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Evaluation of Physico - Chemical Properties of Tea-Based Soils from Sagora Ashram, Jashpur District, Chhattisgarh

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Abstract
Tea-based agro-ecosystems are recognized for their impact on soil qualities due to ongoing litter accumulation, substantial rainfall, and rigorous management techniques. This study assesses the physico-chemical characteristics of tea-based soils in the Sagora Ashram region of Jashpur district, Chhattisgarh, India, employing field observations, Soil Health Card (SHC) data, and laboratory analyses. Soil samples were obtained from tea cultivation regions at two depths (0–15 cm and 15–30 cm) to evaluate physical properties such as bulk density, porosity, and moisture content, as well as chemical properties including pH, electrical conductivity, organic carbon, and available macronutrients (N, P, and K). The findings revealed reduced bulk density, increased porosity, and enhanced moisture retention in surface soils relative to sub-surface layers. The soils were determined to be mildly to moderately acidic and non-saline. Organic carbon and accessible nutrients were markedly elevated in surface soils and diminished with depth. The research underscores the impact of tea production on soil quality and stresses the necessity for depth-specific soil management strategies to maintain soil health and productivity in tea-based systems.

Keywords: Tea-based soils, Physico-chemical characteristics, soil fertility, soil health, Sagora Ashram.

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Introduction
Tea (Camellia sinensis) is a perennial crop that markedly modifies soil characteristics through ongoing leaf litter accumulation, substantial nitrogen absorption, and acidic root exudates. The physico-chemical qualities of soil are essential in influencing soil fertility, water retention, and the long-term sustainability of tea plantations. Attributes include bulk density, porosity, soil pH, organic carbon content, and nutrient availability directly affect root development, microbial activity, and nutrient cycling (Brady & Weil, 2016).

In India, tea is mostly cultivated in areas with significant rainfall, where the leaching of basic cations frequently results in acidic soil conditions. Prior research indicates that tea growing typically elevates soil acidity while promoting organic carbon storage in surface soils as a result of ongoing litter input (FAO, 2006). Comprehending the depth-wise variability in soil qualities is crucial for the sustainable management of tea-based agro-ecosystems. The Soil Health Card (SHC) initiative offers uniform data on soil fertility and nutrient status throughout India, serving as a significant resource for regional soil evaluation (Government of India, 2020). Nonetheless, the site-specific assessment of tea plantation soils utilizing SHC data with field observations is still constrained, especially in burgeoning tea cultivation areas like Chhattisgarh. Geographic Information System (GIS) techniques facilitate the amalgamation of soil data with spatial information and have demonstrated efficacy in evaluating soil variability at regional scales (Shinde et al., 2020; Swain et al., 2023). The Sagora Ashram region in Jashpur district exemplifies a distinctive tea-centric agro-ecosystem shaped by forested areas, varied topography, and substantial precipitation. A scientific evaluation of the physico-chemical features of soils in this location is crucial for comprehending the effects of tea cultivation on soil health. This study is to assess the depth- wise physicochemical parameters of tea-based soils and offer management-oriented insights for sustainable tea cultivation.

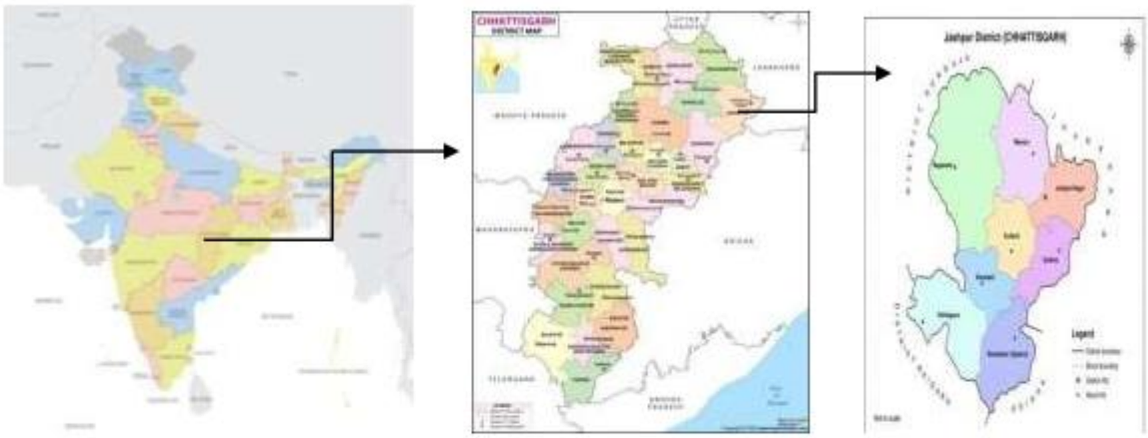

Figure.1: Jashpur District of maps.

Materials and Methods

Study Area

The research was carried out in the Sagora Ashram region of Jashpur district, situated in northern Chhattisgarh, India. The region has a sub-humid climate characterized by substantial yearly precipitation, fostering large forest coverage and tea plantations. The soils are primarily lateritic to red loamy in composition.

Soil Sampling and Data Sources

Soil samples were obtained from representative tea plantation locations during the post- monsoon period. Samples were collected at two depths: surface (0–15 cm) and sub-surface (15–30 cm). Furthermore, Soil Health Card data provided by the Department of Agriculture, Government of India, were utilized to enhance field observations.

Analysis of Physical Properties

Bulk density was assessed via the core sampler method, whereas particle density was quantified using a pycnometer. Soil porosity was determined using bulk and particle density measurements. The gravimetric approach was employed to estimate soil moisture content.

Analysis of Chemical Properties

The pH and electrical conductivity of the soil were assessed in a 1:2.5 soil-water solution. Organic carbon was quantified using the Walkley and Black method. Nitrogen availability was assessed via the alkaline $KMnO_4$ method, phosphorus availability through Olsen's method, and potassium availability utilizing a flame photometer.

Data Analysis

Average values of soil characteristics were calculated for each depth. Comparative analyses were conducted to assess alterations in soil parameters resulting from tea cultivation.

Results

Physical Properties of Tea-Based Soils

Surface soils demonstrated reduced bulk density and increased porosity relative to sub- surface soils, signifying superior soil structure in the upper layer. Elevated moisture levels were observed in surface soils, indicating enhanced water retention attributable to the deposition of organic matter from tea litter. Bulk density values were typically diminished in the surface soils and escalated with depth throughout all blocks. The minimum bulk density in the surface layer was noted in the Manora and Duldula blocks, whereas greater values were documented in the Jashpur block, suggesting more compact sub-surface conditions. Soil porosity demonstrated an inverse relationship with bulk density, with elevated values in the surface layer and a progressive decrease in the sub-surface soils. Surface soils exhibited elevated moisture retention, especially in the Farsabahar, Pathalgaon, and Manora blocks, indicating improved soil structure and the impact of organic matter. The observed depth-wise variation underscores the impact of agricultural practices, organic inputs, and biological activity on the physical characteristics of surface soil.

Table 1.Depth-wise physical properties of soils in Jashpur District based on Soil Health Card and field data

Block	Depth (cm)	Bulk Density (Mg m⁻³)	Particle Density (Mg m⁻³)	Porosity (%)	Moisture Content (%)
Bagicha	0–15	1.28	2.60	50.8	19.1
	15–30	1.34	2.62	48.9	16.9
Duldula	0–15	1.26	2.59	51.4	19.6
	15–30	1.32	2.61	49.4	17.3
Farsabahar	0–15	1.30	2.62	50.4	20.0
	15–30	1.36	2.64	48.5	17.8
Jashpur	0–15	1.33	2.64	49.6	21.2
	15–30	1.39	2.66	47.7	18.7
Kunkuri	0–15	1.29	2.61	50.6	19.4
	15–30	1.35	2.63	48.7	17.1
Manora	0–15	1.27	2.60	51.2	19.9
	15–30	1.33	2.62	49.2	17.6
Pathalgaon	0–15	1.31	2.63	50.2	20.4
	15–30	1.37	2.65	48.3	18.1

Chemical Properties of Tea-Based Soils

Soil reactivity varied from weakly to highly acidic at both depths, with reduced pH values noted in sub-surface soils. The electrical conductivity values were minimal, signifying non- saline conditions. The organic carbon content was markedly elevated in surface soils and decreased with depth. Nitrogen, phosphorus, and potassium availability exhibited a comparable declining tendency with increasing depth. Soil acidity varied from weakly to strongly acidic, with pH values typically lower in the sub-surface layer. Electrical conductivity measurements were consistently low at both depths, signifying non-saline soil characteristics throughout the district. The organic carbon content was continuously elevated in surface soils, with peak levels recorded in the Manora and Farsabahar blocks. A significant reduction in organic carbon with depth was observed, indicating restricted integration of organic matter in deeper strata. The quantities of available nitrogen, phosphorus, and potassium exhibited patterns akin to those of organic carbon, with elevated levels in the surface layer and a gradual decrease in the sub-surface soils. Among the blocks, Manora, Jashpur, and Pathalgaon had somewhat greater nutrient availability at the surface layer.

Table 2.Block-wise and depth-wise chemical properties of soils in Jashpur District

Block	Depth (cm)	pH	EC (dS m⁻¹)	Organic Carbon (%)	Available N (kg ha⁻¹)	Available P (kg ha⁻¹)	Available K (kg ha⁻¹)
Bagicha	0–15	5.6	0.18	0.78	285	14.2	312
	15–30	5.5	0.16	0.62	248	11.6	285
Duldula	0–15	5.8	0.20	0.74	292	15.1	325
	15–30	5.6	0.17	0.60	255	12.3	296
Farsabahar	0–15	5.7	0.19	0.81	301	16.4	338
	15–30	5.6	0.17	0.65	262	13.0	305
Jashpur	0–15	5.9	0.22	0.76	298	17.2	342
	15–30	5.7	0.19	0.61	260	13.8	314
Kunkuri	0–15	5.6	0.18	0.79	289	15.6	330
	15–30	5.5	0.16	0.63	250	12.5	298
Manora	0–15	5.8	0.21	0.83	305	18.1	350
	15–30	5.6	0.18	0.67	268	14.6	320
Pathalgaon	0–15	5.7	0.20	0.80	297	16.8	336
	15–30	5.6	0.18	0.64	259	13.4	308

Macro and Micro nutrient Status

The available nitrogen (N) concentration varied from 285 to 335 kg ha⁻¹ in surface soils (0– 15 cm) and decreased to 245 to 295 kg ha⁻¹ in sub-surface soils (15–30 cm). The majority of blocks demonstrated a moderate nitrogen status, with notably elevated values observed in the Manora and Jashpur blocks. Available phosphorus (P) exhibited a low to medium status, with surface soil concentrations ranging from 14.2 to 18.6 kg ha⁻¹, followed by a steady decline at greater depths (11.4 to 14.9 kg ha⁻¹). The available potassium (K) content was predominantly medium to high, especially in surface soils (290–345 kg ha⁻¹), signifying sufficient potassium stocks throughout the district. Micronutrient study revealed significant variance with depth. The zinc (Zn) concentration varied from 0.62 to 1.12 mg kg⁻¹ in surface soils and diminished to 0.48 to 0.86 mg kg⁻¹ in sub-surface soils. Zinc insufficiency to moderate sufficiency was noted in several blocks, particularly at shallower levels. The iron (Fe) concentration ranged from 7.8 to 12.1 mg kg⁻¹ in surface soils, signifying medium to high availability, while lower concentrations (6.1 to 9.4 mg kg⁻¹) were observed at a depth of 15–30 cm. The copper (Cu) concentration remained at a moderate level throughout all blocks, with surface measurements exceeding those of sub-surface soils.

Table 3.Block-wise and depth-wise macro- and micro-nutrient status of soils in Jashpur District

Block	Depth (cm)	N (kg ha⁻¹)	P (kg ha⁻¹)	K (kg ha⁻¹)	Zn (mg kg⁻¹)	Fe (mg kg⁻¹)	Cu (mg kg⁻¹)
Bagicha	0–15	285	14.2	290	0.62	7.8	0.46
	15–30	245	11.4	265	0.48	6.1	0.38
Duldula	0–15	295	15.6	305	0.78	8.9	0.49
	15–30	258	12.8	280	0.60	7.2	0.41
Farsabahar	0–15	305	16.4	315	0.70	8.3	0.47
	15–30	265	13.1	290	0.55	6.9	0.40
Jashpur	0–15	320	17.8	330	0.95	10.8	0.53
	15–30	280	14.2	305	0.72	8.6	0.45
Kunkuri	0–15	300	15.9	320	0.88	9.6	0.51
	15–30	262	12.6	295	0.66	7.7	0.43
Manora	0–15	335	18.6	345	1.12	12.1	0.59
	15–30	295	14.9	320	0.86	9.4	0.48
Pathalgaon	0–15	310	16.9	325	0.74	8.8	0.47
	15–30	270	13.5	300	0.58	7.1	0.41

Discussion

The diminished bulk density and increased porosity in surface soils can be ascribed to ongoing organic matter contributions from tea litter and minimized soil disturbance. Acidic soil conditions are typical of tea plantations and are influenced by high rainfall, leaching, and acidic root exudates. Higher organic carbon and nutrient availability in surface soils highlight the role of litter decomposition and microbial activity in nutrient cycling. The deterioration of soil quality metrics with depth underscores the need of managing surface soil in tea cultivation systems.

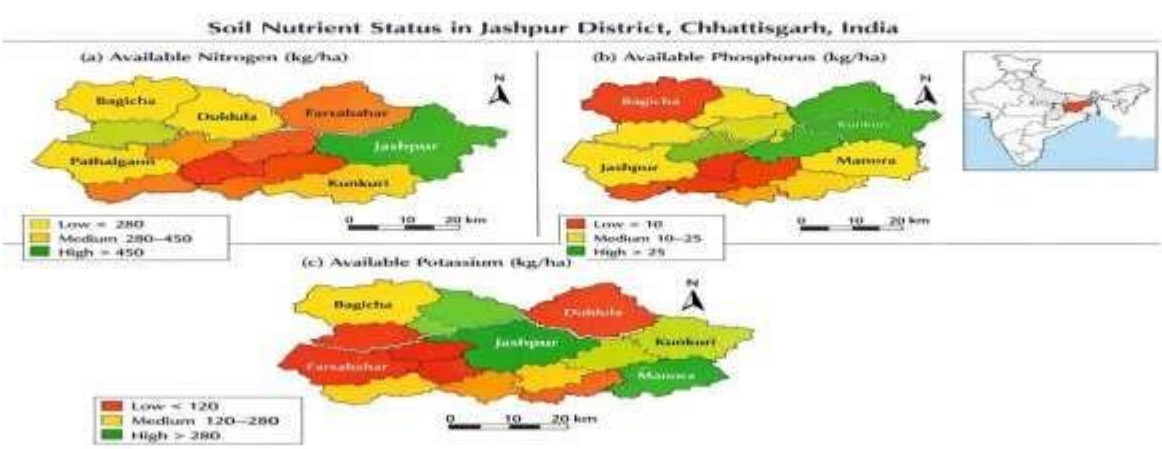

Figure: 2, 3 & 4 .GIS-based block-wise spatial distribution of soil of available N, P, K in Jashpur district, Chhattisgarh.

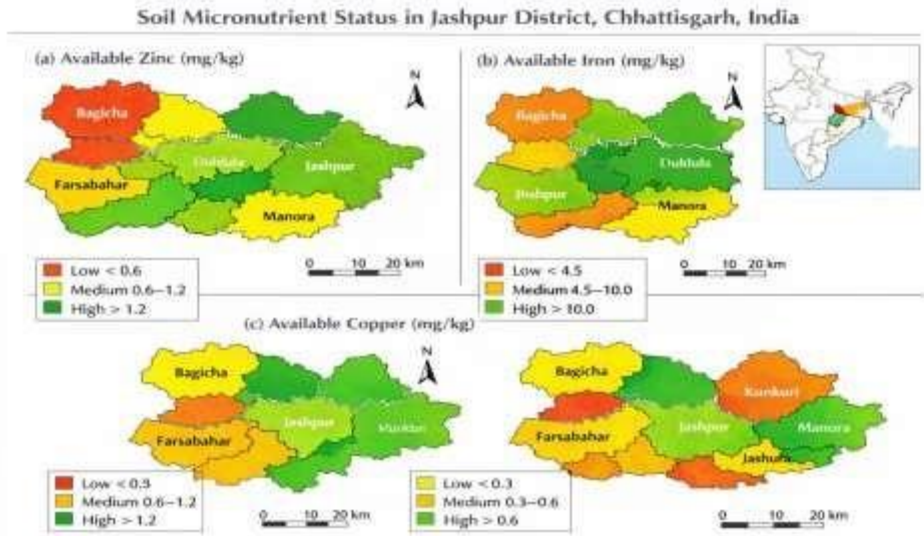

Figure: 5, 6, 7 & 8 .GIS-based block-wise spatial distribution of soil of available Zn, Cu, Fe and B in Jashpur district, Chhattisgarh.

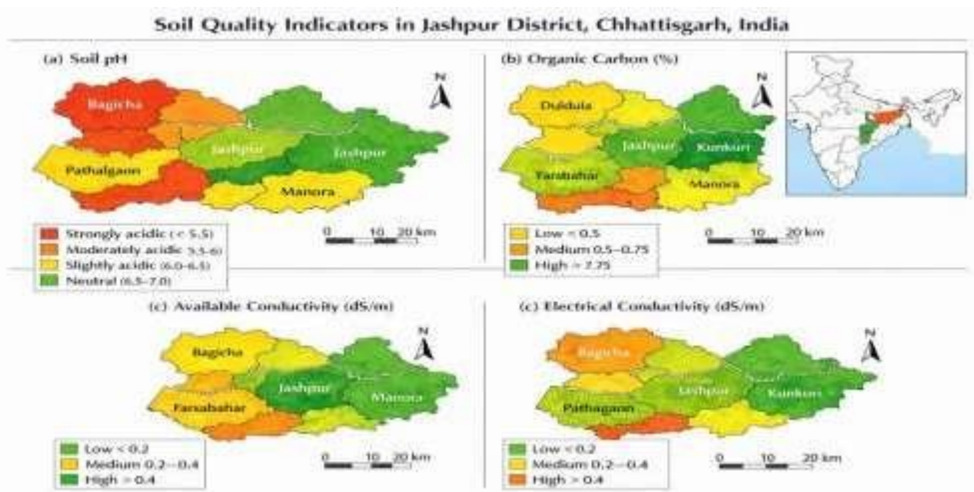

Figure: 9, 10, 11 & 12 .GIS-based block-wise spatial distribution of soil of available pH, OC, EC and BD in Jashpur district, Chhattisgarh.

Conclusion

This study utilized a comprehensive methodology that incorporated Soil Health Card data, field observations, and GIS tools to evaluate the depth-wise and spatial variability of soil physical and chemical parameters in Jashpur district, Chhattisgarh. The findings unequivocally indicated that soil characteristics exhibited considerable variation with depth and within various blocks of the district. Surface soils (0–15 cm) demonstrated reduced bulk density, increased porosity, superior moisture retention, and elevated organic carbon content relative to sub-surface soils (15–30 cm). A steady reduction in organic carbon and accessible nutrients (N, P, and K) with increasing depth was noted, signifying the predominance of biological activity and organic matter accumulation in the upper soil layer. The soils in the research area were determined to be mildly acidic and non-saline, characteristic of locations with significant rainfall and forested environments. GIS-based spatial analysis accurately identified block-wise diversity in soil quality, demonstrating superior soil physical conditions and nutrient status in forest-dominated blocks like Manora and Farsabahar. Conversely, intensively cultivated regions demonstrated comparatively inferior soil quality indices, highlighting the impact of land use and management strategies on soil health. The study underscores the utility of combining Soil Health Card data with GIS for regional soil evaluation and decision-making. presents considerable regional and vertical heterogeneity in soil fertility. Surface soils demonstrated significantly greater availability of nitrogen, phosphorous, potassium, zinc, iron, and copper compared to sub-surface soils, highlighting the influence of organic matter inputs and biological activity on soil fertility. Potassium and iron were usually sufficient throughout the district, although nitrogen and phosphorus primarily fell within the medium range, and zinc exhibited marginal deficit in specific blocks. The results demonstrate that tailored nutrient management measures, unique to both location and depth, are crucial for maintaining soil health and enhancing crop yield in the area. The results highlight the necessity for sustainable soil management approaches, including as the incorporation of organic matter, balanced fertilization, and tailored amendments, to preserve and improve soil health and agricultural output in Jashpur area. The analytical approach utilized in this study is applicable to other places with analogous agro-ecological characteristics.

Prospective Outlook

Future research may concentrate on the long-term monitoring of soil physico-chemical parameters within tea-based agro-ecosystems to evaluate temporal variations in soil health. The amalgamation of high-resolution remote sensing data, sophisticated GIS methodologies, and machine learning-driven digital soil mapping can enhance the spatial prediction of soil properties at more granular scales. The incorporation of soil biological indicators and climatic variables will yield a more thorough comprehension of soil dynamics amid shifting environmental conditions. Furthermore, field-based nutrient management and soil amendment experiments may assist in formulating site-specific guidelines for sustainable tea growth. The methodology framework utilized in this study can be applied to other tea- cultivating and agro-ecological regions of India for regional soil health evaluation and planning.

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