# THE ROLE OF LITTER AND FINE ROOTS IN ORGANIC MATTER AND NUTRIENT DYNAMICS DURING THE RECOVERY OF DEGRADED SUBTROPICAL FOREST ECOSYSTEMS

Abstract

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Thesis Submitted in Fulfilment of the Degree of
**DOCTOR OF PHILOSOPHY IN BOTANY**

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The humid subtropical broadleaved forests of Meghalaya are exposed to various kinds of anthropogenic disturbances of varying magnitude caused by shifting agriculture and massive tree felling for developmental and fuelwood purposes. The disturbed forests are often left for natural recovery of vegetation and soil fertility. The main objective of the present study was to study the relative importance of litter and fine roots in organic matter and N and P dynamics in soil during recovery of degraded humid subtropical forest ecosystem in Meghalaya. Besides emphasising the role of litter and fine roots, changes in soil and vegetation characteristics and microclimatic conditions were also investigated. The study was conducted during 1993-94 in 7-, 13- and 16-year old stands, regrowing after selective tree cutting in a subtropical humid forest ecosystem located near Shillong (latitude 25˚34'N, longitude 91˚56'E, altitude 1900 m asl), the capital of Meghalaya, India.

## VEGETATIONAL CHANGES

The 7-year old regrowth was dominated by early successional species like *Eupatorium adenophorum, Litsea elongata, Pinus kesiya* and sprouting stumps of *Quercus dealbata, Corylopsis himlalayana* and *Schima khasiana*. The 13-year old regrowth having thin ground vegetation was dominated by *Q. dealbata* and *C. kurzii*. *Rhododendron arboreum* and *Q. dealbata* were dominant in the 16-year old regrowth. In this stand the forest floor had a dense growth of shade-tolerant herbs, pteridophytes and mosses.

The number of species in the community sharply declined from 41 in the 7-year old stand to 25 in the 16-year old regrowth. But the number of tree species as well as its species richness index markedly increased during the same period. The species richness index of shrub and herb species, however gradually declined with the regrowth of the forest.

Density and basal area of trees increased significantly from 180 plants $ha^{-1}$ and 3.1 $m^2$ $ha^{-1}$ in the 7-year old regrowth to 1140 plants $ha^{-1}$ and 44.2 $m^2$ $ha^{-1}$, respectively in the 16-year old regrowth. The shrub density was lowest in the 16-year old regrowth and highest in the 13-year old regrowth. Density and basal area of herbaceous species were maximum in the 7-year old stand and minimum in the 13-year old stand. Dominance in the 16-year old community was more evenly distributed than in the 7- and 13-year old regrowths. In all regrowths, tree density and diameter showed an overall straight-line negative relationship.

Broadleaved tree species regenerated mainly through sprouts, while the needleleaved *P. kesiya* reproduced through seeds. Sprouting stumps constituted 43, 75 and 87% of the total stump density in 7-, 13- and 16-year old regrowths, respectively. As a result, density increased from 220 $ha^{-1}$ in the 7-year old regrowth to 1350 $ha^{-1}$ in the 16-year old regrowth. The sprout growth in terms of number and basal area was relatively faster between 7- and 13-year old regrowth than between 13- and 16-year old stands.

MICROENVIRONMENTAL AND EDAPHIC CHANGES

Light intensity and air temperature near the ground showed a significant decline from 7- to 16-year old stand. Relative humidity, however, showed a reverse trend. Soil moisture content increased with increasing stand age, while soil temperature showed a reverse trend. Generally, the temperature and moisture content in the surface soil layer (0-10 cm) were higher during rainy and autumn seasons, but subsurface layers (10-20 and 20-30 cm) had greater soil moisture content during winter and spring seasons. Both WHC and CEC declined with soil depth, but increased with stand age.

Soil texture varied from sandy loam in the 7-year old regrowth to sandy clay loam in the 13-year old regrowth and clay loam in the 16-year old regrowth. Soil pH fluctuated within a narrow range of 4.9-5.6 without showing significant seasonal and depthwise variations. SOC and SOM were significantly lower during rainy season and higher during autumn in all three forest regrowths. Both of them decreased with the increase in soil depth. Seasonal trends of TKN and available-P were similar to SOC. In general, SOC, SOM, TKN, available-P increased with the progressive development of vegetation.

ROLE OF LITTER

Litter accumulation on the forest floor increased significantly from 1231 kg $ha^{-1}$ in the 7-year old regrowth to 2007 kg $ha^{-1}$ in the 13-year old regrowth, and then it became levelled-off. Leaf litter mass on the forest floor increased with the progression of vegetation recovery. Accumulation of woody litter (<20 mm diameter) was more in the 13-year old regrowth compared to the 7- and 16-year old regrowths. In all stands, litter accumulation was maximum during winter or spring and minimum during autumn.

Litterfall increased significantly from 11902 kg $ha^{-1}$ in the 7-year old regrowth to 17402 kg $ha^{-1}$ in the 16-year old regrowth. The contribution of leaf litter to the total litter production in the three stands ranged between 78 and 88%. Production and accumulation of litter were positively correlated with density and basal area of woody species, and OM, TKN and available-P in soil. In all regrowths, turnover rate of the leaf litter was faster than the woody and miscellaneous litter.

N concentration in the forest-floor litter was maximum either during autumn or winter, and minimum during spring in all three regrowths. While its concentration in the fresh litter was higher during autumn and lower during rainy season. Seasonal variation in P concentration both in forest-floor litter and fresh litter was not significant. Leaf and miscellaneous litter had higher N and P concentrations than the woody litter.

Mean standing state of N and P in the forest-floor litter was maximum in the 13-year old regrowth and minimum in the 7-year old regrowth. Generally, leaf litter accumulated more N and P than the woody and miscellaneous litter fractions. Seasonal variation was significant only for N. Addition of N and P to the forest floor through litter in the three regrowths exhibited a marked seasonality with highest inputs during February-April and lowest during June-September. Leaf litter contributed to about 80-99% N and 70-80% P annual nutrients input thorugh litter. N input through litter was maximum in 13- and 16-year old regrowths, and minimum in the 7-year old regrowth, while P input increased from young to old stand.

Decay pattern of leaf litter varied significantly between species and stands. Needles of *P. kesiya* decomposed in a three-phased manner, whereas, all broadleaved tree species except, *R. arboreum* showed only two phases. Leaves of *R. arboreum* decomposed at a constant rate throughout the study period. A composite linear decay model ($Y=a+bX_1+cX_2+dX_3$), fitted well for the decay pattern of *P. kesiya*, while a simple linear regression function, $Y=a+bX$ explained the weight loss pattern of *R. arboreum* leaf litter during decomposition. For other species, a multiple regression equation, $Y=a+bX_1+cX_2$ was more appropriate.

Decompositon of leaf litter (weight loss, mg day$^{-1}$) was significantly correlated with initial lignin and N concentrations and lignin/N ratio of the litter, soil moisture, pH and TKN, and mean daily rainfall and mean monthly air temperature. N and P mineralization patterns during decomposition of leaf litter were similar in all five tree species studied. All of them were characterized by a phase of active N mineralization during rainy season followed by a period of microbial immobilization during winter.

ROLE OF FINE ROOTS

Fine root mass (FRM, <2 mm diameter) increased significantly from 6751 kg $ha^{-1}$ in the 7-year old regrowth to 9088 kg $ha^{-1}$ in the 16-year old regrowth. Coarse root mass (CRM, 2-15 mm diameter) as well as total root mass (TRM=FRM+CRM) increased significantly from the 7-year old regrowth to the 13-year old regrowth, beyond this age the increase was not significant. The proportion of FRM decreased from 87% in the 7-year old regrowth to 77% in the 16-year old regrowth. The contribution of coarse roots followed a reverse trend. As a result, FRM/CRM ratio was significantly higher in the 7-year old regrowth than the 13- and 16-year old regrowths. In all three forest regrowths, the ratio was generally higher during winter and lower during rainy season.

Fine roots were concentrated (upto 65% of the TRM) mainly in the top soil layer (0-10 cm) in all three stands, and their proportion declined upto 19% in the 10-20 cm layer and further down (20-30 cm depth) to 15%. The amount of fine roots in the top soil layer increased with the increase in the age of the stand, but their proportion declined from 63% in the 7-year old regrowth to 57% in the 16-year old regrowth.

Annual fine root production increased upto 13 years of forest regrowth, after this age, the production declined by *ca.* 10% during next 3 years of regrowth. The contribution of fine roots to total root production decreased significantly from 88% in the 7-year old regrowth to 50% in the 16-year old regrowth.

Fine root productivity (kg $m^2$ $day^{-1}$) was positively correlated with mean monthly rainfall and maximum and minimum temperatures, SOM, TKN and available-P. Apart from these edapho-climatic factors, density and basal area of the woody species in the community also influenced the production and accumulation of fine roots. Turnover rate of fine roots did not vary significantly between regrowths and soil depths.

Fine roots had greater N and P concentrations than the coarse roots. Similarly live fraction of the fine roots had greater nutrients concentration than the necromass.

In all three regrowths, N accumulation in fine roots was maximum either during autumn or winter, and minimum during rainy season. On the other hand, maximum N stock in coarse roots was obtained during rainy or post-rainy seasons, and minimum during spring. N stock in fine roots was significantly ($P<0.05$) higher in the surface soil layer than the subsurface layers. Seasonal trend of P accumulation in fine and coarse roots was similar to N, but its stock was inversely related to soil depth.

Maximum amount of N (189 kg $ha^{-1}$ $yr^{-1}$) was returned to the soil through fine roots in the 13-year old regrowth and the input was minimum (158 kg $ha^{-1}$ $yr^{-1}$) in the 7-year old regrowth. P input through fine roots was also maximum (12 kg $ha^{-1}$ $yr^{-1}$) in the 13-year old regrowth, but its minimum value (9 kg $ha^{-1}$ $yr^{-1}$) was recorded in the 16-year old regrowth.

Fine roots decomposed in a three-phased manner. The decay rate was positively correlated with mean daily rainfall, soil moisture and pH, and negatively correlated with initial lignin concentration. The decay constant ($k$=1.62-1.74) increased with the age of the regrowth.

Release of nutrients from decaying fine roots was also influenced by seasonal cycle of mineralization and immobilization processes. Winter represented the period of N and P immobilization, while rainy season was the period of rapid mineralization when N and P contents in the decomposing fine roots recorded 46-58% decrease from the preceding spring season. The net annual N mineralization showed a marginal decrease from about 51% in the 7-year old regrowth to 46% in the 16-year old regrowth, while P showed a reverse trend by registering an increase from 37 to 51%, thereby contributing to its greater availability in the soil supporting the older regrowth.

## CONCLUSION

The three forest regrowths differed markedly in community structure, soil physico-chemical properties and detritus (litter and fine roots) input, accumulation and turnover, despite the fact that all of them are located on a similar toposequence and have developed under similar climatic conditions. Recovery in soil fertility in the disturbed stands was closely related to the regrowth of woody vegetation, since production and accumulation of litter and fine roots were significantly correlated to the density of woody elements in the community. Litter production increased during vegetation regrowth until 16 years, but the fine root production showed a steady increase upto 13 years of forest regrowth, beyond this it levelled-off. Similar trend was observed in case of litter and fine root accumulation also. Accumulation of litter and fine roots were related to each other, but the latter added more organic matter, N and P to the soil thereby playing a more important role than the former in nutrient restoration in soil during the recovery of disturbed subtropical forest ecosystem.

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