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Research Paper

Major Nutrient Biogeochemical Dynamics of Two Plant Species at Tropical Dry Deciduous Forest of West Bengal, INDIA

Biswas Saroni *, Khan Dilip Kumar
Department of Environmental Science, University of Kalyani, Kalyani, West Bengal, INDIA

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Abstract *- The study was carried out in a tropical dry deciduous forest known as Matha Protected Forest (MPF) of Purulia district, West Bengal, India which is fragmented into two parts namely Plot A and Plot B. The forest area is covered mainly with sal (Shorea robusta) as a dominant tree species along with the predominating tree species of piyal (Buchanania latifolia). From the analysis of major nutrients in the plots as well as the nutrient concentration in green leaves and leaf litter of both plant species, it is revealed that P use efficiency is enhanced than N and K for Shorea robusta while K use efficiency is higher followed by P and N for Buchanania latifolia. 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 fragmented Plot B.*

Key words: Biomass; leaf analysis; litterfall; nutrient cycling; tropical dry deciduous forest etc.

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]. Decomposition of litters which produces organic matter is an important factor for soil formation as well as nutrient cycling processes [2]. 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 [3, 4]. However, the index of nutrient use efficiency in litterfall can be used as an indicator of soil nutrient conditions [5]. 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 [6]. The rate of forest litterfall and its gradual decay regulate energy flow, primary productivity and nutrient cycling in forest ecosystems [7] 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 [8].

Ecosystem functions are constrained by low rates of nutrient supply in most of the tropical forests [9, 10]. 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 [11]. Thus nutrient cycling in tropical dry forests receive less scientific attention compared to the humid counterpart [12]. Although there have been several studies on litter dynamics in tropical forest ecosystems in India [13-18]. But very limited information is available for dry deciduous forest. So a study is undertaken on nutrient dynamics in dry deciduous forest of Purulia district, West Bengal. The aim of this study is to assess the potentiality of the habitat as a basis for determining appropriate forest management strategies.

Material and Methods

Study area

The actual global 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. MPF has two fragmented parts- A and B. The area is characterized by undulating topography with highest peak of 665m in Plot A having better vegetative cover while Plot B is smaller with poor vegetative cover. Slope, relative relief, drainage density and road density ranges between <2˚ - >9˚, 6.67 - 184.50m, 0.34 - 1.91km/km^2 and 0.45 – 1.45km/km^2 respectively. The climate is 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 while the highest rainfall (1173 mm) and lowest rainfall (767 mm) were recorded in the year 2000 and 1980 respectively. The south-west monsoon is the source of rainfall in Purulia. 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)* as a dominant species along with piyal (*Buchanania latifolia*).

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 [19].

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

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 [20], 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* and *Buchanania latifolia* 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 [21]. 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 [22], 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 [23].

Computation and statistics

The percent nutrient retranslocation efficiency (NRE) was calculated by the following equation [24]:

$NRE \% = \{(A – B) / A\} \times 100$

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

Nutrient use efficiency (NUE) was calculated by the following equation [25]:

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 Matha Protected Forest of Purulia is a gregarious type of forest where sal (*Shorea robusta*) is the dominant plant species with piyal (*Buchanania latifolia*) as next important species found at two different plots (A and B) of the forest. Basically, the soil is acidic to neutral in nature which is the characteristic feature of lateritic soil. Nutrient characters of soil at two plots are given in table 1. Soil organic carbon (SOC) [0.664 (0.037)] is higher at plot B compared to plot A [0.630 (0.006)]. N% at A and B is 0.023 (0.005) and 0.017 (0.002) respectively. C/N ratio is found to be 27 (in A) and 39 (in B) 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 ($p < 0.001$). From table 1 it is found that SOC is negatively correlated with N as organic carbon is more than the available N. The process 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 [26].

Nutrient characteristics of leaf

Litter fall biomass of sal is highest about 1273 g m^{-2} $year^{-1}$ (average of two plots where plot A litterfall biomass is 1329 g m^{-2} $year^{-1}$ and plot B is 1218 g m^{-2} $year^{-1}$), whereas it is 850 g m^{-2} $year^{-1}$ for piyal (average of two plots where plot A litterfall biomass is 874 g m^{-2} $year^{-1}$ and plot B is 826 g m^{-2} $year^{-1}$). There is a good correlation between the DBH (diameter at breast height) and above ground biomass (AGB) of both the species in the study area. The range of DBH (cm) in the forest is 9.384 – 11.942 and 10.023 – 11.212 for *Shorea robusta and Buchanania latifolia* respectively. Similarly, the extent of AGB (kg/tree) is 31.987 – 43.209 and 28.540 – 37.018 respectively. Nutrient quality of green leaf is given in table 2. N% in *Shorea robusta* is maximum followed by *Buchanania latifolia* (Figure 1). But P concentration of *Buchanania latifolia* is significantly higher than *Shorea robusta* whereas for K concentration, it is more for *Shorea robusta* than *Buchanania latifolia* (Figure 2, 3). But N and P concentrations of leaves are significantly higher in plot B than plot A. whereas, in case of K concentration, it is higher at plot A than at plot B. 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 regional features 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 [27]. The total nutrient characteristic of the litterfall is summarized in the table 2. For

Shorea robusta N (%) in litterfall has recorded the highest value followed by *Buchanania latifolia* (Figure 1). For P, the pattern of concentration in two plant species is *Buchanania latifolia*> *Shorea robusta* (Figure 2). But for K concentration in leaf litter, the pattern is different from that of P (Figure 3).

Nutrient use efficiency

The ability 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 [25]. In our study, the litterfall nutrient concentration is less than green leaf, therefore, NUE is increased. Nutrient use efficiency of dry deciduous forest of MPF is given in table 3. In our experiment, P use efficiency is enhanced than N and K for *Shorea robusta* in both plots (A and B) while K use efficiency is increased followed by P and N for *Buchanania latifolia* in both plot A and B. The forest stand has higher within stand efficiency of P and K at plot B than A (table 3) which is related to lower availability of P and K at plot B. This can be inferred that NUE in litterfall can be used as an indicator of soil nutrient availability [25, 28]. But P and K use efficiency is higher in comparison to evergreen broad-leaved forest [5] and tropical rain forest [25]. N use efficiency of plot A is greater than plot B but P and K use efficiency is high at plot B. Likewise, P use efficiency of *Shorea robusta* is greater than *Buchanania latifolia* but N and K use efficiency of *Shorea robusta* is lower than *Buchanania latifolia.*

Nutrient dynamics and retranslocation

Nutrient concentrations of leaf litter are significantly decreased than green leaf (Table 2) throughout the forest and thus the nutrient retranslocation efficiency is high which suggests nutrient limitation. The indices for retranslocation of nutrients in both the plots are given in Table 3. 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 52 (*Shorea robusta*) and 67 (*Buchanania latifolia*) in plot A while it is 70 (*Shorea robusta*) and 71 (*Buchanania latifolia*) at plot B. But among the two plots, A shows decreased NRE than B, signifying improper nutrient transfer when nutrient concentration of soil, green leaves and leaf litters are considered.

The extent of retranslocation efficiency of N from the leaves in the present study is 40-48% in *Buchanania latifolia* whereas it is significantly higher (about 26-53%) in *Shorea robusta*. Correspondingly, the extent of retranslocation efficiency of P is quite similar for both the species (11-23% in *Shorea robusta* and 12-23% in *Buchanania latifolia*). K retranslocation efficiency is 3-6% in *Shorea robusta* that is considerably lower than *Buchanania latifolia* of about 4-11% (Table 3). The values are quite different than those reported for subtropical evergreen forest [29]. Above all, we find between-species nutrient difference as well as site-dependent differences of nutrients at both plots of the forest.

Conclusion

Matha Protected Forest being dry and a nutrient-poor ecosystem, the amount of nutrient retranslocation is low that certainly retards the growth rate of plants. Nutrient uptake and growth rate is directly related to amount and rate of retranslocation [30]. However, it is clear that P and K is 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 fragmented plot B. Thus proper management of the forest is required for the survival of plant species and maintenance of biodiversity in the area.

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Table 1: Site characteristics and soil properties at Matha Protected Forest (MPF)

Site characteristics	**Plot A**	**Plot B**	t-test
Altitude (m)	278	665	
Soil type	Red soil	Red soil	
Surface mineral soil properties (10-15 cm)	Mean (SD)*	Mean (SD)*	
Organic Carbon (%)	0.630 (0.006)	0.664 (0.037)	*
Nitrogen (%)	0.023 (0.005)	0.017 (0.002)	*
Available P (mg kg^{-1})	14.992 (0.385)	14.261 (0.563)	*
Exchangeable K (mg kg^{-1})	65.008 (0.387)	64.286 (0.608)	*
Levels of significance: *, $p < 0.001$, ($n = 15$) n is number of samples collected from each plot			

* Standard deviation

Table 2: Mean nutrient concentrations with SD in green leaves and leaf litter of two species for Matha Protected Forest (MPF) in 3 year period from March 2007 to February 2010.

	Nutrients in green leaves						**Nutrients in leaf litter**					
	Mean concentration of *Shorea robusta*			**Mean concentration of *Buchanania latifolia***			**Mean concentration of *Shorea robusta***			**Mean concentration of *Buchanania latifolia***		
	Plot A	**Plot B**	**t-test**	**Plot A**	**Plot B**	**t-test**	**Plot A**	**Plot B**	**t-test**	**Plot A**	Plot B	t-test
N (%)	1.317 (0.050)	1.445 (0.009)	**	0.978 (0.063)	0.980 (0.017)	ns	0.979 (0.047)	0.873 (0.081)	*	0.462 (0.006)	0.507 (0.015)	*
P (mg kg^{-1})	251.28 (1.413)	257.612 (1.662)	**	300.004 (1.393)	298.584 (1.118)	*	193.177 (10.569)	198.330 (1.180)	ns	266.698 (0.715)	263.506 (1.493)	**
K (mg kg^{-1})	236.642 (1.176)	244.164 (2.489)	**	188.526 (1.696)	179.374 (1.338)	**	230.128 (1.659)	234.834 (0.570)	*	176.632 (4.638)	159.128 (4.914)	*
Level of significance: *, p value < 0.05; **, p value < 0.001; ns, non-significance							Level of significance: *, $p < 0.001$; **, $p < 0.01$; ns, non-significance					

Table 3: Major Nutrient Use Efficiency (NUE) and Nutrient Retranslocation Efficiency (NRE) of two different species at two plots

Nutrients	***Shorea robusta***				***Buhanania latifolia***			
	Plot A		**Plot B**		**Plot A**		**Plot B**	
	NUE (g g^{-1})	NRE (%)	NUE (g g^{-1})	NRE (%)	NUE (g g^{-1})	NRE (%)	NUE (g g^{-1})	NRE (%)
N	102	26	114	53	216	40	197	48
P	5191	23	5054	11	3735	23	4236	12
K	4357	3	4259	6	5675	4	6305	11

NUE- Nutrient Use Efficiency; NRE- Nutrient Retranslocation Efficiency

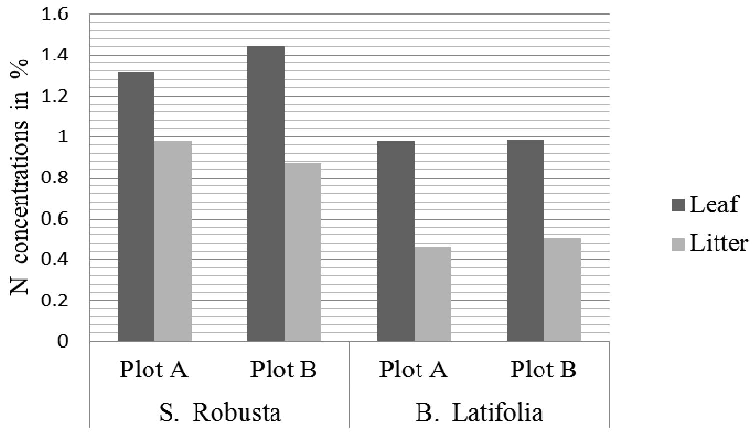

Figure 1: N concentrations in green leaves and leaf litter of two species at two plots of Matha Protected Forest (MPF)

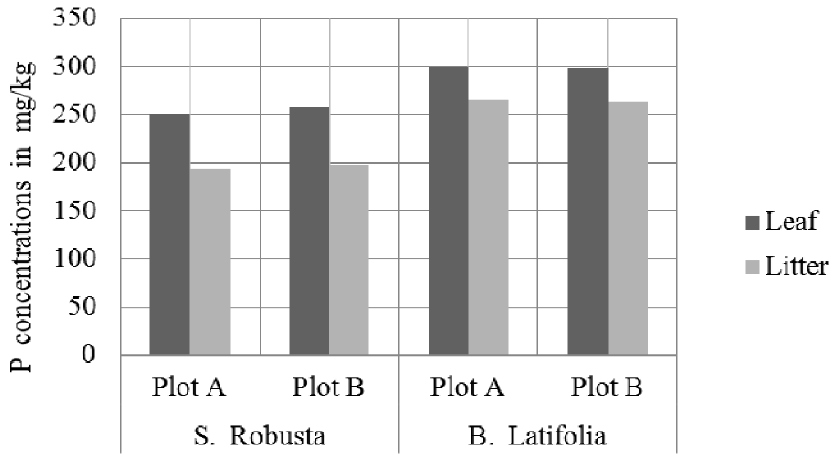

Figure 2: P concentrations in green leaves and leaf litter of two species at two plots of Matha Protected Forest (MPF)

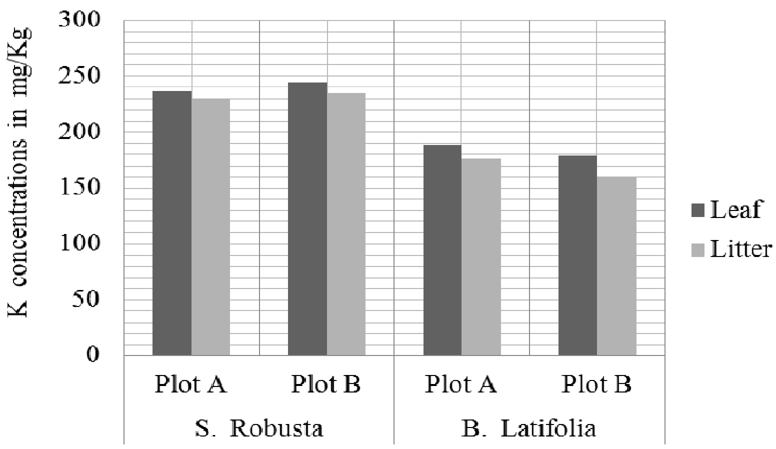

Figure 3: K concentrations in green leaves and leaf litter of two species at two plots of Matha Protected Forest (MPF)