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Physicochemical Characteristics and Soil Organic Matter Status of Forest Soils in the Vazhachal Forest Division, Western Ghats, India

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Abstract

Forest soils play an important role in nutrient cycling, organic matter storage, and maintaining ecosystem functioning. This study evaluated the physicochemical properties and organic matter status of surface soils in the Vazhachal Forest Division, Western Ghats, Kerala. Soil samples were collected from nine sites representing teak plantations, semi-evergreen forests, and evergreen forests during April–May 2021. The samples were analysed for pH, redox potential (Eh), bulk density, specific gravity, moisture content, particle size distribution, total organic carbon (TOC), total organic nitrogen (TON), and total organic matter (TOM). The results showed that all sampling sites had acidic pH ranging from 4.76 to 5.91. Bulk density varied from 0.91 to 1.05 g/cm³, while moisture content ranged from 8.90% to 13.44%. Silt was the dominant soil fraction at most sites, although sandy textures were prominent at selected evergreen forest locations. Significant spatial variations were observed in bulk density, specific gravity, and clay content ($p < 0.01$). TOC (1.87% to 6.02%), TON (0.22% to 0.51%), and TOM (3.22% to 10.38%) varied significantly among the sampling sites ($p < 0.05$), indicating differences in soil organic matter accumulation. The relatively low TOC/TON ratios observed in the present study suggest relatively active organic matter decomposition and nitrogen cycling, with conditions favouring mineralization over microbial immobilization. These findings provide valuable baseline information on forest-soil conditions and support informed soil conservation and sustainable forest management in the Western Ghats.

Keywords

Forest soil, Western Ghats, Physico chemical properties, Total organic carbon

1. Introduction

Forest ecosystems play a vital role in maintaining ecological balance by regulating carbon sequestration, influencing climate change, and supporting biodiversity (Michalzik et al., 2003). Forest soils are essential components of these ecosystems, serving as reservoirs of organic matter, nutrients, minerals, and metals derived from natural processes and anthropogenic activities. Among these constituents, soil organic matter (SOM) is particularly important because it influences soil fertility, nutrient availability, microbial activity, and carbon storage. The quality and composition of SOM are closely associated with soil microbial processes (Fierer et al., 2005; Davidson et al., 2006), plant productivity (Ågren et al., 1996), and the regulation of terrestrial carbon pools (Janzen, 2004; Batjes, 2014). Therefore, understanding the physicochemical characteristics of forest soils is essential for evaluating their ecological functioning and assessing their role in sustaining forest ecosystems.

The Western Ghats of India constitute a globally significant biodiversity hotspot, recognized for their exceptional species richness, endemism, and ecological importance. Located along the western slopes of this mountain range, the Vazhachal Forest Division in Kerala comprises diverse forest types, predominantly southern tropical moist mixed deciduous, west coast tropical semi-evergreen, and west coast tropical wet evergreen forests (Harikrishnan et al., 2012). The region also includes plantation areas and locations influenced by human activities. Variations in vegetation, organic matter inputs, topography, drainage, and soil-forming processes may contribute to spatial differences in soil physicochemical properties. Consequently, characterizing these properties is important for understanding the geochemical conditions that influence nutrient retention, soil development, and ecosystem functioning in this ecologically sensitive landscape.

2.Materials and methods

2.1 Study area and sample collection

Vazhachal forest division located on the western slopes of Western Ghats (10°14' and 10° 23'N Latitudes and 76°25'and 76° 54' E), covers an area of around 413.94 km^2, with altitude varies from 200 to 1300m. Due to their unique geographical location on the western side of Western Ghats, these forests receive abundant rainfall. Surface soil samples (0-20cm) were collected from 9 sites representing different forest types of Vazhachal forest division during April - May, 2021. The details of sampling sites are described in Table 1. Geographical position coordinates of the soil sampling sites were documented with Global Positioning System (Garmin, e Trex). For each sampling site, one quadrat with a dimension 10 × 10 m was placed, and samples were collected from four corners of the quadrat (Kurien et al., 2021). The samples collected in labelled polyethylene bags were transported to the geochemistry laboratory for further analysis.

Table 1. Location and salient features of sampling sites

Station	Name of the station	Latitude(N)	Longitude(E)	Forest Type
S1	Vadappara	10° 17′54.7″	76°33′ 25.6″	Teak plantation
S2	Kamazthi	10° 19′ 36.1″	76° 33′ 28.8″	Teak plantation
S3	Pachilavalam	10°17′ 27.0″	76° 36′ 57.8″	Teak plantation
S4	Orukomban	10° 22′ 03.2″	76° 39′ 02.3″	Semi evergreen
S5	Kalakallu	10° 16′ 40.5″	76°39′24.5″	Semi evergreen
S6	Neelapara	10° 16′19.9″	76° 40′ 58.0″	Semi evergreen
S7	Chanthanthodu	10° 17′55.1″	76° 46′ 48.0″	Evergreen
S8	Pathadipalam	10° 17′ 18.8″	76° 48′ 28.2″	Evergreen
S9	Shorigal	10°17′ 51.6″	76° 49′57.4″	Evergreen

2.2. Physico chemical characterisation of soil and analytical procedures

Electrochemical measurements were employed to determine the pH and redox potential (Eh) in a soil to reagent grade water suspension (Jackson, 1973). Total organic carbon (TOC) content in soil samples determined with a TOC analyser (Vario TOC Select- Elementar, Germany) and total organic nitrogen (TON) using Kjeldahl method (Kjeldahl,1883). Total organic matter (TOM) was obtained by multiplying the organic carbon values with 1.724 (Nelson and Sommers, 1996). Bulk density, specific gravity, and soil moisture content were determined using standard soil-analysis procedures (Masulili et al.,2010). For texture analysis soil samples were treated with HCl (10%) for the removal of inorganic carbon, followed by 30% hydrogen peroxide to remove organic matter and subjected to particle size composition analysis (content of clay, sand, silt) was estimated by pipette analysis (Folk, 1974).

3. Results and Discussion

3.1. Variation of soil physico-chemical properties

The physico chemical composition of soil is represented in Table 2 and 3. All stations exhibited acidic pH (Table 2) ranging from 4.76(S8) to 5.91(S1). This acidic nature can be attributed to high rainfall, fertilizer application, and root activity (Surendran et al., 2024). Positive values of redox potential is noted throughout the study area with minimum at S1 (94mV) and maximum at S6 (134 mV). Well-aerated surface layers have high Eh values indicating oxidizing conditions (Sudha et al., 2026).

Table 2. Variation in fundamental soil quality parameters

Stations	pH	Eh (mV)	Bulk density (g/cm^3)	Specific Gravity	Moisture Content (%)	Sand (%)	Slit (%)	Clay (%)
S1	5.91	94	0.93	0.95	8.9	48.18	46.26	5.56
S2	4.96	129	0.95	1.06	10.05	41.3	51.6	7.1
S3	5.78	98	1.05	1.07	10.3	31.27	56.24	12.49
S4	4.8	128	0.96	0.98	10.71	12.17	70.11	17.73
S5	4.89	119	1.01	1.04	9.47	23.45	70.32	6.23
S6	5.08	134	0.99	1.02	10.43	27.32	64.68	8
S7	5.26	126	0.98	0.99	13.44	60.06	26.19	13.75
S8	4.76	127	0.91	0.93	13.42	62.95	28.91	8.15
S9	5.86	125	0.98	1.09	11.69	66.43	11.5	22.08
Minimum	4.76	94	0.91	0.93	8.9	12.17	11.5	5.56
Maximum	5.91	134	1.05	1.09	13.44	66.43	70.32	22.08
Average	5.26	120.00	0.97	1.01	10.93	41.46	47.31	11.23
p-value	p> 0.05	p> 0.05	p<0.01	p<0.01	p> 0.05	p> 0.05	p> 0.05	p<0.01

Bulk density recorded highest value of $1.05g/cm^3$ at S3 and the lowest value of $0.91g/cm^3$ at S8. The standard measure of soil density is bulk density in undisturbed soils range from about 1.0 to 1.4 g/cm^3, being higher for sands. Meanwhile specific gravity displayed its maximum value at S9 (1.09) and minimum at S8(0.93). Specific gravity has been recognised as a fundamental property of soil used to calculate soil density, void ratio, saturation, and other soil properties. Moisture content varied between 8.9% (S1) and 13.44%(S7) reported that all the stations exhibited higher water holding capacity. Bulk density, specific gravity and clay exhibited significant spatial variation ($p<0.01$) as per ANOVA.

Grain size distribution of soils revealed the dominance of silt at majority of the sites with maximum value of 70.32%(S5) and minimum value of 11.50% at S9. Clay content exhibited its minimum at S1(5.56%) and maximum at S9(22.08%). Sand also recorded enhanced levels at S9 (66.43%) and minimum at S4(12.17%). Silt predominated in teak plantations and semi-evergreen forests, meanwhile sand content was enriched in evergreen forest soils.

Table 3. Content of TOC, TON, TOM and the TOC/TON ratio

Stations	TOC (%)	TON (%)	TOM (%)	TOC/TON
S1	2.13	0.22	3.67	9.68
S2	2.53	0.23	4.36	11.00
S3	6.02	0.51	10.38	11.80
S4	1.87	0.22	3.22	8.50
S5	3.89	0.35	6.71	11.11
S6	4.35	0.34	7.50	12.79
S7	3.26	0.31	5.62	10.52
S8	3.59	0.32	6.19	11.22
S9	3.69	0.35	6.36	10.54
Minimum	1.87	0.22	3.22	8.50
Maximum	6.02	0.51	10.38	12.79
Average	3.48	0.32	6.00	10.80
p-value	$p<0.05$	$p<0.05$	$p>0.05$	$P<0.01$

The carbon that is stored in soil organic matter is known as total organic carbon (TOC). Decomposing plant and animal waste, root exudates, live and dead microbes, and soil all contribute to the introduction of organic carbon into the soil. Soil organic matter (SOM) excludes non-decomposed plant and animal wastes. SOM is a dynamic, heterogeneous substance with a range in turnover time, C concentration, and particle size. TOC recorded peak content at S3(6.02%) and the minimum was noted at S4 (1.87%). The enhanced inputs of litter from vegetation cover contribute to the higher content of organic matter in soil. The enriched levels of silt at S3 indicated better preservation of organic matter. TOM ranged from 3.22 % (S4) to 10.38 % (S3).

Total organic nitrogen (TON) content varied from 0.22 % (S1) to 0.51 % (S3). TON content was significantly higher under natural forest cover indicating the role as a sink of nitrogen that influence the nitrogen cycle. Among surface samples, TOC and TON were significantly lower in teak plantations compared to natural forests. Lower pH in teak plantations enhances the activity of Al and Fe oxides, promoting phosphorus fixation. Additionally, soil compaction associated with plantation establishment may reduce TOC and TON. Changes in microbial diversity and function may further influence organic matter decomposition and nutrient cycling, leading to reduced mineralization rates in subsurface soils.

Soil bulk density is related to the amount of organic matter present in the soil; and consequently, affects TOC and TON within the soil layers. TOC and TON showed significant spatial variation ($p<0.05$) in the study region. The TOC/TON ratios are widely employed to portray the source, fate and seasonal processes of organic matter In the present study, TOC/TON ratio varied from 8.50 (S4) to12.79 (S6). TOC/TON ratios are used as indicators of soil fertility and degradability of organic material in the upper horizons. The TOC/TON ratio of forest soils is influenced by several factors, including forest type, parent material, soil acidity, climate, and land-use history (Averill &Waring, 2018; Berg, 2014). These factors can affect the decomposition of organic matter and the availability and cycling of nitrogen in the soil. The relatively low TOC/TON ratios observed in the present study suggest relatively active organic matter decomposition and nitrogen cycling, with conditions favouring mineralization over microbial immobilization.

4. Conclusion

The present study provides an overview of the physicochemical characteristics and organic matter status of surface soils in the Vazhachal Forest Division, Western Ghats, Kerala. The soils were acidic across all nine

sampling sites, with considerable spatial variation in redox potential, bulk density, specific gravity, moisture content, and particle size distribution. Silt was the dominant soil fraction at most sites, whereas sandy textures were more prominent at selected evergreen forest locations. Significant spatial differences in bulk density, specific gravity, and clay content indicate heterogeneity in soil physical properties. Total organic carbon (TOC) ranged from 1.87% to 6.02%, total organic nitrogen (TON) from 0.22% to 0.51%, and total organic matter (TOM) from 3.22% to 10.38%. Higher TOC and TON contents at certain forest sites highlight the importance of vegetation cover and organic matter inputs in soil carbon and nitrogen storage. The TOC/TON ratios ranged from 8.50 to 12.79, suggesting relatively active organic matter decomposition and nitrogen cycling, with conditions favouring mineralization over microbial immobilization.

Overall, the findings demonstrate that the physicochemical properties and organic matter status of Vazhachal forest soils vary considerably across sampling locations. This study provides useful baseline information on the physicochemical properties of Vazhachal forest soils and highlight the spatial variability of soil characteristics across different forest types. Further studies covering seasonal variations, deeper soil profiles, and additional sites would help clarify the factors governing soil organic matter dynamics and support the sustainable management and conservation of this ecologically sensitive forest ecosystem.

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