area. In surface soils, phosphorus concentrations ranged from 12.50 to 17.80 kg/ha. The lowest values were observed at Sontarai and Jhirmiti (12.50 kg/ha each), while the highest phosphorus content was recorded at Udaipur (17.80 kg/ha). Dandgaon and Ramgarh Road showed moderate levels of 14.40 kg/ha and 15.10 kg/ha, respectively.

In the sub-surface layer, phosphorus values showed slight increases at most sites, falling between 13.00 and 21.00 kg/ha. Jhirmiti recorded the lowest concentration (13.00 kg/ha), whereas the highest value was again observed at Udaipur (21.00 kg/ha), indicating a substantial enrichment at deeper depth. Dandgaon and Sontarai exhibited comparable phosphorus levels (15.00 kg/ha and 14.00 kg/ha, respectively), while Ramgarh Road also showed a moderate concentration (14.00 kg/ha).

Overall, the results indicate that Udaipur consistently possesses the highest available phosphorus in both soil layers, whereas Sontarai and Jhirmiti show comparatively lower values. The slight increase in phosphorus content in the sub-surface soils suggests possible downward movement or retention of phosphorus in deeper horizons at certain sites.

P

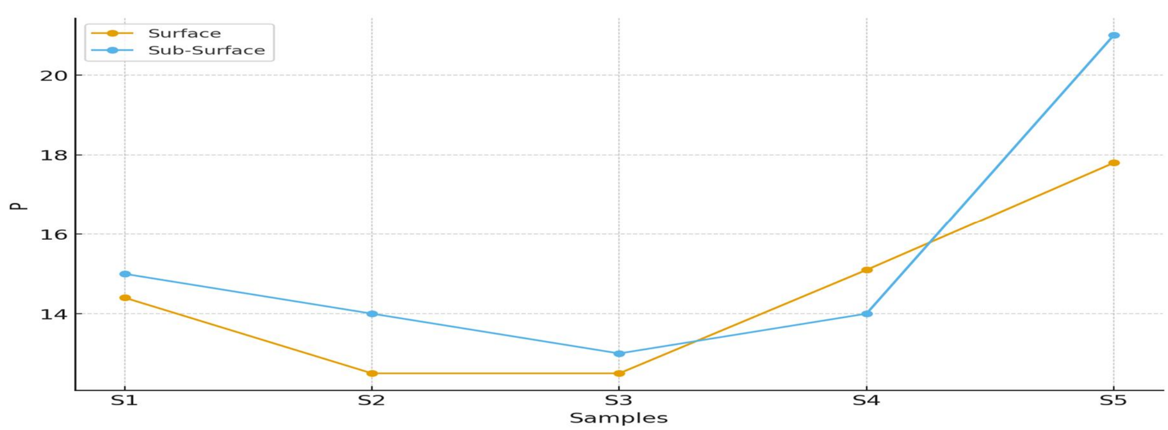

Figure 5: Comparative available Phosphorus values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For P, surface values range between 12.5 and 17.8, while sub-surface values range between 13 and 21. Average surface value = 14.46, and sub-surface average = 15.40. Minor variations among locations indicate spatial heterogeneity in soil profile.

F. Available Potash (kg/ha)

The available potash content in the surface (0–15 cm) and sub-surface (15–30 cm) soil samples showed noticeable variation across the five sampling locations of the Udaipur area. In the surface soils, potash levels ranged from 277 to 304 kg/ha. The minimum concentration was recorded at Sontarai (277 kg/ha), while the maximum value was observed at Udaipur (304 kg/ha). Jhirmiti and Ramgarh Road exhibited relatively higher potash contents of 302 kg/ha and 301 kg/ha, respectively, whereas Dandgaon recorded a moderate value of 286 kg/ha.

In the sub-surface layer, the available potash content showed a slight increase or remained comparable across most sites, ranging between 290 and 308 kg/ha. The lowest value was found at Sontarai and Ramgarh Road (290 kg/ha each), while the highest concentration was recorded at Jhirmiti (308 kg/ha) followed closely by Udaipur (307 kg/ha). Dandgaon also showed a marginal rise to 297 kg/ha compared to its surface layer.

Overall, the findings indicate that Udaipur and Jhirmiti consistently exhibit higher potash availability in both soil depths, while Sontarai shows comparatively lower values. The slight increase in potash content in the sub-surface soils suggests moderate downward translocation or retention of potassium within deeper soil horizons.

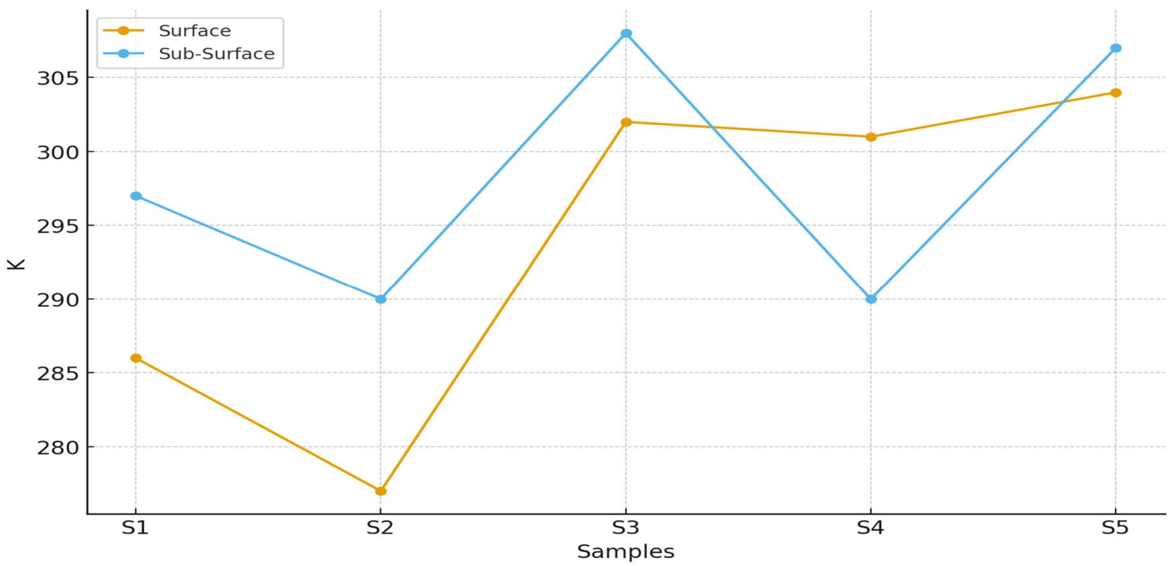

Figure 6: Comparative available Potash values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For K, surface values range between 277 and 304, while sub-surface values range between 290 and 308. Average surface value = 294.00, and sub-surface average = 298.40. Minor variations among locations indicate spatial heterogeneity in soil profile.

G. Boron (mg/kg)

The analysis of available boron in both surface (0–15 cm) and sub-surface (15–30 cm) soils across the five sampling locations of the Udaipur area revealed uniform values throughout the study sites. In the surface layer, all samples- Dandgaon, Sontarai, Jhirmiti, Ramgarh Road, and Udaipur—recorded an identical boron concentration of 0.2 mg/kg, indicating no noticeable spatial variation. A similar pattern was observed in the sub-surface soils, where boron content again remained constant at 0.2 mg/kg across all locations.

The consistency of boron values in both soil depths suggests that boron distribution in these soils is relatively stable and does not vary with location or depth. This uniformity may be attributed to minimal vertical mobility and a relatively homogeneous parent material or similar management practices across the studied sites.

B

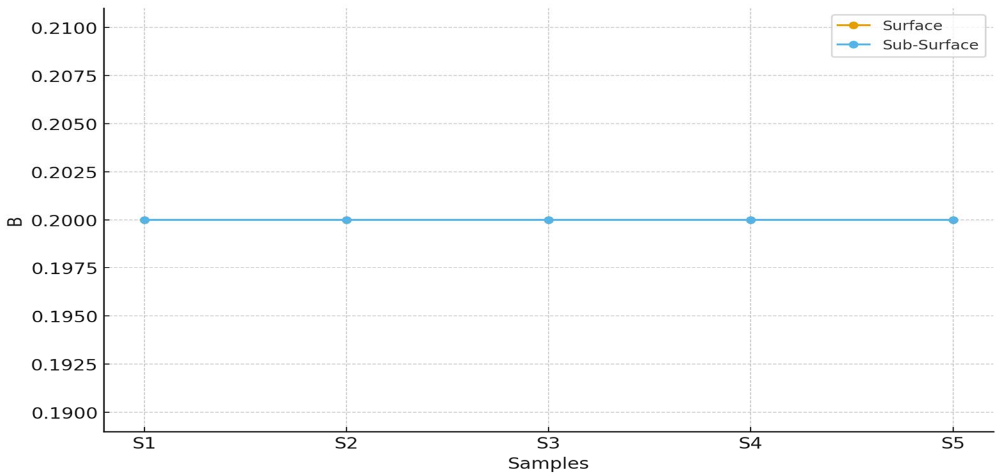

Figure 7: Comparative Boron values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: This uniform distribution suggests that boron is not significantly influenced by soil depth, parent material, or external inputs within this region. It also indicates minimal vertical mobility of boron and relatively homogeneous soil characteristics across Dandgaon, Sontarai, Jhirmiti, Ramgarh Road, and Udaipur. Such consistency may be attributed to similar land-use patterns, geological background, and low leaching tendencies of boron in these soils.

H. Zinc (mg/kg)

The available zinc content in both surface and sub-surface soils showed slight variation across the sampling sites in the Udaipur area. In the surface layer (0–15 cm), zinc concentration remained uniform across all five locations—Dandgaon, Sontarai, Jhirmiti, Ramgarh Road, and Udaipur—with each site recording 0.2 mg/kg. This uniformity indicates stable distribution of zinc in the upper soil layer and minimal influence of local site conditions.

In contrast, the sub-surface soils (15–30 cm) exhibited marginal variation in zinc content, ranging from 0.2 to 0.3 mg/kg. Higher concentrations of 0.3 mg/kg were observed at Sontarai and Udaipur, while Dandgaon, Jhirmiti, and Ramgarh Road maintained a lower value of 0.2 mg/kg. This slight increase in zinc at certain sites may be associated with downward movement of micronutrients or differences in parent material characteristics at deeper depths.

Overall, the results indicate that surface soils display complete uniformity in zinc availability, whereas sub-surface soils show minor spatial variation. Despite these differences, zinc levels across all sites remain within a narrow range, suggesting relatively homogenous micronutrient status in the soils of the studied region.

Zn

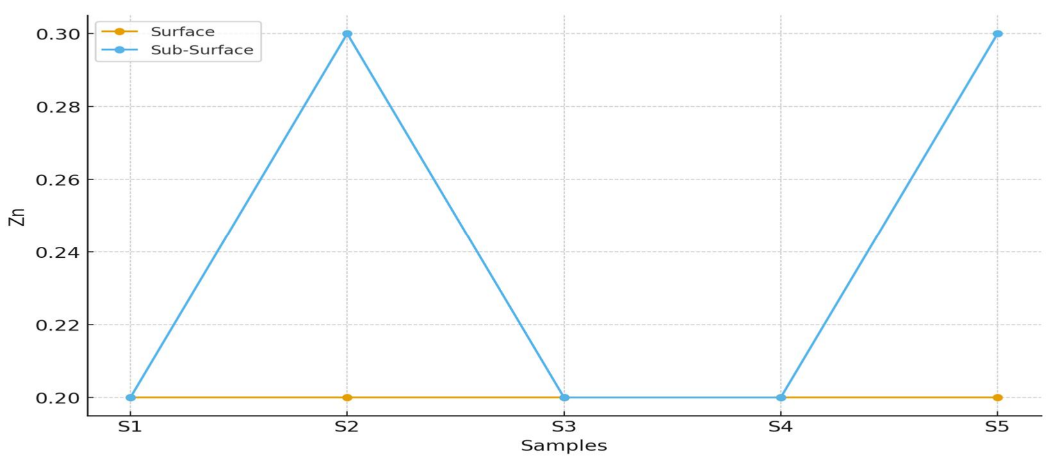

Figure 8: Comparative Zinc values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For Zn, surface values range between 0.2 and 0.2, while sub-surface values range between 0.2 and 0.3. Average surface value = 0.20, and sub-surface average = 0.24. Minor variations among locations indicate spatial heterogeneity in soil profile.

I. Iron (mg/kg)

The available iron content exhibited noticeable variability across both surface (0–15 cm) and sub-surface (15–30 cm) soil layers among the five sampling locations of the Udaipur area. In the surface soils, iron concentrations ranged from 1.0 to 1.7 mg/kg. The lowest value was observed at Jhirmiti (1.0 mg/kg), while the highest concentration occurred at Sontarai (1.7 mg/kg). Dandgaon, Ramgarh Road, and Udaipur recorded moderate iron levels of 1.2 mg/kg, 1.5 mg/kg, and 1.4 mg/kg, respectively, indicating moderate spatial variation in iron availability across sites.

In the sub-surface soils, iron levels ranged from 0.4 to 1.9 mg/kg, reflecting a wider variation compared to the surface layer. The minimum value was found at Dandgaon (0.4 mg/kg), whereas Sontarai (1.9 mg/kg) again recorded the highest concentration, showing a significant increase at deeper depth. Jhirmiti and Udaipur exhibited moderate iron levels of 1.2 mg/kg and 1.0 mg/kg, respectively, while Ramgarh Road maintained a value of 1.4 mg/kg, similar to its surface layer.

Overall, the findings indicate that iron distribution varies considerably with both location and depth. Sontarai consistently shows the highest iron content in both layers, while Dandgaon exhibits the lowest, particularly in the sub-surface soil. The variation suggests differences in parent material, drainage conditions, or redox behavior influencing iron mobility within the soil profiles of the Udaipur region.

Fe

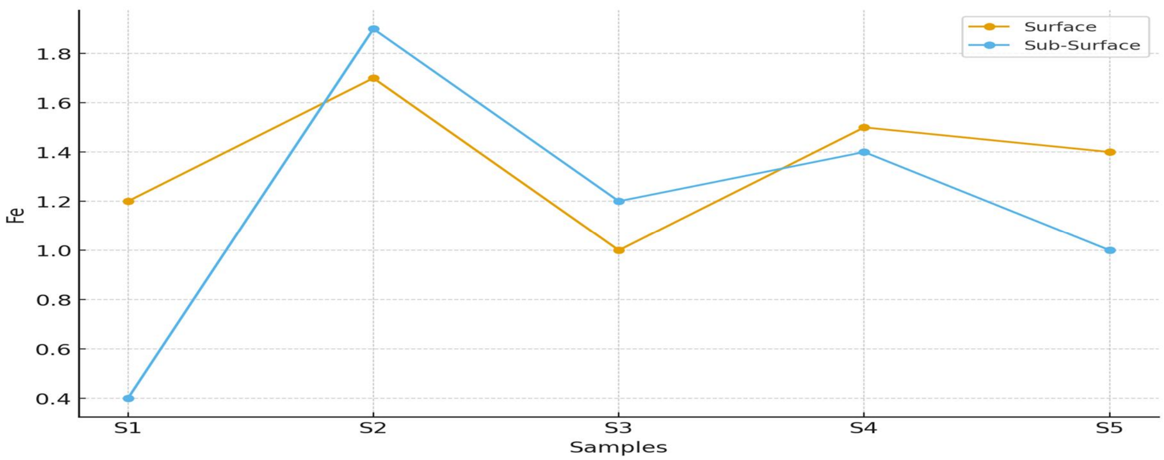

Figure 9: Comparative iron values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For Fe, surface values range between 1.0 and 1.7, while sub-surface values range between 0.4 and 1.9. Average surface value = 1.36, and sub-surface average = 1.18. Minor variations among locations indicate spatial heterogeneity in soil profile.

J. Manganese (mg/kg)

The available manganese content in the soil samples showed noticeable spatial and depth-wise variation across the study locations. In the surface soils (0–15 cm), manganese concentrations ranged from 0.4 to 0.8 mg/kg. The lowest values were recorded at Dandgaon and Jhirmiti (0.4 mg/kg each), while the highest concentration occurred at Ramgarh Road (0.8 mg/kg). Sontarai and Udaipur exhibited moderate levels of 0.6 mg/kg and 0.7 mg/kg, respectively. In the sub-surface soils (15–30 cm), manganese values ranged between 0.6 and 0.9 mg/kg, indicating a slight increase at most sites compared to the surface layer. The maximum value was found at Ramgarh Road (0.9 mg/kg), showing enrichment at deeper depth. Dandgaon and Jhirmiti recorded 0.6 mg/kg, while Sontarai showed a slightly higher value of 0.8 mg/kg. In contrast, Udaipur exhibited a slight reduction to 0.6 mg/kg, compared to its surface value. Overall, manganese distribution shows that Ramgarh Road consistently contains the highest Mn levels in both soil layers, while Dandgaon and Jhirmiti present the lowest concentrations. The generally higher Mn levels in sub-surface soils suggest possible downward movement or accumulation of manganese at deeper horizons, influenced by soil moisture, redox processes, or parent material characteristics.

Mn

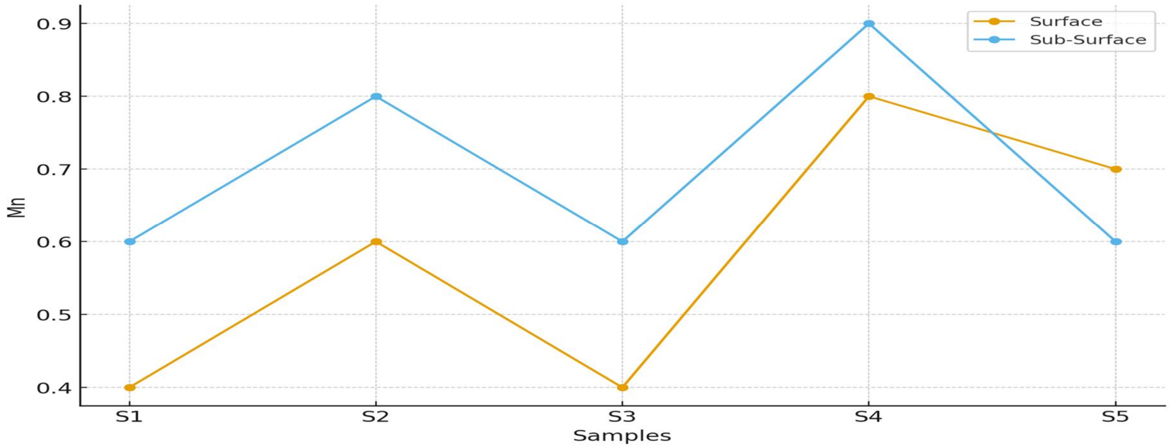

Figure 10: Comparative manganese values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For Mn, surface values range between 0.4 and 0.8, while sub-surface values range between 0.6 and 0.9. Average surface value = 0.58, and sub-surface average = 0.70. Minor variations among locations indicate spatial heterogeneity in soil profile.

K. Copper (mg/kg)

The available copper content in both surface and sub-surface soils exhibited slight variation across the sampling locations in the Udaipur area. In the surface soils (0–15 cm), copper concentrations ranged from 0.1 to 0.2 mg/kg. The highest value was observed at Jhirmiti (0.2 mg/kg), while the remaining sites—Dandgaon, Sontarai, Ramgarh Road, and Udaipur—recorded identical copper levels of 0.1 mg/kg. This indicates limited spatial variation in copper availability within the surface layer.

In the sub-surface soils (15–30 cm), copper values also remained within a narrow range of 0.1 to 0.2 mg/kg. A slightly higher concentration of 0.2 mg/kg was observed at Ramgarh Road, whereas all other locations displayed uniform values of 0.1 mg/kg. The minor increase at Ramgarh Road suggests localized enrichment or downward movement of copper at this site.

Overall, the results indicate that copper distribution in the soils of the Udaipur region is relatively uniform, with only minor site-specific variations. Both soil layers show similar concentration ranges, reflecting low mobility of copper and relatively consistent soil characteristics across the study area.

Cu

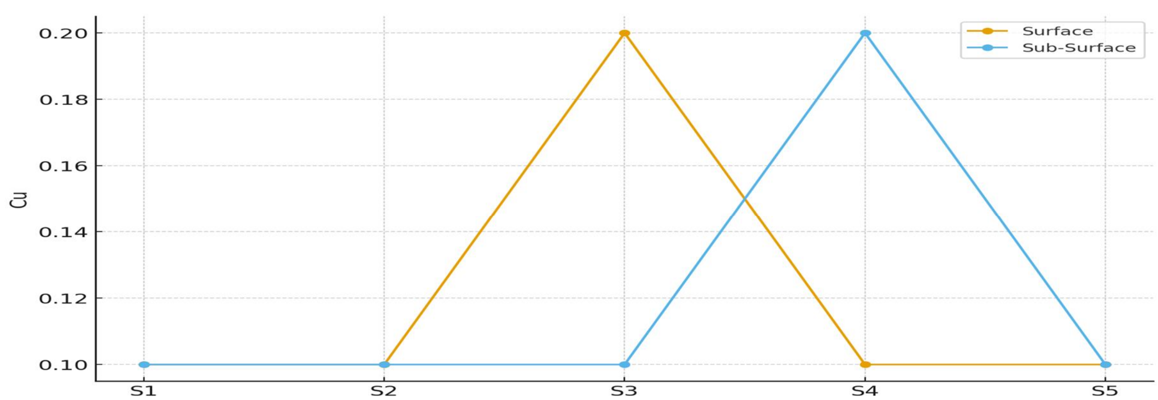

Figure 11: Comparative copper values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For Cu, surface values range between 0.1 and 0.2, while sub-surface values range between 0.1 and 0.2. Average surface value = 0.12, and sub-surface average = 0.12. Minor variations among locations indicate spatial heterogeneity in soil profile.

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L. Molybdenum (mg/kg)

The concentration of available molybdenum in both surface (0–15 cm) and sub-surface (15–30 cm) soils across all five sampling locations—Dandgaon, Sontarai, Jhirmiti, Ramgarh Road, and Udaipur—remained uniform. All samples exhibited a consistent value of 0.1 mg/kg, indicating no spatial variation in Mo availability within the study area.

The identical levels in surface and sub-surface layers suggest that molybdenum distribution is relatively stable and is not significantly influenced by depth or site-specific environmental factors. This uniformity may be attributed to similar parent material, comparable soil management practices, or limited external inputs affecting molybdenum content in these locations.

Overall, the findings show that available molybdenum is present at a low but consistent concentration throughout the soils of the Udaipur area in Surguja District, Chhattisgarh.

Mo

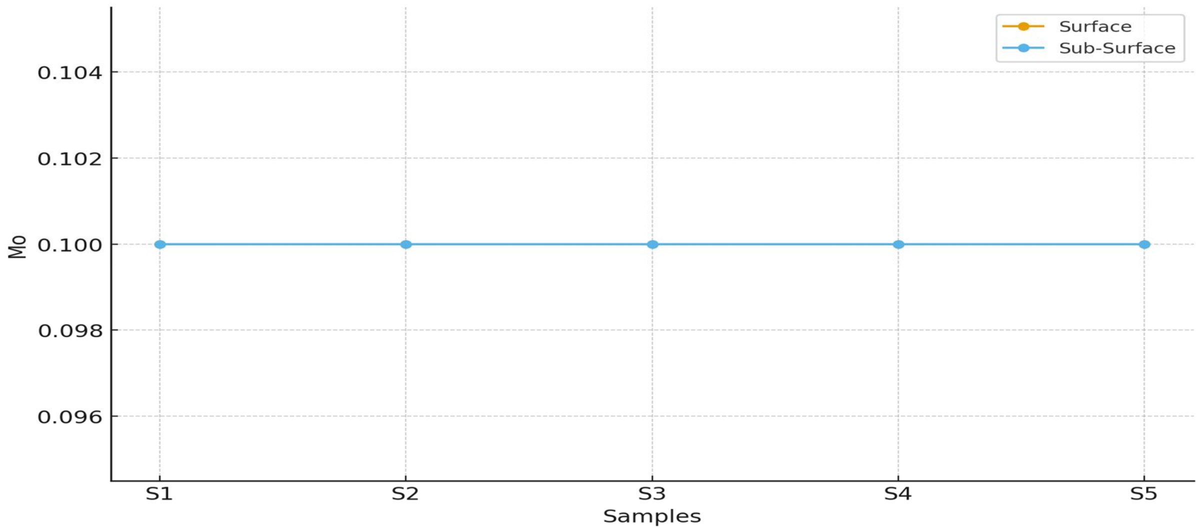

Figure 12: Comparative molybdenum values of surface and sub-surface soil samples across five locations in the Udaipur area, Surguja District, Chhattisgarh.

Discussion: For Mo, surface values range between 0.1 and 0.1, while sub-surface values range between 0.1 and 0.1. Average surface value = 0.10, and sub-surface average = 0.10. Minor variations among locations indicate spatial heterogeneity in soil profile.

Fertilizer Recommendation (kg/ha)

Nutrient	Dose (kg/ha)	Recommended Fertilizer
Nitrogen (N)	60–80	Urea 130–175 kg
Phosphorus (P_2O_5)	40–50	SSP 250–300 kg OR DAP 90–110 kg
Potash (K_2O)	20–30	MOP 35–50 kg
Zinc	20–25	Zinc Sulphate (21%)
Boron	8–10	Borax
Molybdenum	0.5–1.0	Ammonium Molybdate

V. CONCLUSION

The comparative assessment of surface and sub-surface soils collected from different locations of the Udaipur area in Surguja District reveals distinct variations in their physico-chemical properties, reflecting the influence of local geology, land use and micro-environmental conditions. The pH values of all samples fall within the slightly acidic range, indicating that the soils are moderately weathered and may support good nutrient availability, particularly of micronutrients. Electrical conductivity values remain very low in both soil layers across all sites, confirming that the soils are non-saline and favourable for normal crop growth. Organic carbon content is moderate in most samples and slightly higher in the surface horizon, which is consistent with natural accumulation of organic matter in topsoil. Available nitrogen levels range from low to medium, suggesting that periodic nitrogen supplementation would be beneficial for sustaining productivity. Phosphorus availability is generally low in both soil depths, reflecting fixation under acidic conditions, whereas potassium content remains in the medium to high range, indicating sufficient native reserves. Micronutrient analysis shows that zinc, boron, iron, manganese and molybdenum concentrations are either adequate or present at marginally low levels, with little variation between surface and sub-surface layers. These values suggest that the soils possess a reasonably balanced micronutrient profile, though zinc and boron may require attention depending on crop requirements.

Overall, the study demonstrates that the soils of the Udaipur region are moderately fertile but require targeted nutrient management-especially nitrogen and phosphorus- to optimize their agricultural potential. The observed spatial variations also highlight the importance of site-specific soil testing for developing precise fertilizer recommendations. This physico-chemical characterization provides a clear baseline for future monitoring and sustainable soil management practices in the region.

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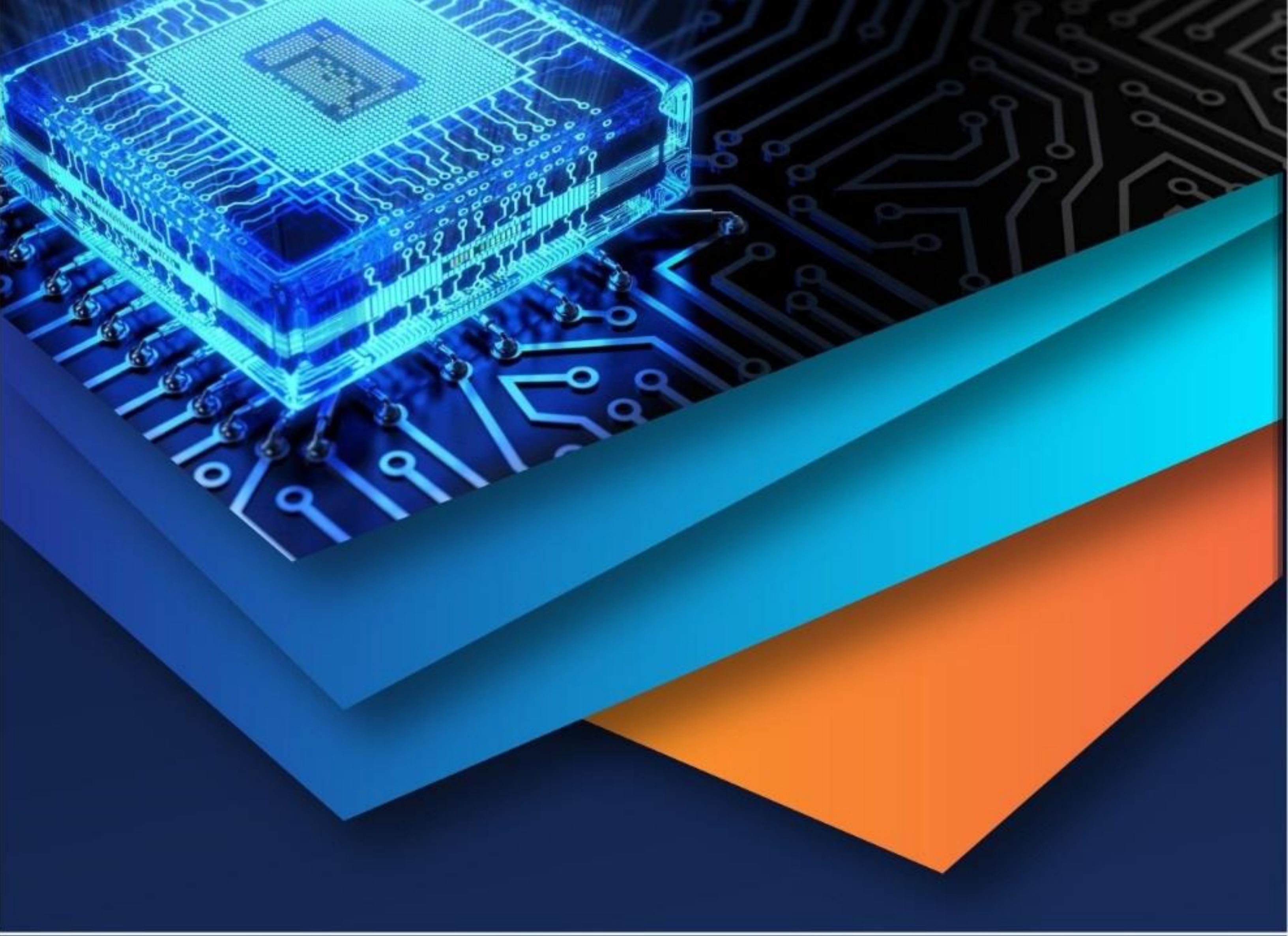

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