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Ecological analysis of traditional agroforest and tropical forest in the foothills of Indian eastern Himalaya: vegetation, soil and microbial biomass

S. DEB[1], A. R. BARBHUIYA, A. ARUNACHALAM[*] & K. ARUNACHALAM

Department of Forestry, North Eastern Regional Institute of Science and Technology, Nirjuli 791109, Arunachal Pradesh, India

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India has a total land area of 329 million ha, of which 43% is under cropping and 23% under forest (MOEn 1999). The National Forest Policy of India (1952) stipulated that country as a whole should aim at maintaining one-third of its total land area under forest for securing ecological stability. Northeast India harbors rich biological diversity and is rich in endemism. In the tropical forest lands, shifting cultivation or slash and burn agriculture is practiced widely that affects forest structure and species composition and subsequent abandonment results in the creation of a mosaic of forest patches of different ages (Ramakrisnan 1985). Further, logging, clear felling, grazing, fire and collection of fuel wood, fodder and non-timber forest products have also contributed significantly to forest degradation (Arunachalam *et al.* 2004). Thus most remaining forests are secondary, arising after significant disturbances through large scale and small scale extractive activities.

Rehabilitation of degraded forest and its sustainable management are urgent issues, and conserving biological diversity requires a far more understanding of both human and natural influences on forests and its vegetation *per se* (Arunachalam *et al.* 2002). The best approach to conserving forests and their biodiversity is through a variety of management approaches ranging from strict protection through intensive use, with a careful consideration of the cost and benefit. Different systems of management may enhance or reduce forest diversity. One of the adaptive strategies to reduce pressure on forest is permaculture (Mollison 1993), which is a sustainable design system stresses the harmonious relationship of humans, plants, animals and earth, as practiced in the western ghats, although agroforestry has been widely advocated in the Indian eastern Himalayan region.

The northeastern India harbours not only rich floristic diversity in the difficult terrain, but is also rich in ethnic diversity where the local people have tremendous traditional knowledge to use the natural resources. Basically, the indigenous communities are farm-based and they have customary laws that accommodate socio-cultural patterns, land tenure system and cultivation practices. The traditional agroforestry system is one of its kind managed by the local people that fulfill productivity, sustainability and adaptability criteria. Nonetheless, the adoption and relevance of tree farming practices varies by region and is

[*] *Corresponding Author*; e-mail: arunachalam_in@yahoo.com
[1]*Present Address*: Centre for Biodiversity, Rajiv Gandhi University, Itanagar 791112, Arunachal Pradesh, India

habitually driven by local tradition, economic factors, and land ownership patterns. In this region, a number of tree species viz. areca-nut, coconut, citrus, guava, jackfruit, etc. are generally grown with understorey crops such as vegetables (beans, cucumbers, squash, spices) and betel vine. However, the combination of trees and understorey crops vary from place to place and tribe to tribe due mainly to socio-cultural variations. In this paper, we have compared the structural and functional differences in the traditional agroforest with that of a tropical forest stand, and the quantified differences have been discussed for its significance to undertake agroforestry as an alternative to rehabilitate the abandoned shifting agricultural lands in the northeastern hills.

The study area is wet (1800 mm annual rainfall) and humid (70-80%). The sites are located at an altitude of 104-118 m asl, between 27°07′N longitude and 93°45′E latitude. Vegetation, soil and detrital parameters were studied following standard procedures (Anderson & Ingram 1993) in 3 replicated traditional agroforests (20 m x 20 m) in Harmutty, Assam and in 3 plots (50 m x 50 m) of a tropical forest of Banderdewa forest range, Arunachal Pradesh. Vegetational analysis was done during peak vegetative growth period in the monsoon (July-September 2005). Species diversity (Margalef 1968) was calculated as: $H' = -\sum \{(n_i/N) \log_e (n_i/N)\}$, where, H'=Shannon index of general diversity, n_i=IVI of a species, N= Total IVI of the community (i.e. 300).

Ten soil samples were collected from 0-15 cm soil depth during three seasons (summer, winter and rainy) from each of the traditional agroforests and the plots in the tropical forest stand and brought to the laboratory for detailed physico-chemical and microbiological analysis. After removing stones, pebbles and large pieces of plant material, the samples were sieved by 2 mm mesh screen and used for further analysis. Soil texture and water holding capacity were determined according to Anderson & Ingram (1993), while soil moisture content was measured gravimetrically by drying 10 g of field moist soil sample in a hot-air oven at 105°C for 24 h. Soil organic carbon (SOC) was determined by dichromate oxidation reduction method (Anderson & Ingram 1993). Total nitrogen was estimated following semi-micro Kjeldahl procedure by acid-digestion, distillation and titration. The pH of the soil sample was determined in a soil-water suspension (1:2.5 w/v H_2O) using a digital pH meter. Chloroform fumigation-extraction (CFE) method was used to estimate the microbial biomass C, N and P (Anderson & Ingram 1993).

Tree density in the tropical forest under study was 658 plants ha^{-1} (Table 1) which is well within the range (245-859 stems ha^{-1}) reported for tropical forests (Campbell *et al.* 1992). The traditional agroforest had greater woody plant density (1006 stem ha^{-1}) than the tropical forest due mainly to the presence of densely planted areca-nut palms and other small woody plants (*Citrus* sp., *Bauhinia variegata* Linn., *Averrhoea carambola* Linn., *Psidium guajava* Linn., etc.). However, species diversity of trees, shrubs and herbs in tropical forests was greater than in the agroforests. Tree density and diversity showed significant relationship in tropical forests and traditional agroforest systems. While comparing older agroforests to natural forest stands, Marjokopri & Ruokolainen (2003) observed similar proportions of species at different successional stages and thus, emphasized on the potential of agroforestry in conserving tree species. However, the stem basal area of humid tropical forest in Tamil Nadu ranged between 28.4-67.4 m^2 ha^{-1} for > 10 cm diameter (Sundarapandian 1997). While basal area of agroforest tree species (37.01 m^{2}ha^{-1}) was well within the above range, the tropical forest recorded a higher value (85.55 m^{2}ha^{-1}). Over all, the differences in density and basal area may be attributed to the composition, age structure, successional stage of the forest and the degree of disturbances (Sundarapandian 1997).

The litterfall in the traditional agroforest (1406 kg ha^{-1} yr^{-1}) was lower than that of tropical forest of this region (11504 kg ha^{-1} yr^{-1}) which was within the reported range (3400-15300 kg ha^{-1} yr^{-1}) for tropical forests globally (Proctor 1984). The fine root biomass in the tropical forest stand was 5294 kg ha^{-1}which is higher than the reported range (1790-3500 kg ha^{-1}) in the western ghats (Parthasarathy 1988). The traditional agroforest recorded a lower fine root mass (534 kg ha^{-1}). Incidentally, the central Amazonian rainforest had 12 times more root biomass (8430 kg ha^{-1}) than the present traditional agroforest. Elsewhere the fine root mass varied between 1 and 6.2 mg ha^{-1} in a number of agroforestry tree species (Tufekcioglu *et al.* 1999).

Table 1. Vegetation and belowground (0-15 cm) characteristics in traditional agroforest and tropical forest.

Properties	Parameters	Traditional agroforest	Tropical forest	% change	t-value
Vegetation					
Species richness (plants ha^{-1})	Trees	17 ±0.33	66 ±1.20	74	ns
	Shrubs	11 ±0.88	34 ± 0.88	68	18.44**
	Herbs	14 ±0.33	20 ±1.86	30	4.6*
Basal area (m^2 ha^{-1})	Trees	37.01 ±0.34	85.55 ±1.08	57	ns
	Shrubs	0.62 ±0.01	2.61 ±0.04	76	ns
	Herbs	0.19 ±0.01	0.27 ±0.02	30	4.67*
Density (plants ha^{-1})	Trees	1006 ±17.2	658 ±13.5	53	15.7**
	Shrubs	3442 ±24.9	7500 ±96.3	54	ns
	Herbs	4726 ±349	15,900 ±64.3	70	ns
Species diversity index (H')	Trees	1.13 ±0.02	1.39 ±0.01	19	15.12**
	Shrubs	1.02 ±0.02	1.06 ±0.01	4	ns
	Herbs	0.86 ±0.01	1.09 ±0.01	21	ns
Soil					
Physical	Texture	Loamy sand	Loamy sand		
	WHC (%)	44.4 ±1.57	56.0 ±2.60	21	ns
	Moisture (%)	22.3 ±0.87	30.1 ±1.91	26	13.7**
	Bulk density (g cm^{-3})	0.6 ±0.01	0.7 ±0.01	10	4.38*
Chemical	pH (1:2.5 w/v H_2O)	5.6 ±0.26	4.9 ±0.23	14	5.03*
	Organic C (%)	1.5 ±0.05	1.7 ±0.04	11	10.98**
	Total N (%)	0.7 ±0.04	0.7 ±0.03	02	ns
	Total P (%)	0.1 ±0.04	0.1 ±0.04	09	ns
	C/N	2.29	2.5	09	4.97*
	NH_4-N (µg g^{-1})	12.1 ±0.54	5.7 ±0.37	113	ns
	NO_3- N (µg g^{-1})	1.9 ±0.23	8.6 ±0.51	78	ns
	PO_4- P (µg g^{-1})	6.7 ±0.65	8.9 ±0.78	25	ns
Microbial	C	377.7 ±21.07	809.5 ± 75.26	53	ns
Biomass	N	17.1 ±2.17	74.2 ±8.57	77	ns
(µg g^{-1})	P	2.4 ±0.16	36.6 ±2.35	93	ns
Population	Fungi (x10^3)	25.5 ±1.02	29.5 ±1.16	14	5.14*
(colonies gm^{-1})	Bacteria (x10^5)	108.0 ± 7.46	112.6 ±9.20	4	4.65*
Plant detritus					
Litter production	Leaf	310.0 ±15.47	9830.7 ±137.56	97	ns
(kg $ha^{-1}yr^{-1}$)	Non leaf	312.9 ±16.89	1673.1 ±41.18	81	ns
Biomass	Leaf	903.7 ±31.07	11577.0 ±178	95	ns
(kg ha^{-1})	Non leaf	502.3 ±10.51	2873.7 ±83.54	92	ns
Root Production	Fine	937.4 ±32.19	1980.9 ±82.50	53	ns
(kg $ha^{-1}yr^{-1}$)	Coarse	261.2 ±11.84	1253.7 ±76.82	79	ns
Biomass	Fine	533.9 ±24.17	5293.7 ±148.00	90	ns
(kg ha^{-1})	Coarse	149.3 ±12.08	1370.1 ±81.34	89	ns

WHC= Water holding capacity; NH_4-N- Ammonium nitrogen, NO_3-N- Nitrate nitrogen; ± SE (n=3; * $p<0.05$; ** $p<0.01$; ns= not significant)

Agroforestry systems provide ways for simultaneously tackling soil constraints such as loss of soil organic matter, limited nutrient availability and water holding capacity (Sanchez & Alvarez-Sanchez 1995). Further, the agroforests utilize more N than natural forest. More efficient sharing of site resources between tree and pasture plants together with N_2-fixation by different selected tree and crop species and microclimatic modification by trees may increase the nutrient content of the study sites. The traditional agroforestry has high N concentration and low C/N ratio (2.3) due to the presence of more N_2-fixing plants and have both forest and crop N storage activities (Sharrow & Ismail 2004). The quantity, quality, timing and mode of addition of organic matter and good quality residue in different fallow systems would also strongly influence the decomposition process and their contribution to soil organic matter pools and nutrient availability (Arunachalam *et al*. 2004). In this context, the role of soil microbes have been advocated in various tropical ecosystems (Singh *et al*. 1989).

Soil microbial biomass C, N and P were greater in tropical forests than in man-made traditional agroforests (Table 1). This might well be due to more nutrient retention by soil microbes in the forest sites; in other words, nutrients are not actively utilized by the agroforestry systems that are relatively disturbed than the tropical forests. Microbial biomass P and N was more in the tropical forest by 93 and 76%, respectively, as compared to the traditional agroforestry system. The soil microbial biomass C and N in the agroforest and tropical forest were 378-809 $\mu g\ g^{-1}$ and 17-74 $\mu g\ g^{-1}$, respectively (Table 1). These values are comparable to microbial biomass C (60-2000 $\mu g\ g^{-1}$; Henrot & Robertson 1994; Singh *et al.* 1989) and N (9-239 $\mu g\ g^{-1}$; Vitousek & Matson 1988) contents of other tropical forests. These values clearly indicate that the role of soil microbial biomass in the soil organic matter and nutrient turnover in the agroforestry is equivalent to that in the tropical forests.

In general, the contribution of microbial biomass C, N and P to soil nutrient pool (Table 2) was greater in tropical forest than in the traditional agroforest. The contribution of microbial biomass C to soil organic C (2.54-4.84%) was within the reported range (1.5-5.3%) for tropical soils (Luizao *et al.* 1992). Nonetheless, microbial biomass P contributed more to the soil total P in the tropical system than the range reported for arable lands (1.4-3.5). Litter biomass contributed ca. 14% C to the tropical forest soil and 3% in the traditional agroforestry system. The contributions of C, N and P from litter and root biomass were also greater in tropical forest than in the traditional agroforestry system. Greater contributions from litter and root mass in the tropical forests are attributed to higher detrital biomass production in this system, and relatively greater microbial population (Table 1). It has also been established that soil microbial biomass C is positively correlated to soil organic matter ($r=0.92$; $p<0.05$). This further substantiates the abundance of microbial population, microbial biomass C, N and P in the tropical forest stand.

This study indicated that the areca-nut based traditional agroforests and the natural tropical rainforests have multi-layered vegetal structures with comparable tree density, but showed significant differences in soil nutrients and microbial biomass that recorded lower values in traditional agroforests as compared to the tropical forests. Nonetheless, the percentage contribution of soil microbial biomass, litter and fine roots to soil C was similar and competitive in traditional agroforests, but substantially lower than that in the tropical forests. Litter had a major role to play in soil nutrient turnover in tropical forests followed by soil microbes and fine roots. The

Table 2. Contribution (%) of different parameters to total soil C, N and P in the top soil (0-10 cm) in traditional agroforest and in tropical forest.

Contribution	Parameters	Traditional agroforest	Tropical forest	% change
Microbial biomass	C	2.54	4.84	51
	N	0.26	1.12	77
	P	0.22	4.09	95
Litter biomass	C	2.97	14.10	79
	N	0.23	2.92	92
	P	0.08	0.30	73
Root biomass	C	2.81	3.04	08
	N	0.24	0.90	73
	P	0.15	0.11	36

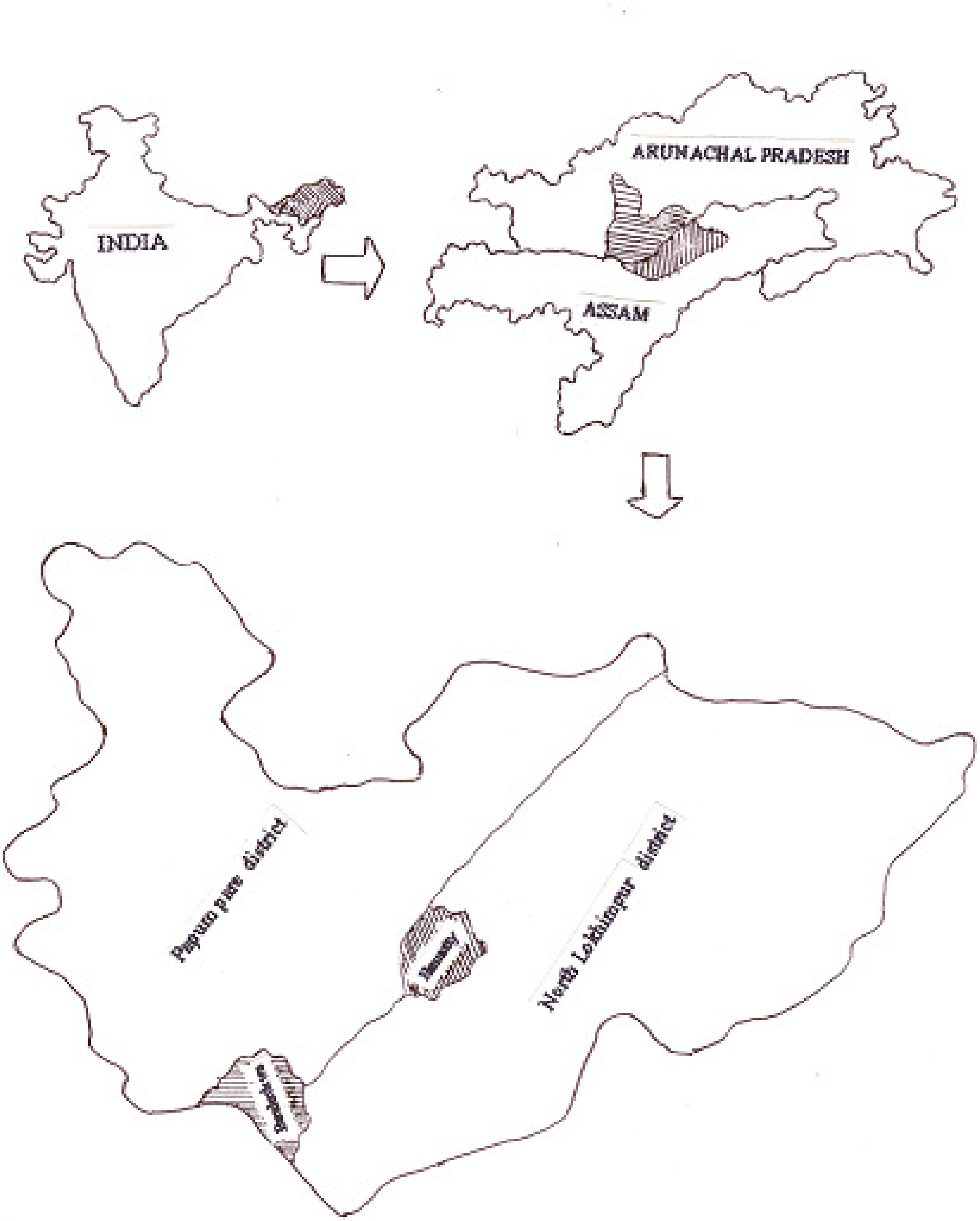

Fig 1. Study area (= North Lakhimpur District;   = Papumpare district).

traditional agroforesty systems studied are, however, not well-managed, but upon scientific management might prove to be a sustainable food production land use system in the hills and flood plains and thus could potentially promote conservation and sustainability of the tropical forests.

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References

Anderson, J. M. & J. S. I. Ingram. 1993. *Tropical Soil Biology and Fertility- A Handbook of Methods.* 2nd edn. CAB International, Wallingford, UK.

Arunachalam, A., M. L. Khan & K. Arunachalam. 2002. Balancing traditional jhum cultivation with modern agroforestry in eastern Himalaya- A biodiversity hotspot. *Current Science* **83**: 117-118.

Arunachalam, A., R. Sarmah, D. Adhikari, M. Majumder & M. L. Khan. 2004. Anthropogenic threats and biodiversity conservation in Namdapha nature reserve in the Indian eastern Himalayas. *Current Science* **87**: 447-454.

Campbell, D. G., J. L. Stone & A. Rosas. 1992. A comparison of the phytosociology and dynamics of three floodplain (varzea) forests of known ages, Rio Jurua, western Brazilian Amazon. *Botanical Journal of Linnaean Society* **108**: 213-237.

Henrot, J. & G. P. Robertson. 1994. Vegetation removal in two soils of the humid subtropics: Effects of microbial biomass. *Soil Biology and Biochemistry* **26**: 111-116.

Luizao, R. C. C., T. A. Bonde & T. Rosswall. 1992. Seasonal variation of soil microbial biomass - the effects of clear felling a tropical rainforest and establishment of pasture in the central Amazon. *Soil Biology and Biochemistry* **24**: 805-813.

Margalef, R. 1968. *Perspective in Ecological Theory*. University of Chicago. Press, Chicago.

Marjokopri, A. & K. Ruokolainen. 2003. The role of traditional gardens in the conservation of tree species in west Kalimantan, Indonesia. *Biodiversity Conservation* **12**: 799-822.

MoEn. 1999. *Annual Report*. Ministry of Environment and Forest. Government of India.

Mollison, B. 1993. *The Permaculture Book of Ferment and Human Nutrition*. Tagari Publication, Australia.

Parthasarathy, N. 1988. Seasonal dynamics of fine roots in a tropical forest in south India. *Journal of Indian Botanical Society* **66**: 338-345.

Proctor, J. 1984. Tropical forest litter fall. II. The data set. pp. 83-113. *In*: A. C. Chadwick & S. L. Sutton (eds.) *Tropical Rain Forest: Ecology and Management*. Supplementary Volume. Proceedings of the Leads Philosophical and Literary Society.

Ramakrishnan, P. S. 1985. Conservation of rain forests in northeastern India. pp. 69-84. *In*: J. S. Singh (ed.) *Environmental Regeneration in the Himalaya, Concept and Strategies.* Himalayan Environmental Association, Nainital, India.

Sanchez, R. G. & J. Alvarez-Sanchez. 1995. Litter fall in primary and secondary tropical forests of Mexico. *Tropical Ecology* **36**: 191-201.

Sharrow, S. H. & S. Ismail. 2004. Carbon and nitrogen storage in western Oregon agroforests forests and pastures. *Agroforestry Systems* **60**: 123-130.

Singh, J. S., A. S. Raghubanshi, R. S. Singh & S. C Srivastava. 1989. Microbial biomass acts as a source of plant nutrients in dry tropical forest and Savanna. *Nature* **399**: 499-500.

Sundarapandian, S. M. 1997. *Ecological Studies on Forest Ecosystems at Kodayar in Western Ghats of Tamil Nadu.* Ph. D. Thesis, Madurai Kamraj University, Madurai, India.

Tufekcioglu, J. W. Raich, T. M. Isenhart & R. C. Schultz. 1999. Fine root dynamics, coarse root biomass, root distribution and soil respiration in a multi-species riparian buffer in Central Lowa, USA. *Agroforestry Systems* **44**: 163-174.

Vitousek, P. M. & P. A. Matson. 1988. Nitrogen transformation in tropical forest soils. *Soil Biology and Biochemistry* **20**: 361-367.