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Components of Forest Floor Biomass and Soil Properties under Teak Plantation in Zunheboto District, Nagaland, India

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ABSTRACT

This study examines the forest floor biomass components and soil physico-chemical properties in a 20-year-old teak plantation in Lumami, Zunheboto district, Nagaland. Forest floor biomass analysis reveals significant variations in fresh leaf litter and woody litter contributions during the study period. Soil properties showed seasonal variations in temperature, pH, particle density, porosity, organic carbon, texture, and moisture content. Soil temperature decreases with depth, while pH remains slightly acidic. Particle density increases with depth, and porosity is higher at lower depths, indicating surface soil compaction. Organic carbon is highest in the topsoil layer, with seasonal fluctuations consistent with previous findings. These results demonstrate the impact of teak plantations on forest floor biomass and soil properties, highlighting the need for sustainable management practices to maintain forest health and productivity. Further research is recommended to investigate nutrient dynamics and the long-term effects of monoculture plantations on soil fertility.

Keywords: *Forest floor biomass, Teak plantation, Soil properties, Soil organic carbon, Litter biomass and Nutrient cycling.*

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INTRODUCTION

Teak (*Tectona grandis*) emerges as a leading species for plantation initiatives, particularly in India, owing to its significant economic value in timber production [1]. Besides their economic role, forests are indispensable components of global ecosystems, offering many benefits for human well-being, such as climate regulation, carbon sequestration, and essential ecosystem services. However, with the world's population increasing and the demand for forest products increasing, the efficient management of forest resources has become imperative [2, 4]. Therefore, the successful cultivation of teak hinges on various soil conditions, including depth, texture, drainage, moisture, and fertility. Teak's preference for specific soil conditions, such as deep, well-drained alluvial soils derived from certain rock types, underscores the significance of understanding soil properties for successful plantation management [5].

One means of an accurate comprehension of ecosystem dynamics and evaluating ecosystem health can be achieved by biomass estimation [6]. The biomass and productivity of tree species, including teak, exhibit significant variability depending on age, climate, soil characteristics, and geographical location. Forest floor biomass, comprised of organic matter from vegetation litter, plays a pivotal role in nutrient cycling and regulating forest hydrology. Soil properties, influenced by vegetation type and tree species, profoundly impact forest ecosystems.

The interaction between plant tissues, soil organic matter, and soil physico-chemical characteristics, such as texture, pH, nutrient availability, and water-holding capacity, directly influences plant growth and overall ecosystem health [7, 8].

Thus, a comprehensive understanding of forest floor biomass dynamics and soil physico-chemical properties is essential for effective forest management, particularly in teak plantations like the one in Lumami, Zunheboto, Nagaland. Hence, this study aims to assess the different components of forest floor biomass and determine the physico-chemical properties of soil under teak plantation in the Zunheboto district of Nagaland.

MATERIALS AND METHODS

The study site was a 20-year-old teak plantation located in Lumami, Nagaland, India, within the Akuluto sub-division of the Zunheboto district. Situated at 727 meters above sea level, the area experiences a subtropical monsoonal climate characterized by an average annual rainfall of approximately 200 cm and an average temperature of 19.1 °C. This region falls under the classification of subtropical broadleaf forest (Fig. 1).

Forest floor biomass estimation involved using five randomly positioned 1m X 1m quadrats on the forest floor, surveyed monthly from October 2017 to April 2018. All herbaceous live and dead shoots within each quadrat were carefully harvested at ground level and stored in labeled polythene bags. The remaining material on the forest floor, after removing standing vegetation, was collected and categorized into distinct components: fresh leaf litter, wood litter (including twigs, branches, cones, fruiting bodies, and barks), partially decomposed litter, and herbaceous vegetation (both above-ground and below-ground). All collected samples underwent oven-drying at 105°C until a constant weight and biomass was calculated from the difference of fresh and dry weight and expressed as gm/m2 dry weight. Next, soil properties were evaluated during the autumn and spring seasons. Soil temperature was measured at depths of 0-10 cm, 10-20 cm, and 20-30 cm using a soil thermometer. A pH meter determined pH levels, while soil particle density and porosity were calculated using the core method. Soil texture analysis was performed using the International Pipette Method [9]. Soil moisture by the gravimetric method and Organic carbon was estimated by Walkley and Black [10]. Each test was conducted in triplicate and expressed as mean ± standard deviation using SPSS 26.0.

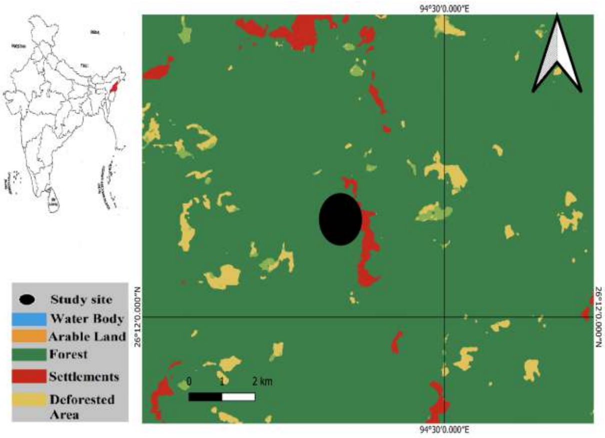

Fig.1: Map showing the teak plantation site in Lumami, Zunheboto (26°13'27.90" N, 94°28'7.00"E)

RESULTS AND DISCUSSION

Overall, the biomass components under the teak plantation varied with distinct contributions from different categories. Fresh leaf litter, partially decomposed litter, woody litter, herbaceous above-ground, and herbaceous below-ground biomass constituted 43.96%, 20.12%, 31.19%, 2.54%, and 2.18%, respectively. This observation aligns with previous findings in similar forest ecosystems [8, 10-12]. For fresh leaf litter, the highest fresh weight values were found in March, i.e., 48.09±3.94 g/m^2, and the minimum in November, i.e., 9.08±1.20 g/m^2 (Fig. 2A). The total fresh litter biomass accounted for a value of 190.99 g/m^2. This succession reflects the monthly variations in fresh leaf litter fall, as shown in Fig. 2b. Biomass of partially decomposed litter ranged from 8.16±2.33 g/m^2 to 26.45±2.55 g/m^2 (Fig 2.B). A total of 87.43±7.80 g/m^2 was recorded during the study period. Fluctuations are observed, which reflect a response of two simultaneously operating processes: transfer of fresh leaf litter into forest floor compartment and decomposition of materials. Maximum partial decomposition of litter takes place during October and lowest in February. Maximum amount during October may be due to the significant biomass of fresh leaf litter in the preceding months. The lower amount in subsequent months is due to lower input from the fresh litter compartment and a higher rate of disappearance of old litter. Monthly variation of partially decomposed litter is shown in Fig. 2.B. Maximum woody litter fall was recorded during October (34.29±1.20 g/m^2) and minimum in January (6.40±1.05 g/m^2). The total biomass of the woody litters accounted for a value of 135.55±11.50 g/m^2. The monthly variation of wood litter is shown in Fig. 2.C. Biomass of the above-ground herbaceous plants ranged from 0.14±0.01 to 5.05±0.12 g/m^2 (Fig. 2.D). Values were higher in October and minimum in February. The values were found to be minimum in the winter season and maximum in the monsoon and summer seasons. The total biomass of herbaceous above ground accounted for a value of 11.04±1.08 g/m^2. The relatively more significant amounts of biomass during summer and monsoon may be due to the transfer of live herbaceous shoots accompanied by favorable environmental conditions. The belowground herbaceous vegetation biomass ranged from 0.12±0.01 to 4.52±0.10 g/m^2. The minimum value was observed during January, i.e., in the winter season, and the maximum was observed during post-monsoon. The total biomass of the below-ground vegetation accounted for a value of 9.46±0.50 g/m^2. The monthly variation of herbaceous below-ground biomass is shown in Fig. 2.E. In all biomass components, the herbaceous category observed the minimum value. This lower value may be due to fewer herbaceous species under the teak plantation, accompanied by a cover of forest floor that partially decomposes litter, woody litter, and fresh leaf litter of teak trees [12]. Overall total production of biomass in all the five categories of biomass component under teak plantation was 434.47±12.90 g/m^2 under the study plot.

The soil temperature was recorded as maximum, rising to 22.4±1.20^{0}C during the spring, while the minimum temperature was recorded during the autumn (20.2±1.01^{0}C) as depicted in figure 3. A. It was observed that the soil temperature decreased with an increase in depth. This may be due to the high inertia of the soil; the temperature fluctuations at the ground surface are diminished as the depth of the soil increases. Soil p^H was higher in the upper layer (0-10 cm) in both the seasons, i.e., autumn and spring. During autumn, pH lies within the range of 5.64±0.85 to 5.78±0.75, and in spring, 5.14±0.10 to 5.40±0.51 (Fig. 3.B). The soil p^H was observed to be nearly acidic under the teak plantation. This may be due to the decomposition of soil organic matter, which releases organic acids leading to a decrease in pH in the forests [12, 13]. Soil porosity was found to be lower in the upper layers and higher with an increase in depth. The soil porosity was recorded to be maximum during the autumn season (47±5.60%) and minimum during the spring season (31±4.32%), as shown in Fig. 3.B. Minimum value of soil porosity in the upper layer may be due to the compaction of soil in the topmost layer. Loose, porous soils have lower bulk densities and greater porosities than tightly packed soils. Seasonal variation of organic carbon is shown in Fig. 3.C. Organic carbon was higher in the top soil layer (0 – 10 cms), i.e., 2.26±0.50 % in autumn and 2.69± 0.79 % during spring. Maximum moisture content was observed at the soil's top layer (0-10 cm) during autumn and spring (Fig. 3.D). The value of soil moisture in the upper layer of soil during the autumn season was found to be 23.89±1.25% and in the spring season, it was recorded to be 26.93±3.98% (Fig. 3. D). The moisture content shows a decreasing trend as the depth layers. The high soil moisture content at the top layers may be due to the high litter layers on the surface, which help protect the moisture from evaporation. Another reason for the high moisture content at the top layers may be the texture of the soils. The dynamics and properties of litter are essential not only for investigations of carbon dynamics but also for those of mineral nutrient dynamics in forest ecosystems because the return of nutrients through litter is an essential pathway for nutrient transfer between plants and soil [15]. Temjen et al. [14] (2022) suggested that nutrient dynamics are closely linked to seasonal variations in temperature and moisture.

Tangshimankong et al. [16] (2007) studied the carbon stocks in the soil of mixed deciduous forests and teak plantations. Results revealed that soil organic carbon from all sites generally with increasing depth from the surface to the lower layer soil. Similar observations were observed in the present study. The percentage of sand was higher in both seasons, followed by silt and clay, indicating the texture of soil in the teak plantation site to be sandy loam. The soil texture variation in both seasons is shown in Fig. 3. E and F.

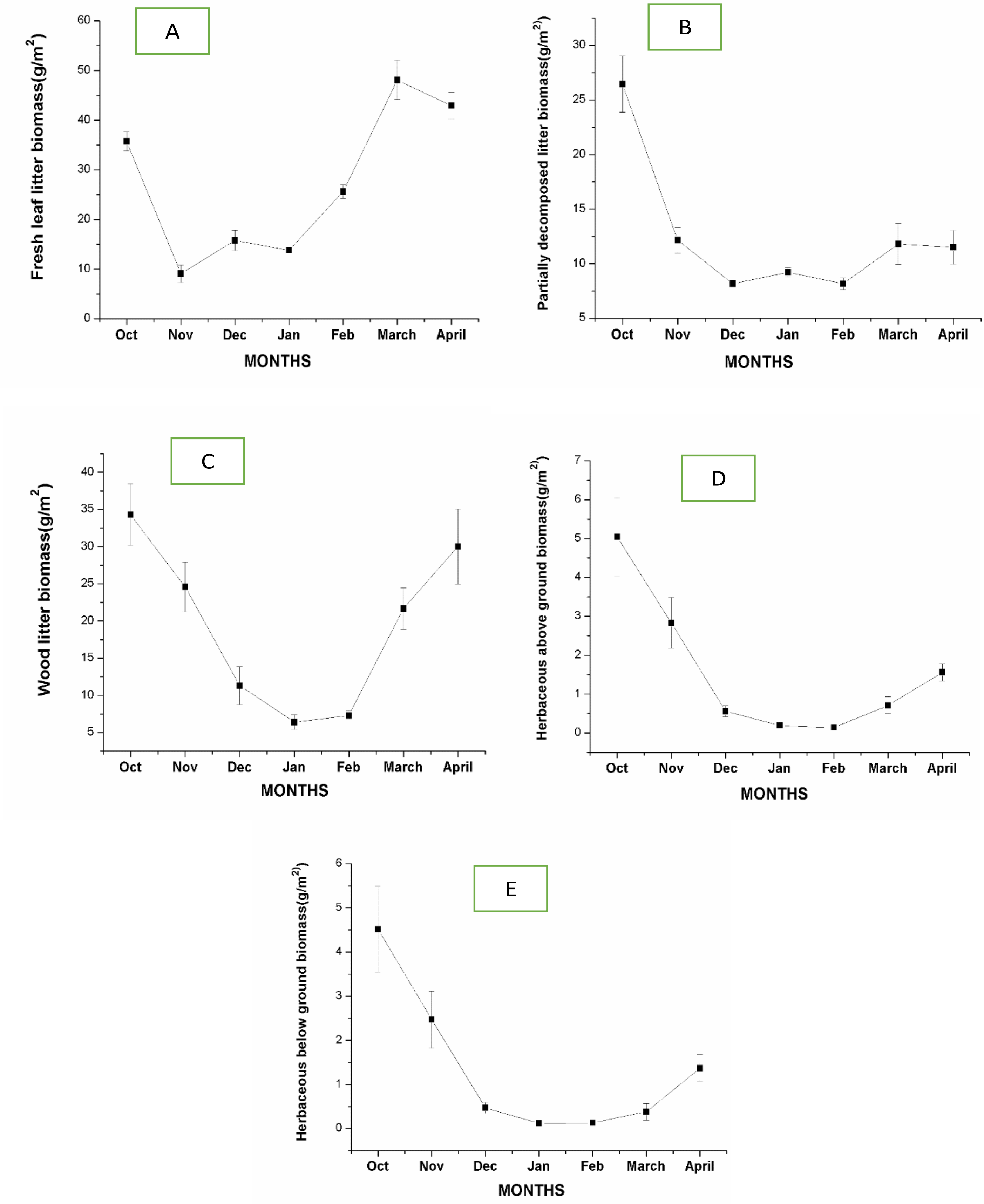

Fig. 2: A**.** Monthly variation of fresh leaf litter biomass of teak plant B: partially decomposed litter biomass of teak plant. C: wood litter biomass of the teak plant. D: herbaceous above ground biomass under teak plantation. E: herbaceous below-ground biomass underteak plantation.

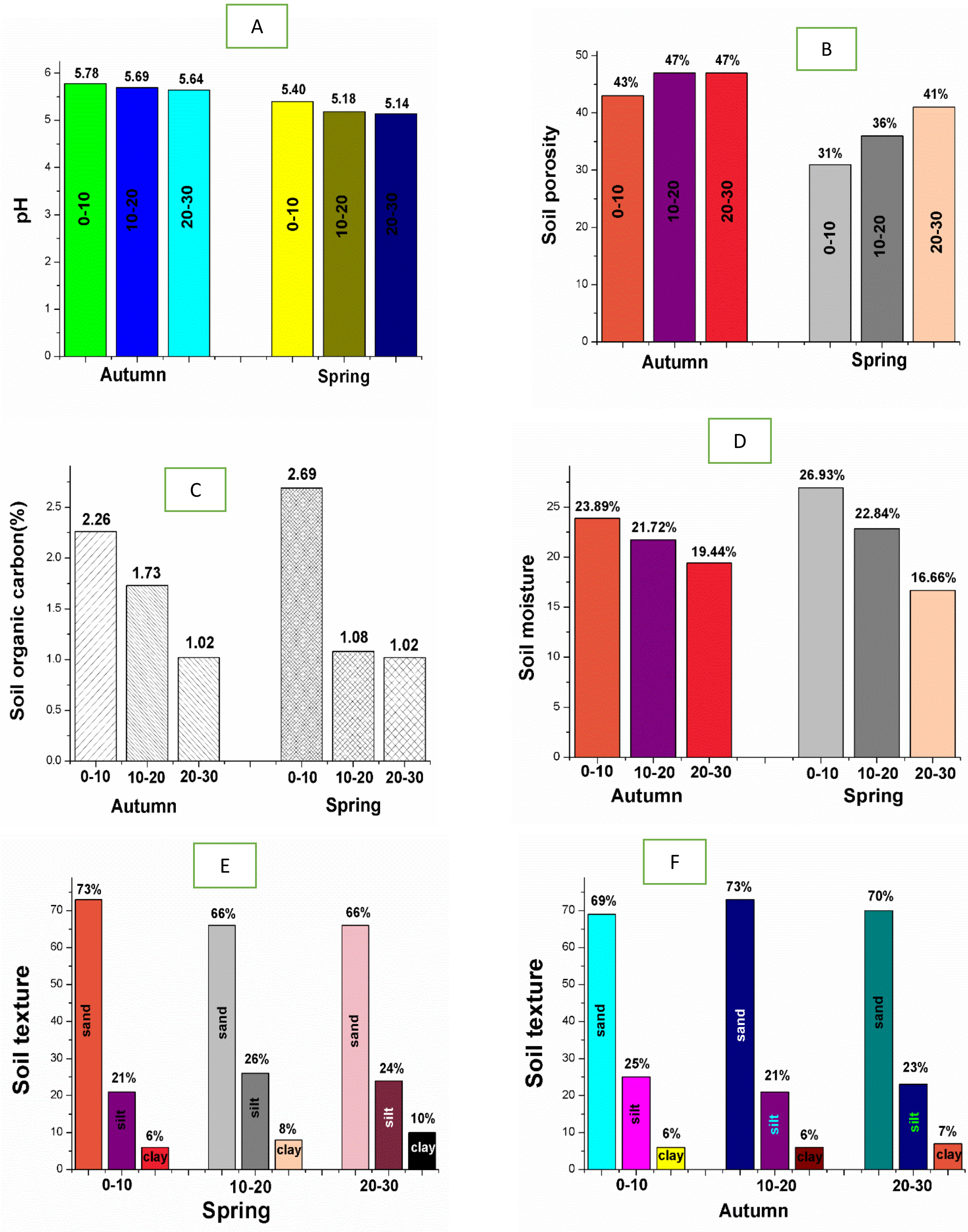

Fig. 3: A: Seasonal variation in soil pH p^H. B: soil porosity. C: Seasonal variation in Soil organic carbon. D. Variation in soil moisture during autumn and spring. E**:** Variation in soil texture at autumn. F: Variation in soil texture at spring under the teak plantation

CONCLUSION

In conclusion, this study sheds light on the dynamics of forest floor biomass and soil physicochemical properties within a 20-year-old teak plantation in Lumami, Zunheboto, Nagaland. The findings underscore the significance of understanding these dynamics for effective plantation management and ecosystem sustainability. The results reveal variations in forest floor biomass components, with notable contributions from fresh leaf litter, partially decomposed litter, woody litter, and herbaceous vegetation. These variations highlight the complex interactions between vegetation dynamics and environmental factors, such as climate and soil characteristics, impacting nutrient cycling and ecosystem health. Additionally, the study elucidates seasonal disparities in soil temperature, pH levels, porosity, organic carbon content, and moisture levels, emphasizing the importance of considering temporal variations in soil properties for informed management decisions. The observed reduction in soil organic matter content underlines potential implications for soil fertility and long-term sustainability in teak plantations. Overall, this study contributes valuable insights into the functioning of teak plantations and underscores the need for adaptive management strategies that account for dynamic ecosystem processes. By integrating scientific knowledge with practical management approaches, we can enhance the resilience and sustainability of teak plantations, ensuring their continued ecological and economic viability in the face of changing environmental conditions.

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