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MAJOR NUTRIENT CYCLING OF TWO DIFFERENT TROPICAL DRY DECIDUOUS FOREST OF WEST BENGAL, INDIA

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Abstract- The study was carried out at tropical dry deciduous forest of Matha Protected Forest (MPF) of Purulia district and Protected Forest of Birbhum (PFB) district, West Bengal which are subjected to repeated human disturbances impending under increasing land use stress with increase in population density. The forest at Purulia and Birbhum district is covered mainly with sal (*Shorea robusta* Roxb.) as dominant tree species along with the predominating tree species of piyal (*Buchanania latifolia* Roxb.), sidha (*Lagerstroemia parviflora* Roxb.) and piyal (*Buchanania latifolia* Roxb.), mahua (*Madhuca longifolia* J.Konig) as predominating tree species respectively. From the analysis, it is revealed that P use efficiency is enhanced than N and K for *Shorea robusta* Roxb. while K use efficiency is higher followed by P and N for *Buchanania latifolia* Roxb., *Lagerstroemia parviflora* and *Madhuca longifolia* J.Konig at both the forests. But nutrient retranslocation efficiency of *Shorea robusta* Roxb. is higher than other species under study and hence the predominating species are more affected in respect to plant growth. However, we found site-dependent and between-species differences in nutrient content and nutrient remobilization. P and K use efficiency is increased in the forest which in turn depicts nutrient limitation mainly at Protected Forest of Birbhum (PFB).
Keywords- Nutrient analysis; green leaf nutrient; leaf litter; nutrient use efficiency; nutrient retranslocation efficiency.

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Introduction

Nutrients and energy is transferred from living biological components to the soil which is closely related to litterfall and is the starting point for nutrient cycling [1]. Litterfall of leaves, branches and other tree organs is usually the main path of nutrients and organic matter transfer to soil and together with root turnover constitutes the biggest proportion of nutrients annually incorporated to forest soils [2,3]. Decomposition of litters which produces organic matter is an important factor for soil formation as well as nutrient cycling processes [4]. Studies on nutrient content in plant debris fall give the functional state of the forest and can be used to improve forest management and production [5,6]. Some researcher in their study dealt with quantification of litter production, seasonal variations in litter nutrient concentration and nutrient return to the forest floor at tropical dry deciduous teak forests of Satpura plateau in India [7]. However, the index of nutrient use efficiency in litterfall can be used as an indicator of soil nutrient conditions [8,9]. In many cases, the seasonal variation of different parts of litter that falls, constitute an important aspect of nutrient cycling while the role of litter nutrients may be critical in tropical dry forests [10]. The rate of forest litterfall and its gradual decay regulate energy flow, primary productivity and nutrient cycling in forest ecosystems [11] and also acts as an input-output system of nutrients which is particularly important in the nutrient budget of tropical forest ecosystems on nutrient-poor soils, where vegetation depends on recycling of nutrients contained in the plant detritus [12].

Ecosystem functions are constrained by low rates of nutrient supply in most of the tropical forests [13,14]. Generally, nutrient limitation in dry tropical forest is related to water limitation because dry conditions prevent plant uptake of nutrients from the soil and reduce the release of nutrients during decomposition. Nutrient limitation of growth is correlated with low concentrations of nutrient in leaves which indicate lower availability of that particular nutrient [15]. Comprehensive multi-disciplinary studies have been carried out to assess the biogeochemical cycles of nutrients in temperate forested watersheds [16,17] but information in tropical environments is scarce and most studies have focused on specific ecological processes [18,19]. Thus nutrient cycling in tropical dry forests receive less scientific attention compared to the humid counterpart [20]. Although there have been several studies on litter dynamics in tropical forest ecosystems in India [21-28]. But very limited information is available for dry deciduous forest. So a study is undertaken on nutrient cycling in dry deciduous forest of Purulia and Birbhum district, West Bengal. The aim of this study is to assess the nutrient availability and its uptake by the tree species found in the study area and to compare the potentiality of each forest habitat as a basis for determining appropriate forest management strategies.

Materials and Methods

Study Area

The actual location of the study area, Matha Protected Forest (MPF) is enclosed within the parallel 23˚05'00" N and 23˚12'30" N and meridian 86˚02'30" E and 86˚10'00" E and Protected Forest of Birbhum (PFB) is enclosed within 23˚32'30" and 24˚35'00" N latitudes and 87˚05'25" and 88˚01'40". MPF is characterized by undulating topography with highest peak of 665m while protected forest at Birbhum is a plain land. The climate for both the areas are hot and dry with three distinct seasons viz. summer, monsoon and winter. Summer is intense and lasts from middle of March to mid of June. The monsoon starts from mid- June and lasts till end of September. Winter lasts from November to February. Minimum temperature fluctuates from 7˚C to 14˚C during months of December, January and February. Maximum temperature ranges from 42˚C to 45˚C during April to June. The average rainfall is 1031 mm and the south-west monsoon is the source of rainfall in Purulia and Birbhum. The soil in the area is laterite, red to brown in color and sandy loam in texture. The study area is covered with sal *(Shorea robusta* Roxb.*)* as a dominant species along with piyal (*Buchanania latifolia* Roxb.) and sidha *(Lagerstroemia parviflora* Roxb.*).* But the forest at Birbhum district comprises of Piyal *(Buchanania latifolia* Roxb.*),* Mahua *(Madhuca longifolia* J.Konig*)* as predominating species.

Vegetation Study and Soil Sampling

Studies on vegetation were done through quadrat method (minimum size of quadrat for each sample plot was 20 × 20 m and minimum number of quadrats was 5). Diameter at breast height (DBH) was measured. Biomass was estimated using the following regression equation [29].

$Y = \exp\{-1.996 + 2.32^{*}\ln(D)\}$

Where Y= biomass per tree in kg and D is the tree diameter at breast height (cm).

Samples of soil were collected at five points randomly distributed in each plot at depths of 10 - 15 cm. All of the soil samples were oven-dried at 70˚C, then grounded and passed through 2 mm sieve.

Litterfall Collection

Litterfall was measured using five litter traps placed regularly within each plot [30] having 1 m^2 area. Litterfall collection took place seasonally (in the month of March, July and November) for three years. Samples was washed thoroughly with water then air dried and finally oven dried at 60˚C overnight, then milled for chemical analysis. Fresh mature leaves were collected from the crowns of *Shorea robusta* Roxb.*, Buchanania latifolia* Roxb.*, Lagerstroemia parviflora* Roxb. and *Madhuca longifolia* J.Konig in the month of March, July and November for three consecutive years. These green leaves were processed in the same way as litterfall.

Chemical Analysis

Soil pH was measured by digital pH-meter (Systronics-121, India) in a 1:5 (w:v) soil water suspension. Organic carbon was estimated by Walkley and Black method [31]. The samples of ground leaf litter and green leaf samples were digested with $HNO_3 – HClO_4$ and analyzed for concentrations of P, K Subsamples of soil were analyzed for available P following the molybdenum blue method of Jackson [32], K was extracted from the soil in an ammonium acetate solution (pH=7) and measured with a digital flame photometer (Systronics-121, India). The total Kjeldahl nitrogen was determined by the micro-Kjeldahl procedure[33].

Computation and Statistics

The percent nutrient retranslocation efficiency (NRE) was calculated by the following equation [34]:

$$NRE\ \% = \{(A – B) / A\} \times 100$$

where A is the nutrient in green leaves and B is the nutrient in leaf litter.

Nutrient use efficiency (NUE) was calculated according to Vitousek:

NUE = litterfall mass (g m^{-2} $year^{-1}$) / nutrient content in litterfall (g m^{-2} $year^{-1}$).

After generating the data, statistical analysis was done using Statistical Package for Social Sciences (SPSS version 16).

Results and Discussion

Nutrient Characteristics of Forest Soil

The soil at Matha Protected Forest (MPF) of Purulia and Protected Forest of Birbhum (PFB) is basically acidic to neutral in nature which is the characteristic feature of lateritic soil. Soil organic carbon (SOC) [0.664 (0.037)] is higher at PFB compared to MPF [0.614 (0.054)] ($p < 0.001$). N% at MPF and PFB is 0.023 (0.002) and 0.019 (0.004) respectively and is significant at $p < 0.001$. C/N ratio is found to be 29 (in MPF) and 32 (in PFB) which reveals slower rates of decomposition and nutrient immobilization. In case of available P and exchangeable K the nutrient pattern in soil is similar at 99% level of significance ($p < 0.0001$). The concentration of available P and exchangeable K in soil is found to be [14.900 (0.258) mg/kg], [30.271(1.547) mg/kg] and [64.897 (0.286) mg/kg], [51.824 (1.060) mg/kg] at MPF and PFB respectively. From analysis it is found that SOC is negatively correlated with N as organic carbon is more than the available N. The course of decomposition of litterfall decreases N availability as the carbon–nitrogen ratio of soil organic matter is related to the patterns of nitrogen immobilization and mineralization during organic matter decomposition by microorganisms and its value decreases as decomposition proceeds [36].

Nutrient Characteristics of Leaf

Litter fall biomass of sal is highest about 1229 g m^{-2} $year^{-1}$

(average of two forests where MPF litterfall biomass is 1273 g m^{-2} $year^{-1}$ and PFB is 1186 g m^{-2} $year^{-1}$), whereas it is 859 g m^{-2} $year^{-1}$ for piyal (average of two plots where MPF litterfall biomass is 850 g m^{-2} $year^{-1}$ and PFB is 868 g m^{-2} $year^{-1}$). For sidha and mahua, the litter fall biomass is found to be 750 g m^{-2} $year^{-1}$ and 736 g m^{-2} $year^{-1}$ respectively. Nutrient quality of green leaf is given in Table 1. N% in *Shorea robusta* Roxb. is maximum followed by *Madhuca longifolia* J.Konig, *Lagerstroemia parviflora* Roxb. and *Buchanania latifolia* Roxb. considering both the forests. But P concentration of *Lagerstroemia parviflora* Roxb. is significantly higher than *Madhuca longifolia* J.Konig, *Buchanania latifolia* Roxb. and *Shorea robusta* Roxb. whereas for K concentration, it is more for *Shorea robusta* Roxb. than *Lagerstroemia parviflora* Roxb. N concentration of green leaves is significantly higher in MPF than PFB when only *Shorea robusta* Roxb. and *Buchanania latifolia* Roxb. are considered. P and K concentration at MPF is increased than PFB while considering all the four tree species (Table 1). Therefore, the mineral component showed site-dependent differences as well as between-species differences.

Nutrient Quality of Litterfall

The total litterfall amount was significantly affected by the local topographies of the studied sites. The litterfall study was concentrated during three major period e.g. pre-monsoon, monsoon and post-monsoon and was strongly influenced by the high and low range of temperature and soil moisture. A pattern of litterfall in this study was broadly comparable to tropical deciduous forest of Mexico [37]. The total nutrient characteristic of the litterfall is summarized in the Table 2. *Madhuca longifolia* J.Konig. leaf litter has recorded the highest value followed by *Lagerstroemia parviflora* Roxb., *Shorea robusta* Roxb. and *Buchanania latifolia* Roxb. For P, the pattern of concentration in four plant species is similar to that of the green leaves P concentration. But for K concentration in leaf litter, the pattern is different from that of P which is found to be peak in *Shorea robusta* Roxb. followed by *Madhuca longifolia* J.Konig, *Lagerstroemia parviflora* Roxb. and *Buchanania latifolia* Roxb.

Nutrient Use Efficiency

The capacity of efficient uptake of nutrients from soil along with the transport, storage, mobilization, usage within the plant and the environment influences nutrient use efficiency (NUE). Efficient nutrient use is generally characterized by the lower nutrient concentration in the litter fall [35]. In our study, the litterfall nutrient concentration is less than green leaf, therefore, NUE is increased. In our experiment, considering both the forests, it is revealed that N and K use efficiency is higher in *Buchanania latifolia* Roxb. The N use efficiency of all the species follows the order as *Buchanania latifolia* Roxb. > *Shorea robusta* Roxb. > *Lagerstroemia parviflora* Roxb. > *Madhuca longifolia* J.Konig but in case of K use efficiency by the species is in the order of *Buchanania latifolia* Roxb. > *Lagerstroemia parviflora* Roxb. > *Madhuca longifolia* J.Konig > *Shorea robusta* Roxb. The forest stand has higher within stand efficiency of P and K at PFB (P:5738, K:5773) than MPF (P:5613, K:5370) (Fig. 1) which is related to lower availability of P and K at PFB. This can be inferred that NUE in litterfall can be used as an indicator of soil nutrient availability [35,38]. But P and K use efficiency is higher in comparison to evergreen broad-leaved forest [8] and tropical rain forest [35]. N use efficiency of PFB is also greater than MPF and as a whole and major nutrient use efficiency of dry deciduous forest is in the order of P > K > N.

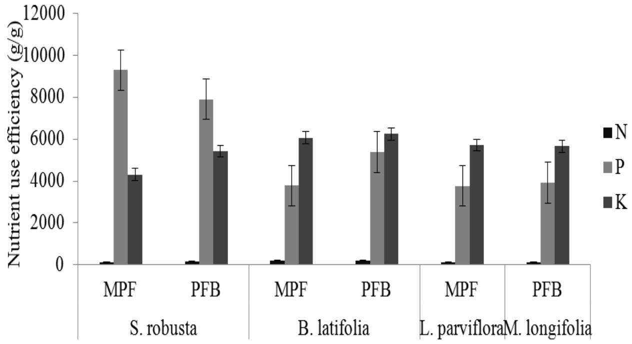

Fig.1- Nutrient Use Efficiency with standard error of four tree species at Matha Protected Forest (MPF) and Protected Forest of Birbhum (PFB)

Nutrient dynamics and retranslocation

Nutrient concentrations of leaf litter are significantly decreased than green leaf (Table 1 and 2) in the forest and thus the nutrient retranslocation efficiency is high which suggests nutrient limitation. The nutrient retranslocation efficiency of both the forest is represented in Fig. 2. Throughout the forest N retranslocation efficiency is higher than that of P and K, i.e. N is highly remobilized. Accordingly, within stands total NRE percent is 91 (*Shorea robusta* Roxb.), 69 (*Buchanania latifolia* Roxb.), 34 (*Lagerstroemia parviflora* Roxb.) in MPF while it is 48 (*Shorea robusta* Roxb.), 61 (*Buchanania latifolia* Roxb.), 23 (*Madhuca longifolia* J.Konig) at PFB. But among the two forest areas, Protected Forest of Birbhum (PFB) shows decreased NRE than Matha Protected Forest (MPF), signifying improper nutrient transfer when nutrient concentration of soil, green leaves and leaf litters are considered.

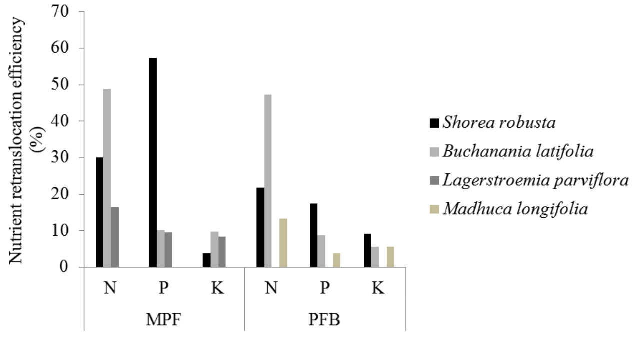

Fig. 2- Nutrient Retranslocation Efficiency of four tree species at Matha Protected Forest (MPF) and Protected Forest of Birbhum (PFB)

The extent of retranslocation efficiency of N from the leaves in the present study is 22-30% in *Shorea robusta* whereas it is significantly higher (about 47-49%) in *Buchanania latifolia* Roxb. Correspondingly, the extent of retranslocation efficiency of P is different for both the species (17-57% in *Shorea robusta* Roxb. and 8-10% in *Buchanania latifolia* Roxb.). K retranslocation efficiency is 4-9% in *Shorea robusta* Roxb. that is considerably lower than *Buchanania latifolia* Roxb. of about 5-10% (Fig. 2). The values are quite different than those reported for subtropical evergreen forest [39]. Above all, we find between-species nutrient difference as well as site-dependent differences of nutrients at both plots of the forest.

Conclusions

Tropical dry deciduous forest being arid and a nutrient-poor ecosystem, the amount of nutrient retranslocation is low that certainly retards the growth rate of plants. In this study it is revealed that *Shorea robusta* Roxb. can translocate nutrients well than the predominating tree species studied in both the forests. Therefore, the growth and uptake of nutrients are affected mostly in *Buchanania latifolia* Roxb., *Lagerstroemia parviflora* Roxb. and *Madhuca longifolia* J.Konig. Nutrient uptake and growth rate is directly related to amount and rate of retranslocation [40]. However, it is clear that P and K are more efficient in the stands. Therefore P and K limitation to primary production appears to be worth examining. Naturally the nutrient cycling in the forest is inadequate that reduces the growth of the plants mainly at Protected Forest of Birbhum (PFB). Thus proper management of the forest is essential for the persistence of plant species and conservation of biodiversity in the area.

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Table 1-Mean nutrient concentrations with SD in green leaves of four species for Matha Protected Forest (MPF) and Protected Forest of Birbhum (PFB) in 3 year period from March 2007 to February 2010

	Nutrients in green leaves at MPF and PFB										
	Mean concentration of *Shorea robusta*			Mean concentration of *Buchanania latifolia*			Mean concentration of *Lagerstroemia parviflora*		Mean concentration of *Madhuca longifolia*		
	MPF	PFB	t-test	MPF	PFB	t-test	MPF	PFB	MPF	PFB	t-test
N (%)	1.330 (0.088)	0.749 (0.093)	*	0.978 (0.024)	0.881 (0.037)	*	0.953 (0.004)	nf	nf	0.960 (0.001)	*
P (mg kg-1)	254.382 (2.244)	154.264 (3.634)	**	295.438 (5.647)	204.587 (7.543)	**	294.267 (2.445)	nf	nf	266.094 (13.005)	*
K (mg kg-1)	242.066 (1.006)	204.622 (9.282)	*	183.971 (1.167)	170.612 (2.701)	*	191.514 (1.233)	nf	nf	187.711 (1.232)	*

*Level of significance: *, p value < 0.001; **, p value < 0.0001*

nf- not found as predominant tree species at the respective forest area; MPF- Matha Protected Forest; PFB- Protected Forest of Birbhum

Table 2- Mean nutrient concentrations with SD in leaf litters of four species for Matha Protected Forest (MPF) and Protected Forest of Birbhum (PFB) in 3 year period from March 2007 to February 2010.

	Nutrients in leaf litter at MPF and PFB										
	Mean concentration of *Shorea robusta*			Mean concentration of *Buchanania latifolia*			Mean concentration of *Lagerstroemia parviflora*		Mean concentration of *Madhuca longifolia*		
	MPF	PFB	t-test	MPF	PFB	t-test	MPF	PFB	MPF	PFB	t-test
N (%)	0.929 (0.010)	0.585 (0.093)	**	0.500 (0.028)	0.465 (0.006)	*	0.796 (0.013)	nf	nf	0.832 (0.009)	**
P (mg kg^{-1})	108.690 (1.786)	127.348 (4.172)	**	265.183 (2.179)	186.823 (10.263)	***	266.148 (2.602)	nf	nf	256.138 (3.755)	**
K (mg kg^{-1})	232.561 (1.501)	185.695 (6.606)	***	165.868 (1.272)	161.051 (0.586)	**	175.340 (0.416)	nf	nf	177.025 (0.919)	**

*Level of significance: *, p value < 0.01; **, p value < 0.001; ***, p value < 0.0001*

nf- not found as predominant tree species at the respective forest area; MPF- Matha Protected Forest; PFB- Protected Forest of Birbhum