Summary

Traditional agroforestry and related indigenous knowledge system of different ethnic communities of northeast India provide ample opportunities for agricultural diversification as well as escalation while simultaneously ensuring a large degree of endogeneity. The intimate mix of diversified agricultural crops and multipurpose tree species fulfils most of the basic needs of the local inhabitants while the multi-storied configuration and high species diversity of the agroforestry system helps to reduce the environmental hazards that is commonly associated with monoculture production system. It is now increasingly felt that major impetus has to be exercised to make this traditional system a more sustainable, conducive and pragmatic. An understanding of indigenous practices, therefore, offers excellent opportunities for finding solutions to the problems of self reliance in agricultural development of the region. Reportedly, soil or the edaphic factors, particularly the soil nutrients determine the aboveground production and yield. Thus, the traditional agroforests can not be an exception and the litter, as in case of agroforest would play a significant role in soil nutrient cycling, particularly in the top soil. In this study, an attempt has been made to understand the dynamics of the plant detritus (above and below-ground litter) in traditional agroforestry systems practiced by two different ethnic groups and also to evaluate their contribution to soil organic matter and nutrient budget for sustainable plant production.

Species diversity

Different plant species grown in multistoried traditional agroforestry systems are confounded by the livelihood requirements and traditional knowledge. The stratification was however based on light requirements of selected plant species. The total number of trees, shrubs and herbs species recorded was 35, 20 and 30 respectively in traditional agroforestry managed by two different ethnic communities, the ‘Nyishis’ and the ‘Kalitas’. Botanically, the genus to species ratio remained 1:1 throughout the study.
Vegetation analysis revealed that areca-nut palm was dominant in the agroforests of Kalita dominated Harmutty site, whereas *Livistona jenkensiana* was dominant in Nyishi dominated Doimukh and Nirjuli sites. The Nyishis practice agri-horti-silvicultural and horti-silvi-pastoral system and the Kalitas practice agri-horti-silvi-piscicultural systems respectively. Overall, the plants have been distributed contagiously (83.19%). Shannon’s diversity index varied between 1.02 and 1.22 for tree species and between 0.44 and 0.48 for the herbaceous species. Nonetheless, the variation in species composition and diversity and the economic returns are linked to the traditional beliefs and the day-to-day requirements of the people of these communities.

**Physico-chemical properties of soil**

Soil was loamy and acidic. Water holding capacity (WHC) of the topsoil (0-10 cm) layer was always greater as compared to other depths in all the sites; WHC was highest in Harmutty, followed by Doimukh and Nirjuli. Exceptionally, soil moisture content (SMC) was greater during rainy season and low during winter in all the sites.

Total N, NH$_4$-N, NO$_3$-N, total P and other organic compounds were not showing any trend of increase or decrease across depths. But in general, the middle (10-20 cm) soil layer contained more nutrients than the top (0-10 cm) and deeper (20-30 cm) layer in all the sites which is due to the infiltration and percolation of water along the soil profile that causes a vertical leaching of available nutrients. The soils in the agroforestry system of Harmutty (practiced by Kalitas) had more available nutrients, as the farmers alternate crops in every season and prefer N$_2$-fixing plants in their system. The burning of plant detritus may have increased soil organic C in the traditional agroforestry system in Doimukh, however soil available nutrients and total N were low mainly due to a poor management practices such as frequent cutting and burning, grazing by animals, etc.

**Litter dynamics**

The litterfall pattern in traditional agroforestry systems varied across seasons and sites. Leaf fall contributed more towards litterfall than other parts of litter. A total of 29 species
belonging to 26 plant families contributed more than 1 g litter month$^{-1}$. The variety of species and their different components of litter and anthropogenic effect played a greater role in litter biomass production in agroforestry systems of Kalita and Nyishi communities. Two peaks of litterfall in each year were observed: the main one in the late dry season (February-March) and a lesser one during post-monsoon (October-November). For instance, litterfall was highest during spring (29.14%), followed by autumn (29.05%), winter (22.95%) and rainy (18.86%) in all the traditional agroforestry systems.

The estimated standing crop of litter in the agroforest floor was greatest in the dry season (February-March), and least in the wet season (September). The relative contribution of partially and more decomposed litter to the total agroforestry floor litter was less than that of fresh litterfall all the year round. Turnover rates and turnover time for the various components of litter indicated leaves to decompose faster as compared to twigs and miscellaneous fractions.

Although there were no significant differences between mean seasonal nutrients concentrations in leaf, miscellaneous and woody litter parts, concentration of all elements in different litter parts were greater in dry season than in wet season. N concentration varied significantly between sites and seasons in traditional agroforestry systems, whereas P concentration in the fresh litter were not significantly different between leaf, woody and miscellaneous litter fractions in all the three agroforestry systems. Eventually, N return to the agroforestry floor through litterfall followed a marked seasonal pattern and maximum input was recorded in Harmutty site, whereas the lowest N input through litterfall was in Nirjuli site. P input through litter attained its peak during spring in all the three sites. Leaf litter contributed 50% of the total P added to the agroforest floor. The nutrient turnover rates did not show any seasonal trends in these three traditional agroforestry stands.

Decomposition study of the selected leaf litter samples recorded that the decay rate was highest in *Colocasia esculenta* ($k = 8.61$), followed by *Bauhinia variegata* ($k = 8.38$), whereas lowest decay rate was in *Livistona jenkensiana* ($k = 0.68$) followed by
*Areca catechu* (*k* = 2.58). The lignocellulose index during the decay phase showed significant (+) ve correlation in all the species except *Colocasia esculenta* and *Musa* sp. This indicated that in these two species lignin did not play a significant role in litter decomposition and implies that there might have some other factors (like C/N ratio) controlled their decomposition. Overall, the study exemplifies weight loss with field incubation time and also that the seasonal factor do play vital role in decomposition. Among the dominant agroforestry species, the leaf litter of *Ageratum conyzoides, Bauhinia variegata, Colocasia esculenta, Erythrina indica, Zingiber officinale* can be considered to have good resource quality due to their rapid decomposition rate confounded by low C/N and lignin contents.

**Root dynamics**

Root mass showed a pronounced seasonal pattern with unimodal peaks obtained during September *i.e.*, after the heavy rainy season. The minimum root biomass was, however, obtained during winter in all sites. Fine root biomass was significantly higher than the fine root necromass in all the study sites. Different root size classes contributed different proportion of nutrients in the system. Thus, the diameter class can be used to define the role of roots in traditional agroforestry systems. In Harmutty site, the fine roots of 1-2mm size showed maximum production rate, whereas in Nirjuli and Doimukh sites coarse roots (> 2 mm diameter) had maximum biomass production. Production of coarse roots was maximum during rainy season and minimum during autumn in the traditional agroforestry system. The decrease in fine roots with increasing soil depth was significant (*F*=257.48, *P*<0.01) in all the three agroforestry systems. There was no any significant relation between root turnover rate and different soil depths in the agroforestry systems.

Fine roots (<2 mm diameter) generally contained higher nutrient concentration than the coarse roots (>2 mm diameter). The very fine roots (< 1 mm) had significantly greater N concentration than the 1-2 mm fine roots. Biomass and necromass of the fine roots did not show marked seasonality in P concentration. The P accumulation was more
during winter than the three other seasons studied. The live roots accumulated greater P than the dead fraction. P accumulation however decreased with increasing depth.

Decomposition study of the selected root samples recorded that the decay rate was maximum in *Erythrina indica* (7.72) and *Ageratum* sp (7.67), and minimum in *Bambusa* (3.19) and *Areca catechu* (1.89). Rapid rate of decay in all the agroforestry systems coincides with the rainy season. Most of the species showed three phase decay model. Similar to the weight loss pattern, N and P were mineralized in three distinct phases. An initial decline in N and P concentrations marked a phase of nutrient release. This was followed by a phase of nutrient immobilization when a marginal increase in N and P concentration was recorded in the decaying roots. This was again followed by a phase of mineralization. Among the dominant agroforestry species, the roots of *Erythrina indica*, *Ageratum conyzoides*, *Musa* sp., *Bauhinia variegata* can be considered to have good resource quality due to their rapid decomposition rate confounded by low C/N and lignin contents.

**Relative importance of litter and fine roots in C and nutrient budget**

Contribution of coarse roots to soil C was much greater than the fine roots and above ground litter. On the other hand, fine roots contribute significantly to the soil N and P stock. While comparing litter and root samples, it is inferred that the leaf litter contribute significantly to soil C pool while the fine roots are important in N and P cycling.

**Conclusion**

The present study clearly revealed that the community structure, dynamics of litter and fine roots have been substantially altered by traditional management practices of different ethnic communities and their livelihood requirements.

Over all, litter and fine roots contribute significantly to soil organic matter and nutrient build-up in the traditional agroforestry systems. The fine roots played a vital role in N and P cycling than the litter through their rapid turnover in the traditional agroforestry system. While comparing the role of litter and roots in soil C, N and P stock,
it was observed that the trends for nutrient turnover being fine roots > litter>coarse roots. Thus fine roots could not only be a sensitive indicator of SOM and nutrient dynamics, but also can improve productivity if managed properly in synchronization with soil nutrient mineralization and uptake by plants in the traditional agroforestry systems that could result in fairly a high plant productivity. The species composition, detrital biomass and soil physico-chemical properties in the traditional agroforest of Harmutty village revealed its sustainability than the other sites. Further, the Kalitas preferred N₂-fixing plants in their agroforestry system that enriched the soil.

Nonetheless, the traditional practices of agroforestry would become more productive if designed and managed properly. Therefore, much work has to be conducted in this direction for improvement of these traditional agroforestry for sustainable production.