RESEARCH ARTICLE

FINE ROOT BIOMASS AND SOIL PHYSICO-CHEMICAL PROPERTIES IN ACHANAKMAR-AMARKANTAK BIOSPHERE RESERVE

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Abstract: The present study was aimed to assess the fine root biomass and soil physico-chemical properties in Achanakmar-Amarkantak Biosphere Reserve. Four sites characterized by varying vegetation attribute and representative of the region were selected. The belowground plant material (stand fine roots < 5 mm diameter) was sampled from 10 monoliths (15 x 15 x 15 cm) on each site. Proportions of live and dead fine roots were estimated on the basis of visual observations such as colour, texture, etc. Sample were dried at 80^0C to constant weight and weighed. Fine root biomass varied between 0.95 - 3.85 t ha^{-1}, respectively Organic C in soil ranged from 0.62 - 2.1 %, total N from 0.06 - 0.18 % and total P from 0.029 - 0.037 %. Available Pi ranged from 0.0002 - 0.00028 %. The exchangeable K ranged between 0.025 - 0.288 %. The short-lived components of the ecosystem viz., foliage, herbs and fine roots play a significant and dominant role in the functioning (relative contribution to nutrient cycling) of the present tropical deciduous forest.

Keywords: Fine root biomass, Nutrient cycling, Physico-chemical properties, Soil sample, Tropical deciduous forest

INTRODUCTION

Fine root biomass in tropical forest ecosystem plays a vital role in carbon and nutrient dynamics which alters the vegetational diversity, standing biomass and subsequently the productivity of an ecosystem (Yadav et al. 2017; Jordan, 1983). The transformation of forest landscape into various forms for other land-uses leads to severe degradation of such ecosystems which causes the biodiversity loss (Yadav et al. 2017; Jhariya and Yadav, 2018). Tropical forests possess rich floral and faunal diversity which highlighted the conservation and management priority of these valuable ecosystems for sustainable development (Sahu et al. 2008; Jhariya et al. 2019). In Indian context, the protected forests are under severe threats due to various anthropogenic processes which alter the structure and function of these ecosystems (Pawar et al. 2012 and 2014; Jhariya, 2014). From the study by Kaul and Sharma (1971), majority of Indian forests represent tropical (86%) both dry deciduous and moist deciduous in nature and nearly 14% of forest comprises wet evergreen or semi evergreen.

Fine roots play a key role in regulating the biogeochemical cycles of ecosystems and are important to our understanding of ecosystem responses to global climate changes (Yuan and Chen, 2010). Further it supports and performs various physiological functions in soil systems which facilitate soil solution uptake into the plant systems (Wells and Eissenstat, 2001). Fine root biomass adds little share in the total biomass input but have substantial importance due to its role in soil nutrients and carbon pool (Norby and Jackson, 2000; Sahu et al. 2013). There is less information is available related to fine root biomass and soil attributed at different forest stand level in Achanakmar-Amarkantak Biosphere reserve (Chhattisgarh). Therefore, the present investigation was carried out to study the fine root biomass and soil physico-chemical properties in Achanakmar-Amarkantak Biosphere Reserve (C.G.), India.

MATERIALS AND METHODS

The present study was carried out at Achanakmar-Amarkantak Biosphere Reserve. The study sites are located in 22º15'-22º58' N latitude and 81º25'-82º 5' E longitude having an area of 3835.51 km^2. Climate is tropical and is influenced by monsoon conditions. The mean monthly temperature varies from 17.2^0C (January) to 31.8^0C (May) and the total annual rainfall average 1383 mm, of which 85 % occurs in the rainy season (Yadav, 2016, 2018). The soils of the area are generally lateritic, alluvial and black cotton type, derived from granite, gneisses and basalts. The forest is seasonally dry tropical and includes extensive tracts of old growth *Shorea robusta* forest. Forest is classified into Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous forests (Champion and Seth, 1968). The former type predominates in the Biosphere Reserve area.

Four sites (Dense, Medium, Regenerating and Degraded) characterized by varying vegetation attributes and representative of the region's vegetation were selected. The belowground plant material (stand fine roots < 5 mm diameter) was sampled from 10 monoliths (15 x 15 x 15 cm) on each site. Monoliths were washed with a fine jet of water using 2 mm and 0.5 mm mesh screens (Bohm, 1979). Proportions of live and dead fine roots were

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estimated on the basis of visual observations such as colour, texture, etc. Sample were dried at 80^0C to constant weight and weighed. Fine roots were classified into two classes: fine roots < 1 mm diameter and (2) fine roots > 1 - 5 mm diameter. Finally each fine root class was converted into live fine roots and dead fine roots using live and dead fine roots proportions.

Soil samples were collected randomly from 5 locations on each site from the upper 10 cm depth. The samples were mixed thoroughly and large pieces of plant material were handpicked. Soils were sieved through a 2 mm mesh screen. Samples were divided in two parts, one part was air dried while the other was kept field-moist. Field-moist samples were used for the analysis of P. Rest of the analysis was carried out on air dried soil. Particle size distribution (texture) was analysed by using pipette method (Piper, 1950). Bulk density was determined by measuring the weight of dry soil of a unit volume to a depth 10 cm. Water holding capacity (WHC) was determined using perforated circular brass boxes (Piper, 1950). Total soil N and organic-C were analysed by CHNOS-Auto Analyzer "Elementar Vario EL. $NaHCO_3$ – extractable Pi was determined by ammonium molybdate-stannous chloride method (Sparling et al., 1985). Total soil phosphorus (TSP) was determined after $HC1O_4$ digestion of air dried soil (Jackson, 1958). All data are expressed on oven dry weight basis (105^0C, 24 hr).

RESULTS AND DISCUSSION

Fine Root Biomass

Dense forest

The fine root biomass measured on different site and season given in Table 1 and Table 2. The maximum fine root biomass occurred in October (end of the rainy season) and minimum in July (the beginning of the rainy season). Total fine root biomass, averaged for all sampling intervals, was 3.85 t ha^{-1} (Table 1) and ranged seasonally from 3.15 t ha^{-1} (summer) to 4.29 t ha^{-1} (rainy season), (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (84 % of the total). In this diameter class live roots averaged 79 % and dead roots 21 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 93 % biomass. In an annual cycle proportion of dead fine roots was maximum (29 %) in June and minimum (11 %) in August.

Regenerated forest

Data on fine root biomass are included in Appendix Table 3.The maximum fine root biomass occurred in September and minimum in April. Total fine root biomass, averaged for all sampling intervals, was 2.75 t ha^{-1} (Table 1) and ranged seasonally from 2.02 t ha^{-1} (summer) to 3.36 t ha^{-1} (rainy season) (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (85 % of the total). In this diameter class live roots averaged 81 % and dead roots 19 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 85 % biomass. In an annual cycle proportion of dead fine roots was maximum (25 %) in April and minimum (13 %) in February.

Medium forest

The fine root biomass measured on different sampling dates is given in Appendix Table 3. The maximum fine root biomass occurred in September and minimum in July. Total fine root biomass, averaged for all sampling intervals, was 3.48 t ha^{-1} (Table 1) and ranged seasonally from 2.89 t ha^{-1} (summer) to 3.78 t ha^{-1} (rainy season), (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (83 % of the total). In this diameter class live roots averaged 78 % and dead roots 22 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 96 % biomass. In an annual cycle proportion of dead fine roots was maximum (32 %) in April and minimum (12 %) in August.

Degraded forest

The maximum fine root biomass occurred in September and minimum in December and April. Total fine root biomass, averaged for all sampling intervals, was 0.95 t ha^{-1} (Table 1) and ranged seasonally from 0.72 t ha^{-1} (summer) to 1.10 t ha^{-1} (rainy season), (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (77 % of the total). In this diameter class live roots averaged 80 % and dead roots 20 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 84 % biomass. In an annual cycle proportion of dead fine roots was maximum (25 %) in April and minimum (6 %) in September.

The fine root production and its decomposition in soil substratum are very much essential towards mineralization and nutrients cycling perspectives. The variation in the fine root biomass in different forests stand is found to be substantial in the total mass and by components in different season basis. The present finding was supported by Sahu et al. (2013) as they mentioned the total fine root biomass in the tropics of Chhattisgarh was ranged between 4.80-9.81 t ha^{-1}.

The mean fine root biomass in the boreal forest was 5.28 Mg ha^{-1}, and the production of fine roots was 2.82 Mg ha^{-1} yr^{-1}, accounting for 32% of annual net primary production of the boreal forest. Fine root biomass, production, and turnover rate generally increased with increasing mean annual temperature and precipitation (Yuan and Chen, 2010). The fine root biomass, production, turnover and nutrient pools have been found to be the results of internal factors as the genotype of plant species and several external factors such as soil properties, stand age, and climate (Vogt et al., 1986; Jackson et al., 1996; Vogt et al., 1996; Cairns et al., 1997; Joslin et al., 2000; Pregitzer et al., 2000; Leuschner and Hertel, 2003; Block et al., 2006; Kalyn and Van Rees, 2006; Brassard et al., 2009). However, it is still unclear how fine roots change over a large biome scale.

Physico-Chemical Characteristics of Soils

Tables 3 and 4 summarize the values for physico-chemical characteristics of the soil on different sites. Silt content was 28 %, 26 % , 29 % and 28 % while the clay content was 18 %, 13 % ,15 % and 4 % on dense, regenerated, medium and degraded forest sites, respectively, indicating maximum silt + clay content on dense and medium sites (44 %) and minimum on degraded site (32 %).Bulk density ranged between 1.33-1.56 g cm^{-3}, being maximum on degraded site and minimum on closed. The Water holding capacity was maximum on dense site (46 %) and minimum on degraded site (38 %).

Total soil N ranged from 0.06 - 0.18 % with the maximum on dense forest site and minimum on degraded forest site. Total soil P and mean annual $NaHCO_3$ - extractable Pi were least on degraded forest and highest on dense forest site and ranged between 0.029 - 0.037 % and 0.0002 - 0.00028 %, respectively. Soil organic C contents for dense, regenerated, medium and degraded forest sites were 2.1 %, 1.68 %, 1.67 % and 0.62 %, respectively. C:N ratio was highest on dense forest and least on medium forest and ranged from 9.8-11.67.

Total P: mean annual available pi ratio

The ratio was computed to assess the capacity of soil to release the available phosphate ions, which are readily absorbed in the exchange reaction between plant and solution. Wider ratio show a low releasing capacity and narrower ratio a high rate of release of the available fraction. In the present study the ratio ranged between 124 and 145 on different sites with the mean value being 132. Thus, the present study indicates a very low rate of release of the available fraction.

Exchangeable K

The value for exchangeable potassium ranged from 0.025 - 0.288 % in the present soils. Highest concentration of exchangeable K occurred on dense forest site.

Soil resource availability greatly impacts plant growth but its effects on fine roots are still unclear (Nadelhoffer, 2000). The findings of Janmahasatien and Phopinit (2001) were also supports the present value of soil attributed of different forest stand. Soil nutrient status and its associated dynamics are interrelated with climatic factors, site conditions, soil parental materials and weathering process, mineralization, soil properties and vegetation mix and its dynamics over the sites (Burke, 1989). Similar to present finding Sahu et al. (2013) reported total N ranged from 0.083 to 0.143% for 0-10 cm soil layer and 0.064 to 0.091% for lower layer soil (10-20 cm). The total C ranged from 1.124-1.736% for surface soil sample and 0.703 to 1.312% for lower layer soil sample. The concentration of available P (0-20 cm) under different sites varied from 8.55-15.72 kg ha^{-1} and 13.74-12.06 kg ha^{-1}. The results of available K for the soil were 249.54-382.21 kg ha^{-1} in different soil depths. Further, Chauhan et al. (2010) mentioned the 2.2% soil organic carbon for natural forest and 1.5% for planted stand whereas the available P ranged from 8.4-10.7 kg ha^{-1} for different sites. The N was 209.2 kg ha^{-1} for natural stand and 170 kg ha^{-1} for plantation site whereas K in available form 294.5-331 kg ha^{-1} for different sites. Tangsinmankong *et al.* (2007) revealed decreased pattern in the concentration of soil organic carbon in different sites with the increase in soil depth from upper horizon to lower layer soil.

Singh *et al*. (2000) revealed that temporal variation in soil organic carbon, increased soil organic carbon associated with fine root and litter biomass. Further, Singh and Singh (2002) mentioned that nutrient availability in soil was significantly higher under the tree canopy than the open forest area or non-planted sites.

Table 1. Mean live and dead fine root biomass on different forest sites (g m^{-2} ±1SE)

Components	Dense	Regenerated	Medium	Degraded
< 1mm live	254.75±26.64	190.00±20.09	225±21.41	64.38±8.10
< 1 mm dead	67.5±4.73	43.75±4.80	65.0±6.62	8.75±1.34
>1-5 mm live	58.25±10.73	35.25±3.88	56.25±7.55	18.12±2.30
> 1-5 mm dead	4.25±0.88	6.0±0.91	2.6±0.42	3.38±0.50
Total	384.75	275.00	348.85	94.63

Table 2. Seasonal pattern of fine root biomass on different forest sites (g m^{-2} ±1SE)

Seasons	Dense	Regenerated	Medium	Degraded
Rainy	429.5±54.11	335.5±55.55	377.75±65.08	110.25±15.04
Winter	364.5±55.51	227.5±32.37	350.0±50.26	86.00±8.79
Summer	315.5±35.43	201.5±32.70	289.5±47.24	72.00±8.89

Table 3. Physical properties of soil on different forest sites

Properties	Dense site	Regenerated site	Medium site	Degraded site
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Mechanical composition				
Sand (%)	54±2.6	61.0±4.4	56.0±6.2	68.0±6.2
Silt (%)	28.0±4.1	26.0±3.5	29.0±4.0	28.0±4.0
Clay (%)	18.0±2.1	13.0±2.3	15.0±0.6	4.0±0.6
Bulk density (g cm^{-3})	1.33±0.3	1.36±0.2	1.35±0.3	1.56±0.3
Water holding capacity (%)	46.0±8.7	44.0±7.0	45±9.2	38.0±9.5

Table 4. Chemical properties of soil on different forest sites

Properties	Dense site	Regenerated site	Medium site	Degraded site
Total N (%)	0.18±0.06	0.15±0.05	0.17±0.05	0.06±0.01
Total P (%)	0.037±0.004	0.031±0.005	0.033±0.0009	0.029±0.005
Available Pi* (PO_4-P) (%)	0.00028±0.00002	0.00025±0.00003	0.00026±0.00003	0.0002±0.00003
Organic carbon (%)	2.1±0.5	1.68±0.12	1.67±0.18	0.62±0.09
C/N ratio	11.67	11.2	9.8	10.30
C/P ratio	56.76	54.19	50.61	21.37
N/P ratio	4.9	4.84	5.2	2.06
Total P/available Pi	132.1	124	126.9	145
Exchangeable K (%)	0.288±0.008	0.228±0.05	0.249±0.007	0.025±0.005
Bulk density (g cm^{-3})	1.33±0.3	1.36±0.2	1.35±0.3	1.56±0.3

Note: (*) these analyses were carried out three times (rainy, summer and winter) in an annual cycle. The values in this table are averages of all seasons.

CONCLUSION

The study suggests that the high level of disturbance due to over exploitation of trees for timber and firewood had critically affected the fine root biomass and soil properties in the study area. This is evidenced by the very low density, diversity and basal area on degraded site. Litterfall and forest floor and fine root biomass are essential from the nutrient cycling perspective which leads toward healthy forest soil and its development. It is found that open forest and degraded forest stand were deficit in soil nutrient status and there availability. Therefore, appropriate management regime is required to protect the forest from subsequent degradation. To gain a better mechanistic understanding the controls of fine root dynamics, future studies shall emphasize decoupling the influences of individual environmental factors, tree species traits, and stand development on fine root dynamics. Further protections of regenerated and degraded site are prerequisite to regain the healthy vegetation cover and sustainable management.

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