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NUTRIENT PARTIONING IN AN EVERGREEN FOREST ECOSYSTEM

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Introduction

Tropical forests have been studied from a variety of view points but, ecosystem sutdies per as are relatively recent (Golley, 1983). The International Biological Programme (IBP:1964-74) gave impetus to broad-scale ecosystem studies which were mostly concentrated in New World Tropics. Of the two ecosystem studies in Asia under IBP,the one in India (Singh and Mishra, 1978) threw light on the ecology and productivity of dry decidious forests, grasslands, and agricultural ecosystems near Varanasi. On the contrary, studies are absent with regard to tropical evergreen forest ecosystems in South India with the exception of the work of Rai (1981).

Recent literature on tropical forests stresses the importance of nutrients in the ecosystem and the role played by the vegetation in conserving the same (Jordan, 1985) in contrast to temperate ecosystems where nutrients are primarily held in the soil (Richards, 1952). This peculiarity has a direct bearing on the nutrient removals from a forest ecosystem through harvesting. The nutrient loss will depend on the overall nutrient status of the ecosystem, which in turn is the sum of the nutrients locked up in the biomass and stored in the soil. This type of information, necessary for making appropriate management decisions, is available for semi-natural and man-made forests of the temperate zone (Duvigneaud and Denayer De Saet, 1970; Freedman et al., 1986). Nutrients have been more or less well investigated in the forest ecosystems of New Uorld Tropics (Gessel et al., 1977; Jordan, 1985; Russel, 1983). Individual observations are available from Africa (Bernhard-Reversat, 1975), Thailand (Zinke et al., 1978), New Guinea (Grubb and Edwards, 1982). Studies on nutrient reserves in the evergreen forests of India are virtually absent. The aim of the present investigation is to establish the nutrient distribution pattern in an evergreen forest ecosystem.

Study Area and Methods

Study Area:- Investigations were carried out in an unworked evergreen forest at Pothurnala of Nenmara Forest Division ($10^o25'$-$10°30'$N and $76^o35'$-$76^o45'$E) situated on the Western Ghats at an elevation of 1000 m. The area enjoys an annual rainfall of 3660 mm and the terrain is hilly.

Methods:- A plot of 50 x 50 mm was demarcated and an enumeration of all trees > 10 cm grith at breast height (gbh) was carried out. For further work, the ecosystem was divided into three components vir. (1) vegetation (above ground and roots) (2) litter and (3) soil. The following investigations were carried out:-

Biomass:- The standing biomass was arrived at by harvesting and weighing in the following pattern:

a) All large trees > 30 cm gbh.

b) All small trees from 10 subplots of 5 x 5 m.

c) Roots from soil layer up to 60 cm from 2 subplots of 10 x 5 m.

Litter:- Litter was sampled from 30 quadrats of 1 x 1m within the plot.

The plant materirl (above ground, root and litter) was oven dried at 85°C and all weights expressed in Mg ha^{-1}. The above ground biomass was divided into leaf, bole and branch. Sub samples of each component were prepared by pooling the material belonging to each component giving due weightage to the biomas of each.

Soils:- Soil samples were collected from four pits of one metre depth from the layers, 00-20, 20-40, 40-60, 60-80 and 80-100 cms. The samples from identical layers of the pits were composited. Bulk density (BD) of the soil was determined in the field by taking sample cores from each layer.

The soil samples were air dried and passed through a 2 cm sieve. Particles >2 mm were determined so as to give correction for coarse fragment content. The weight of the soil was arrived at by multiplying the volume of the soil in each layer by BD.

Chemical analysis

Total Nitrogen in plant material and soil was determined by Kjeldahl's digestion and subsequent spectrophotometry using Nessler's reagent. For analysing total P,K,Ca and Mg, the plant samples were dry ashed while the soil was digested in tri-acid (9:2:1 HNO_3 :H_2SO_4 :$HClO_4$). P and K were determined by spectrophotometry using ascorbic acid as reducing agent (Alexander and Robertson, 1972) and sodium 'cobaltinitrite respectively. Ca and Mg were analysed by titration with EDTA.

Nutrient inventory.

Elemental concentrations in plant samples were multiplied by respective biomass to arrive at an inventory of bioelements. For soils, the nutrient concentration in the sample from a layer was multiplied by the weight of the soil to assess the stock.

Results and Discussion

The forest: The wet evergreen forests of Pothumala represent a typical unworked patch of such type of ecosystems on the Western Ghats. Balasubramanian (1987) and Basha (1987) have indicated that the forest is normal and that all three storeys are well represented. Vegetational analysis of the 50 x 50 □ plot revealed 335 individuals of >10 cm gbh spread over 33 species (all trees1 belonging to 18 families. The Simposn's index worked out to be 0.87 suggesting high species diversity. Further analysis indicated that Palaauium ellipticurn and Cullenia exarillata are the dominant species (Table 1) and are followed by IInd storey ones, Agrostistachys meiboldii and Drypetes alata.

Table 1, Vegetational analysis (50 x 50 m plot)

Species	No	RF*	RD	RBA	IVI
1. *Palaquium ellipticum*	79	14.32	23.51	34.34	72.17
2. *Cullenia exarillata*	23	11.11	6.84	20.19	38.14
3. *Agrostistachys meiboldii*	55	11.69	16.36	5.85	33.90
4. *Drypetes alata*	55	12.86	16.36	4.57	33.79
5. *Mesua ferrea*	11	5.26	3.27	10.57	19.10
6. *Unona pannosa*	28	7.60	8.33	1.55	7.48
7. *Caiophyllum elatum*	4	2.33	1.19	11.19	15.43
8. *Euphorea longana*	11	3.50	3.27	1.83	
9. *Isonandra lanceolata*	11	4.67	3.27	0.34	8.28
10. *Artocarpus heterophyllus*	3	1.75	0.89	5.49	8.04
11. Others (23 species)	55	24.00	16.71	3.45	45.07

*RF = Reletavie Frequency; RD = Relative Density; RBA = Relative Basal Area; IV1 = Importance Value Index.

Total phytomass and its distribution among components

The oven dry plant biomass of the ecosystem under consideration is 511 Mg ha^{-1}. The distribution of biomass among various components is given in Table 2.

Table 2. Distribution of biomass among various components, Mg ha^{-1}

Bole	Branch	Root*	Leaf	Total
349 (68.3)**	136 (26.6)	20 (3.9)	6 (1.2)	511 (100)

* tap roots excluded
** % to total in parenthesis.

Stem weights being greater, bole and branch constitute 60.3 and 26.6 % of plant biomass, while leaves represent only 1.2 %, This figure of ecosystem phytomass 1511 Mg ha^{-1}) corresponds well with those obtained for similar forest types in Karnataka, India (Rai, 1981), Ivory Coast (Bernhard-Reversat, 1975), New Guinea (Edwards, 1977) and Cambodia (Hozumi et al., 1969). Among the components of the biomass {Table 2) the value for roots (20 Mg ha^{-l}) alone may be substantially low compared to those recorded elsewhere 172.3 Mg ha^{-l}-Odun and Pigeon, 1970; 123.0 Mg ha^{-l} Klinge, 1976). The non inclusion of tap roots can be reason for the underestimation of root phytosass in the present study.

The contribution of different species to the ecosystem biomass is presented in Table 3 (root biomass is excluded). The data indicates that emergent species (1 to 5) constitute nearly 90% of the biomass. Although IInd storey species like Agrostistachys meiboldii and Drypetes elata are higher up than Mesua, Calophyllum and Artocarpus when taking important value index {Table 1) into consideration, on the basis of biomass they are below. Thus basal area and height tend to govern the biomass more than the number of individuals.

Table 3. Percentage distribution of biomass among tree species.

No.	Species	No. of individuals	% total biomass
1.	*Palaquium ellipticum*	79	46
2.	*Cullenia* exarillata	23	19
3.	Mesua *ferrea*	11	13
4.	*Calophyllum elatum*	4	7
5.	*Artocarpus heterophyllus*	3	4
6.	*Agrostistachys meiboldii*	55	4
7.	*Drypetus alata*	55	3
8.	*Euphorea longana*	11	2
9.	Unona pannosa	28	1
10.	Rest	66	2
	Tota1	335	100

Nutrient concentration and stocks in phytomass

The nutrient concentration in different components of the biomass is given in Table 4. The data reveal that the highest concentration of elements are in the leaves. Branch wood has more N,P,K,Ca and Mg than bole wood, while roots contain higher concentration of all elements than wood, the exception being Ca.

Table 4. Concentration of nutrients in various Components of biomass Mg kg^{-l}.

Component	Nutrient, mg kg-l N	P	K	Ca	Mg
Leaf	17000	900	7600	13000	6600
Bole	4200	300	3100	7100	1800
Branch	7000	400	4800	9600	1700
Roots	7200	600	6000	7400	4200

Elements concentrations multiplied by the biomass gives the inventory of the nutrients. The stocks of N,P,K, Ca and Mg in the evergreen forest under consideration are given in Table 5.

Table 5. Stocks of nutrients in various components of biomass kg ha^{-1}

Component	Dry weight Mg ha^{-l}	Nutrient, Kg kg^{-l} N	P	K	Ca	Mg
Leaf	6	102	5	46	78	40
Bole	349	1466	105	1082	2478	628
Branch	136	952	54	653	1306	367
Roots-	20	144	12	120	148	84
Total	511	2664	176	1901	4010	1119

While the study area contains 2664 kg ha^{-1} of N, Klinge (1976) and Russel (1983) have reported over 5000 Kg N ha^{-1} in tropical forest phytomass of Brazil. Compared to N, phosphorus stocks in the biomass are extremely low being only 176 kg ha^{-1}. Hase and Folster (1382) and Gessel et al., (1977) have assessed the biomass P to be 400 kg and 150 kg ha^{-1} in seasonal of Venezuela and rainforests of Costa Rica respectively. The K content in the phytomass (1901 kg ha^{-1} of the study area is . comparable to those reported from elsewhere. Zinke et a]., (1978) estimated 2500 kg ha^{-1} and Gessel et al., (1977) 1500 kg ha^{-1} of K in the biomass of tropical forests from Thailand and Costa Rica respectively. The stocks of calcium (4010 *kg* ha-l) are higher than those reported from other sites (Gessel et al., 1977-2500 kg ha^{-1}) and that of magnesium is considerably less than Ca.

Stem weights being larger than weights of other components, nutrient content in the bole and branch dominate (Table 6). Nearly or over 90% of the bioelements are present in the same.

Table 6. Percentage distribution of nutrients among components of biomass.

	Nutrient %				
Component	N	P	K	Ca	Mg
Leaf	4	3	2	2	3
Bole	55	60	57	62	56
Branch	36	30	35	32	33
Roots	5	7	6	4	8

Nutrient concentrationt and stocks in the litter.

The oven dry biomass of litter (fine + coarse) in the ecosystem was estimated to be 9 Mg ha^{-1}. The elemental concentration in the litter and the stocks are provided in Table 7. Herrera (1979) has found that N and Ca are the dominant nutrients in the litter of Amazon forest of Venezuela. High amounts of Ca is noticed in the litter of the ecosystem under study and complexes dominated by this element in the litter have been reported (Golley and Richardson, 1977).

Table 7. Concentrations and stocks of nutrients in litter

Nutrient	Concentration mg kg^{-1}	Stock kg ha^{-1}
Nitrogen	8100	73
Phosphorus	300	3
Pottassium	2900	26
Calcium	11000	99
Magnesium	4000	36

Nutrient concentrations and stocks in the soil

The soils in the study area belong to typical red ferrallitic ones. They are strongly acid in reaction with moderate content of organic carbon (2.2-1.7%) in the surface and subsurface layers.

The concentration of nutrients (total) is given in Table 8. The data reveal that but for P and Hg, surface layers have highest levels of nutrients. Potassium is the element with the maximum concentration.

Table 8. Nutrient concentration in the soil mg kg^{-1}

Depth (cm)	Nutrient mg kg^{-1} N	P	K	Ca	Mg
00-20	2570	750	4000	2160	648
20-40	1830	1000	4375	2160	648
40-60	1260,	1400	5000	540	1620
60-80	2200	1850	1250	1620	972
80-100	1880	2000	1250	1080	1296

The nutrient content of the soil (1 m depth in different layers is presented in Table 9. The total ecosystem soil stock of N is 16273 kg ha^{-1}. Klinge (1976) has reported over 9000 kg ha-1 while Grim and Fassbender (1981) over 20000 kg ha^{-1} of in tropical rainforest soils. The P content is less than that of N (11935 kg ha^{-1}) and Gessel et a1 (1977) have estimated the P stock of a rainforest soil in Costa Rica to be 8000 kg ha^{-1}.

Table 9. Stocks of nutrients in the soil, kg ha^{-1}

Depth (cm)	Dry weight Mg ha^{-1}	Nutrient, kg ha^{-1} N	P	K	Ca	Mg
00-20	1458	3747	1094	7290	3149	945
20-40	1680	3074	1680	7350	3629	1089
40-60	1650	2079	2310	8250	892	2673
60-80	1872	4188	3463	2340	3032	1819
80-100	1694	3185	3388	2118	1890	2195
Total	8354	16273	11935	27348	12591	8721

Potassium is the eleaent aost abundantly present in the soil of the ecosystem under consideration (27348 kg ha^{-1}), Values for K from similar studies in tropical forest ecosystems relate to extractable forms of K which are substantially low (500 kg ha^{-1} Gessel et. *al.*, 1977). Same is the case with Ca and Mg as values reported from .other comparable ecosystems are for extractable forms.

Nutrient stocks in the ecosystem and partitioning among biomass, litter and soils

The total nutrient stocks in the evergreen forest ecosystem under consideration and the contribution of the three components to the same is given in Table 10.

Table 10. Total stock (kg ha^{-1}) and partitioning (%) of nutrients in the ecosystem.

Nutrient	Stock kg ha^{-1}	% in Biomass	% in litter	% in Soil
N	19010	14.0	0.40	85.6
P	12114	1.5	0.02	98.3
K	29275	6.5	0.09	93.4
Ca	16700	24.0	0.59	75.4
Mg	9876	11.3	0.40	88.3

Potassium is the nutrient most abundant in the ecosystem followed by N, Ca, P and Mg. Bulk of the nutrients belong to the soil stock with litter contributing only negligible amounts. Soil contribtion (%) is highest for P and least for Ca. The only element that exhibits a tendency for biomass storage is Ca. Locking up of Ca in the biomass may be a nutrient conserving mechanism.

It has been widely stated that soils of tropical forest ecosystems, especially, the humid types are nutrient poor (Gomez Pompa et al., 1972) and that bulk of the nutrients in the ecosystem are stored in the biomass. This popular view need not be justified and Proctor (1987) reports that some rainforests occur on fertile soils with a high proportion of at least some nutrients below ground. Golley *et al.* (1975) have estimated that 98% P, 85% K, 48% Ca and 22% Mg of the total ecosystem nutrient stock belongs to the biomass component in permontane wet forests of Panama. Accounting of only extracable forms of nutrients in the soil may be the reason for this shift in favour of biomass. It is worthwhile to consider that the soil capital of a nutrient may be labile or recalcitrant. Furthermore, the capabilities of trees with a long span of life to draw up and later efficiently recycle the nonavailable forms of nutrients, are not known. Baillie (1987) is of view that many nutrients, held in less iemdeiately available forms and which have to be extracted by more drastic analytical methods, may contribute to the nutrient supply of long lived trees. Analysis of total forms of N, K, Ca and Mg in the soils of the study area and using these values for nutrient inventory calculations, provide an entirely different nutrient scenario of the ecosystem, with soils contributing bulk of the elements. Detailed investigations on the ecosystem are warranted before drawing up arbitrary conclusions regarding the fertility of soils of the humid tropics.

Conclusion

The biomass (511 Mg ha^{-1}) of the evergreen forest under consideration is comparable to that of similar ecosystems elsewhere. Stocks of nutrients in the phytomass reveal that elements follow the trend Ca>N>K>Mg>P. Inventory of total forms of nutrients in the soil indicates that K is the element most abundant with N>Ca>P>Mg. Bulk of the nutrients belong to the soil component (>85%) the only exception being calcium.

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