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ASSESSMENT OF NUTRIENT TURNOVER AND SOIL FERTILITY OF NATURAL FORESTS OF CENTRAL WESTERN GHATS

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ABSTRACT
This study was undertaken to quantify the nutrient turnover and soil fertility status in the natural forests of Central Western Ghats. Major nutrients such as nitrogen, phosphorus and potassium were analyzed in the litter, both from the samples collected in pre and post monsoon seasons. There was no much difference seen in the values between the two seasons studied in all the three nutrients studied among all the forest types studied. All the three nutrients analyzed were found to be marginally higher in evergreen forest among the forest soils analyzed. The major nutrients NPK turnover from the litter studied was different among the different forest types, it was found to be highest in evergreen forest type (9.36 t $ha^{-1}yr^{-1}$, 0.57 t $ha^{-1}yr^{-1}$, 4.43 t $ha^{-1}yr^{-1}$) followed by semi evergreen (8.42 t $ha^{-1}yr^{-1}$, 0.55 t $ha^{-1}yr^{-1}$, 4.39 t $ha^{-1}yr^{-1}$) and least was found in dry deciduous forest type (2.87 t $ha^{-1}yr^{-1}$, 0.30 t $ha^{-1}yr^{-1}$, 2.52 t $ha^{-1}yr^{-1}$).

KEY WORDS: Nutrient turnover, soil fertility, and natural forest

INTRODUCTION

The forests spread over 78.37 million ha area in India which account for 23.84 per cent of the geographical area of the country and in Karnataka it is reported to be about 36,190 km^2 area which accounts 18.87 per cent, and in Kodagu it is reported to be about 3,339 km^2 area which accounts 81.40 per cent of total geographical area (FSI, 2009).

Forest soils influenced the composition of forest stand and ground cover, rate of tree growth, vigour of natural reproduction and other silviculturally important factors (Bhatnagar, 1968). Physico-chemical characteristics of forest soils vary in space and time because variation in topography, climate, weathering processes, vegetation cover, microbial activities (Paudel and Sah, 2003) and several other biotic and abiotic factors. Vegetation also plays an important role in soil formation (Champan and Reiss, 1992). The yearly contribution of surface vegetation to soil, in the form of needles, leaves, cones, pollen, branches and twigs, gradually decomposes and becomes a part of the soil (Singh and Bhatnagar, 1997). The nutrient thus, returned to the soil, exerts a strong feed back on the ecosystem processes (Pastor *et al*., 1984). Plant tissues (above and below ground litter) are the main source of soil organic matter, which influences the physico-chemical characteristics of soil such as, texture, water holding capacity, pH and nutrients availability. Nutrients supply varies widely among ecosystems (Binkly and Vitousek, 1989), resulting in differences in plant community structure and its production (Ruess and Innis, 1977).

Soil organic matter (SOM) is an important factor in evaluating management system of the forest soil fertility (Doran and Parkin, 1994). When plant litter enter the mineral soil, soil inherent stabilization mechanisms such as inclusion into aggregates or protection due to the interaction with soil minerals are operative (Soilins *et al.,* 1996). Organic matter can be transported downward by soil animals. Earthworms, for example, can completely mix soil to depths of a meter or so, transferring organic matter downward in the process. Burrowing animals move soil material low in organic matter from the deeper horizons to the surface and vice versa (Anderson *et al.,* 1989).

SOM is a fundamental for many reasons. It improves the structure of soil and its resistance to erosion, and allows storage of nutrients, the ion exchange and nutrient support to microflora (Campbell, 1978). In tropical and subtropical regions, where soils are strongly weathered and contained variable charged mineral, interaction of SOM and these soils can result in increasing SOM protection from microbial attack compared with that found in less-weathered temperate soils (Martin *et al.,* 1982and Parfitt *et al.,* 1997). Great stability of mineral-associated SOM in highly weathered soils, which may be an important in maintaining and restoring soil quality, determines the soil potential for acting as an atmospheric CO_2 sink in tropical and subtropical regions (Parfitt *et al.,* 1997).

Study Area

This study was carried out in the natural forest of Kodagu in the central part of the Western Ghats located between 75^0 25' – 76^0 14' E and 12^0 15' – 12^0 45' N. The total geographical area of the district is 4104 km^2, of which 1841.36 km^2 is occupied by natural forest. The annual rainfall of the district varies from 2000 – 5000 mm with a dry spell of four months. Mean annual temperature is 24^0C and it ranges from 25^0 C to 31^0 C during hot months (Pascal and Maher, 1986). The altitude varies from 650 to 1400 m. The major soils of the district are found to be Mollisols, Alfisols, Ultisols, Inceptisols, Entisols and red soil. All these variations in the locality factors contribute for wide variations of climatic conditions prevailing in the district and helpful in housing large biological diversity as well as forest types.

Sampling design

The land cover of the district is classified into different forest types using the vegetation map of the district with the help of satellite images developed by National Remote sensing Agency, Hyderabad. Among the different forest types of the district, four major forests types were selected for the study. Based on the earlier study conducted (Annon, 2009) in these forest types, Where in 0.1 per cent of each of the major forest types have been sampled using one hectare plots. Out of these one hectare plots one permanent sample plot in each forest type have been established in four forest types. Present study was conducted using these four permanent plots. In these plots standing trees have been permanently labeled using the metal labels and the co-ordinates of the plots are also recorded with the intention of monitoring these plots continuously. The details of the study sites are as follows table 1.

Method of plant sample analysis

Nitrogen: A known quantity of the powdered samples were digested using concentrated H_2SO_4 and dilute mixture (K_2SO_5: $CuSO_4$: Se: at 100:20:1 ratios) the digested samples were distilled directly in Kjeladal plus distillation unit. The ammonia was trapped in boric acid and titrated against standard acid (Jackson, 1937; Page, *et. al* 1982).

Digestion of plant samples: the other nutrient in plant samples were extracted by digestion known quantity of plant samples with diacid mixture (10:4-HNO_3: HCl) and the plant acid mixture was heated on sand bath until colourless and clear residues developed. After cooling, the residue was dissolved in dilute acid (0.1N HCl) and the volume was made up to 50 ml. the digested samples were used for determining the phosphorous and potassium.

Phosphorous: the P in digested samples was determined by vanado molybdate yellow colour method. The yellow colour was read using Bosch and lamb spectronic-20P spectrophotometer at 420 nanometer (Jackson, 1937; Page, *et. al* 1982).

Potassium: the K in digested samples was determined using Systronis flam photometer (model-128) proper dilution was done with distilled water where the concentration was found higher (Jackson, 1937; Page, *et. al* 1982).

Soil Sampling:

Soil samples were collected at three depths namely 10, 20 and 30 cm. At five locations in one-hectare plot samples were collected and major nutrients such as N, P, K, was estimated in these samples and also soil organic carbon to assess the soil nutrient content. This was done in two seasons of the year. Before collecting soil samples, all the vegetation and litter from the soil surface was cleared. Soil samples were collected using a core sampler. Soil was sliced on the plastic sheets and coarse fragments were removed using a 5 mm sieve.

Estimation of soil physical properties

Bulk density: The bulk density of soil was determined under field condition by adopting core method. A metallic core with a known dimension was inserted and the soil mass in the core was quantified on dry weight basis (Minaci *et al,* 1984).

Soil Nutrient Estimations

For major nutrient estimations, soil samples were collected from five locations with in the plot from a depth of 0-30 cm. Major soil nutrients such as nitrogen, phosphorus, potassium and organic carbon were estimated in pre and post monsoon seasons.

Soil chemical analysis

pH and Electrical conductivity : Soil pH was determined in 1:2.5 soil : water suspension using a digital pH meter (Elico LI 127). The same suspension was kept undisturbed for 6 hrs to measure the electrical conductivity using conductivity meter (Elico CM 180) (Sarma *et al,* 1987).

Organic-C: The dry soil samples were powdered using agate pestle and mortar and passed through 0.2 mm sieve. A known weight of finely powdered sample was treated with known volume of standard $K_2Cr_2O_7$ and concentrated H_2SO_4. The unused $K_2Cr_2O_7$ was quantified by back titration with standard ferrous ammonium sulphate using ferroin as an indicator (Jackson, 1937).

Available nitrogen: The alkaline permanganate method was adopted to assess the available nitrogen content in soils (Subbaih and Asija, 1956). The easily oxidizable portion of the soil organic matter was oxidized using hot alkaline potassium permanganate solution and the evolved ammonia was distilled to boric acid. Later, the ammonia trapped in boric acid was quantified using standard acid.

Available phosphorus: The soil samples were found in both acid and alkaline range. Hence, both Bray's reagent (for acid soils) and Olsen's reagent (for alkaline soils) were used for extraction. The phosphorus content in the soil extract was determined by the blue color formed by ascorbic acid-molybdate complex and the color intensity was read at 660 nm using spectrophotometer (Systronics Visiscan 167) (Jackson, 1937).

Available potassium: The exchangeable potassium was extracted with neutral normal ammonium acetate from a known quantity of soil. The extractant was fed to flame photometer (Systronics SYS-121) for measuring potassium contents (Page *et al,* 1982).

RESULTS

Major nutrient content in the leaf litter

Major nutrients such as Nitrogen, Phosphorus and Potassium were analyzed in the litter, both from the samples collected in pre and post monsoon seasons (Table.1). There was no much difference seen in the values between the two seasons studied in all the three nutrients studied among all the forest types studied. All the three nutrients analyzed were found to be marginally higher in Evergreen forest among the forest soils analyzed. The major nutrients NPK turnover from the litter was studied difference among the different forest types (Table 2) it was found to be highest in evergreen forest type (9.36 t/ha/yr, 0.57 t/ha/yr, 4.43 t/ha/yr) followed by semi evergreen (8.42 t/ha/yr, 0.55 t/ha/yr, 4.39 t/ha/yr) and least was found in dry deciduous forest type (2.87 t/ha/yr, 0.30 t/ha/yr, 2.52 t/ha/yr).

Major Nutrient status of the soils (kg/ha/yr) in of different forest types in central Western Ghats

TABLE 1: Major nutrient composition in leaf litter in permanent one ha plots of different forest types of central Western Ghats

Forest type	Major nutrients in litter								
	% N			% P			% K		
Season	Pre monsoon	Post monsoon	Average	Pre monsoon	Post monsoon	Average	Pre monsoon	Post monsoon	Average
Dry deciduous	0.86	0.91	0.885	0.058	0.061	0.0595	0.52	0.47	0.495
Moist deciduous	0.94	0.97	0.955	0.069	0.065	0.067	0.53	0.49	0.510
Semi evergreen	1.16	1.12	1.140	0.080	0.070	0.075	0.61	0.58	0.595
Evergreen	1.34	1.28	1.310	0.080	0.080	0.080	0.64	0.60	0.620

TABLE 2: Litter nutrient turnover in permanent one ha plots in different forest types of central Western Ghats

Forest type	Major nutrients (t/ ha)		
	N	P	K
Dry deciduous	2.87	0.30	2.52
Moist deciduous	4.46	0.31	4.76
Semi evergreen	8.42	0.55	4.39
Evergreen	9.36	0.57	4.43

TABLE 3: Available nitrogen in different depths of permanent one hector plots studied in different forest types of central western ghats (kg/ha)

Depth (cm)	Dry Deciduous	Moist Deciduous	Semi ever green	Evergreen	C.D. @ 5%
Pre monsoon (kg/ha)					
0-10	340	351	360	368.5	
10-20	312.5	341	348.5	352	
20-30	309	339	345	349.5	0.05
C.D. @ 5%	0.101				
Post monsoon (kg/ha)					
0-10	335	342	353.5	360.5	
10-20	310	331.5	340	356	
20-30	302	328	339.5	351.5	0.009
C.D. @ 5%	0.05				

TABLE 4: Available phosphorus in different depths of permanent one hector plots studied in different forest types of central western ghats (kg/ha)

Depth (cm)	Dry Deciduous	Moist Deciduous	Semi ever green	Evergreen	C.D. @ 5%
Pre monsoon (kg/ha)					
0-10	30	32	35	36.5	0.03
10-20	24	25.8	29.5	31.5	
20-30	23.4	23.9	28	30.5	
C.D.@ 5%	0.73				
Post monsoon (kg/ha)					
0-10	29	30	30	30.9	0.10
10-20	24.9	26.2	26	28.6	
20-30	23	26	24.9	27.6	
C.D.@ 5%	0.01				

TABLE 5: Available potassium in different depths of permanent one hector plots studied in different forest types of central western ghats (kg/ha)

Depth (cm)	Dry Deciduous	Moist Deciduous	Semi ever green	Evergreen	C.D. @ 5%
Pre monsoon (kg/ha)					
0-10	173	175	176.6	180	
10-20	167.2	164	165	169.5	N.S
20-30	156.9	159.9	160	163	
C.D. @ 5%		0.12			
Post monsoon (kg/ha)					
0-10	169.2	170.3	173	175	
10-20	159	160	162.9	164	0.060
20-30	154	159	160.6	162	
C.D. @ 5%		1.053			

TABLE 6. Soil pH in different depths of permanent one hector plots studied in different forest types of central Western Ghats

Depth	Dry Deciduous	Moist Deciduous	semi evergreen	Evergreen
0-10	7.2	7.65	6.4	7.0
10-20	6.8	7.30	6.1	6.5
20-30	6.1	7.20	6.0	6.0

TABLE 7: Bulk density of soil different forest types of central Western Ghats

Forest type	Bulk density (Mg M^{-3})	Electrical conductivity (dS m^{-1})
Dry Deciduous	1.03	0.02
Moist Deciduous	1.10	0.02
Semi evergreen	1.13	0.04
Evergreen	1.20	0.10
C.D. @ 5%	N.S	

The available nitrogen in different forest types pre monsoon did not differ significantly among the forest types studied and also at three different depths of the soils (Table 3). As the depth increased the nitrogen content in the soil decreased. However, there was statistical difference seen in the values of soils analyzed in post monsoon the available N was comparatively low (Table 3), both among the forest type studied and at different soil depths. Available phosphorus showed significant difference at different depths studied but it did not vary among the forest types in the soils analyzed pre monsoon (Table 4). The values of available P in pre monsoon showed a marginal increase over post monsoon values (Table 4). Here there was a significant different seen among the different forest types also. Available Potash content in the soil did not differ among the forest type as well as at different depths of the soil analyzed pre monsoon (Table 5). However it was statistically different post monsoon both at different depths and forest types (Table 5).

Soil pH of different forest types studied did not show much difference among the soils as well as at different depths studied (Table 6). In case of 0-10, 10-20, and 20-30 cm depths, it was found to be high in case of moist deciduous forest type (7.65, 7.30, and 7.20) and least was observed in case of evergreen forest type (6.4, 6.1, and 6.0). Most of the soils between the depths of 0-20 cm were found to be in the neutral, while at 30 cm depth except in case of moist deciduous forest soils it was in alkaline range

Bulk density, which is another important physical property of the soil was monitored from the soils of all the forest types studied (Table 7). It varied between 0.93 to 1.42 Mg m^{-3}, which was not statistically significant. The electrical conductivity range varied between 0.02 to 0.10 dS m^{-1}.

DISCUSSION

Soil chemical and physical characters of different forests of Central Western Ghats

The nutrient status of major nutrients analyzed (Table 3, 4 and 5) revealed that, the soil available nitrogen content in post monsoon was low but it was in the medium range in pre monsoon and it was comparatively higher in the evergreen forest type and was less in dry deciduous forest soils. Phosphorus was low in Dry deciduous forest and was found in medium range in other forest soils during post monsoon. During pre-monsoon period also similar trends were seen in case of phosphorus and potassium. The pH of the soil of all the soils studied (Table 6) found to be neutral and the bulk density did not show any variations among the different forest soils (Table 7). The physical characters of the soil being favorable and the nutrient availability is also reasonably good during post monsoon indicates the nutrient turnover occurring in these forests, which coinsides with the growth periods of the trees which is generally during post monsoon season. Therefore, nutrient availability in these forests required for growth may not be a major limiting factor for the slow growth of trees seen in these forests.

The major forest types of Central Western Ghats studied is found to sequester substantial amount of carbon dioxide from the atmosphere mainly in its above ground biomass and soil. The contribution of herbs and litter were mainly useful in supplementing the soil organic carbon, nutrients and help in maintaining good physical properties of the soil, which are essential for growth. The annual growth increment of trees is found to be poor (which is not surprising if we take such natural forests across the globe). However, it is important to monitor the increments for few more years. The growth of herbs on the floor of the forest floor, litter accumulated and the physical and chemical properties of the soils of majority of the forests types studied indicate that, these forests have the potential to act as carbon sinks. These natural forests are not only the sinks of carbon but are also serving as repositories of a large number of tree species and help in conserving the biodiversity and providing many non-tangible benefits.

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