

Traditional Agroforest *vs* Tropical Forest

*S. Deb, A.R. Barbhuiya,
A. Arunachalam and K. Arunachalam*

Introduction

Tropical forests cover less than 7 percent (Richard, 1952) of the earth's land area and they contain the vast majority of the world's plant and animal genetic resources. These forests are home for tribal hunter-gatherers whose way of life has been relatively unchanged for centuries. Though forests in general have both economic and ecological values, tropical forests are especially important in global economy. A study by the Food and Agriculture Organization (FAO) of the United Nations, which considered 23 countries in tropical America, 37 in tropical Africa, and 16 in tropical Asia, identified dozens of different types of tropical forests: open and closed canopy forests, broad leaved trees and conifer forests, closed forests and mixed forest grasslands, and forests where agriculture has made inroads.

India has a total land area of 329 million ha of which 43% is under cropping and 23% is classified under forests (Anon., 1999). The National Forest Policy of India (1952) stipulated that India as a whole should aim at maintaining one third of its total land area under forest for securing ecological stability. Even though

the world tropical forests occupy 7% of the land area, they contain over half of the world's species (Caulfield, 1985). Over 45000 species occur in tropical Asia and about 100000 of plant species are found in the tropical forests (Myers, 1980). At the present time, about 1.5 million species have been described in total. It is certain that at least twice these numbers of species remain undescribed, primarily in the tropics, leading to an estimate of nearly 5 million species worldwide.

More than 2.5 million people live in areas adjacent to tropical forests. These people depend on the forests for their livelihood. They rely on the forests for their water, fuelwood, and other resources and on its shrinking land base for their shifting agriculture. For urban dwellers, tropical forests provide water for domestic use and hydroelectric power. Their scenic beauty, educational value, and opportunities for outdoor recreation support tourist industries. Though the forests have originated from acclimatized climatic processes and rejuvenated from past human activities, still the literature and legislator favours human separation from these forests (Mc Neely, 2004). A brief review about the history of the people, forest and biodiversity will show how humans have affected the birth, growth, death and renewal cycle of forests in a variety of ways, with various outcomes in different parts of the world (Holling, 1978).

The Northeastern India abode rich biological diversity with greater endemism. Nonetheless, the rich resource bases are facing serious threat of species extinctions due to habitat destructions. In the tropical forest lands, shifting cultivation or slash or burn agriculture is practiced widely that also affects forest structure and species composition and subsequent abandonment results in the creation of a mosaic of forest patches of different ages. Nevertheless, other disturbances including logging, clear felling, grazing, fire and the collection of fuel wood, fodder and non-timber forest products have also contributed significantly to forest degradation. Thus, most remaining forests are secondary, primary post-extinction secondary forests arising after significant

disturbances through large scale and small scale extractive activities. The deforestation rate is greatest in Asia, at amount 1.2% per year, extending the projection forward in time reveal that, at the current rate of loss, there will be virtually no tropical forest left after the year 2040 except in the relatively small protected area and inaccessible area (Richard, 2002).

Thus, rehabilitation of degraded forests and its sustainable management of these forests 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*. 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 by human interference may enhance and reduces forest diversity. One of the adaptive strategies to reduce pressure on forest is permaculture (Mollison, 1993), as practiced in Western Ghats, although agroforestry has been widely advocated in the Indian eastern Himalayan region.

Traditional farming system reaffirms the fact that traditional practice and technologies and knowledge are locally conditioned and restricted and therefore strives to establish linkage between the various land use units in the rural landscape. This traditional practice developed through generations of refinements of farmers innovation are product of dynamic evolution, resultant of innovative response to changing socioeconomic and ecological conditions (Rastogi, 1998). These traditional practices have been found to be highly effective in resource conservation and management. Traditional farming system ranges from management of genetic resources to the complexities of integrated dynamics of land, water, forest and agricultural resources.

Agroforestry is a collective name for all land use systems and practices where perennials are deliberately grown on the same land management units as crops and/or animals, either in a spatial mixture or in time sequence. Proper selection of various

components coupled with right management practices will certainly reduce these ill-effects and help to rehabilitate the *jhumias*. Agroforestry is widely considered as a potential way of improving socioeconomic and environmental sustainability in the tropics (Alavapati and Nair, 2001). Agroforestry systems contribute to the rural economy, employment, poverty alleviation and environmental protection at a local, regional and national level. One of the key factors in determining

agroforestry adoption is the relative profitability of the practice in comparison to other land use practices. Agroforestry system provide a mixture of market goods such as food, wood production and fodder to cattle and non market goods and services including soil conservation, water and air quality improvement, biodiversity conservation and scenic beauty.

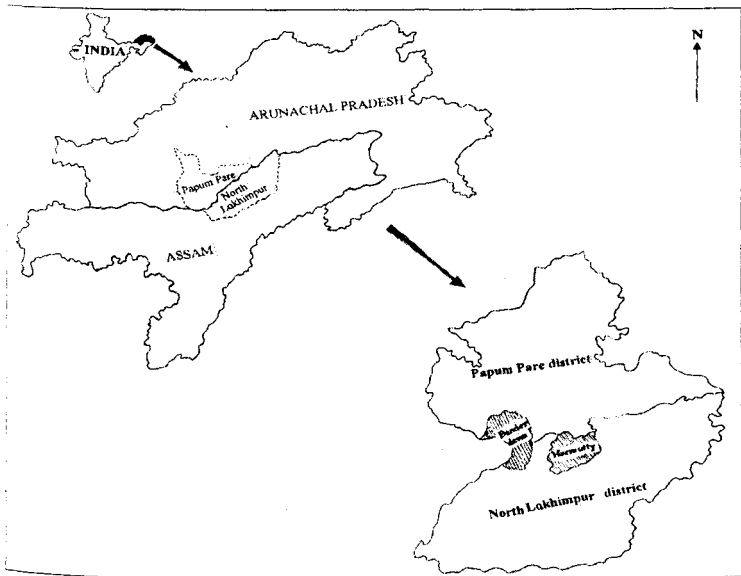


Figure 1. A map showing the tropical forest and traditional agroforest of the study area

Table 1. Vegetation and belowground (0-10 cm) characteristics in traditional agroforest and tropical forest.

Properties	Parameters	Traditional agroforest	Tropical forest	% change
Vegetation				
Stratification		Four layered	Four layered	
Species richness (plants ha ⁻¹)	Trees	17	66	74.24
	Shrubs	11	34	67.65
	Herbs	14	20	30.00
Basal area (m ² ha ⁻¹)	Trees	37.01	85.55	56.74
	Shrubs	0.62	2.61	76.25
	Herbs	0.19	0.27	29.63
Density (plants ha ⁻¹)	Trees	1006	658	-52.89
	Shrubs	3442	7500	54.11
	Herbs	4726	15,900	70.28
Species diversity index (H)	Trees	1.13	1.39	18.71
	Shrubs	1.02	1.06	3.77
	Herbs	0.86	1.09	21.10
Soil				
Physical Texture		Loamy sand	Loamy sand	
Chemical (1:2.5 w/v H ₂ O)	WHC (%)	44.41 ±1.57	55.99 ±2.60	20.68
	Moisture (%)	22.28 ±0.87	30.06 ±1.91	25.88
	Bulk density (g cm ⁻³)	0.60 ±0.007	0.67 ±0.008	10.45
	pH	5.61 ±0.26	4.93 ±0.23	13.79
	Organic C (%)	1.49 ±0.05	1.67 ±0.04	10.78
	Total N (%)	0.65 ±0.04	0.66 ±0.03	1.52
	Total P (%)	0.11 ±0.04	0.09 ±0.04	9.48
	C/N	2.29	2.53	9.49
	NH ₄ ⁺ -N (µg g ⁻¹)	12.08 ±0.54	5.57 ±0.37	-113.05
	NO ₃ ⁻ -N (µg g ⁻¹)	1.91 ±0.23	8.56 ±0.51	77.68
	PO ₄ ⁻ -P (µg g ⁻¹)	6.68 ±0.65	8.85 ±0.78	24.52
	Microbial Biomass (µg g ⁻¹)	C	377.74 ±21.07	809.45 ±75.26
Population*	N	17.07 ±2.17	74.12 ±8.57	76.96
	P	2.42 ±0.16	36.85 ±2.35	93.43
	Fungi (x10 ⁵)	25.45 ±1.02	29.45 ±1.16	13.58
	Bacteria (x10 ⁵)	108.01 ±7.46	112.63 ±9.20	4.10
Plant detritus				
Litter prod. (kg ha ⁻¹ yr ⁻¹)	Leaf	310.02 ±15.47	9830.74 ±137.56	96.85
	Non leaf	312.87 ±16.89	1673.12 ±41.18	81.30
Biomass (kg ha ⁻¹)	Leaf	903.67 ±31.07	11577.00 ±178	94.62
	Non leaf	502.33 ±10.51	2873.67 ±83.54	92.41
Root Production (kg ha ⁻¹ yr ⁻¹)	Fine	937.39 ±32.19	1980.49 ±82.50	52.67
	Coarse	261.22 ±11.84	1253.67 ±76.82	79.16
Biomass (kg ha ⁻¹)	Fine	533.87 ±24.17	5293.69 ±148.00	89.91
	Coarse	149.34 ±12.08	1370.05 ±81.34	89.09

WHC= Water holding capacity; * no. of colonies per gram dry soil; ± SE (n=3)



Figure 2. Vegetation structure of Tropical forest (A) and Traditional agroforest (B).



Traditionally, people have been maintaining homegardens in northeast India with abundant trees of food and/or commercial value and culturally a few agroforestry crops and medicinal plant in the homeyard space. It has been reported that agroforests are similar to natural forests (Marjokopri and Ruokolainen, 2003). We observed that physico-chemical properties of soil and species

composition and structure of the well-managed traditional agroforestry system (Figure 1) is to some extent equivalent to tropical forests (Table 1). The agroforestry system enhances productivity and contributes to biological conservation. The traditional agroforestry may bring under control the disorder of the tropical forests like the ancient people who domesticated many wild animals and plants. A more sophisticated understanding between forest and people may lead to better forest conservation and better agroforestry. The age-old shifting cultivation practiced in the humid tropics doing in different tropical forests can be converted to agroforestry systems which can promote sustainability of the tropical forests. Diagnosis and designing of improved agroforestry technologies for the rehabilitation of degraded tropical forests is the main goal of researcher in the field of eco-restoration and conservation. With this object, a study was initiated to document system characters of tropical forest and traditional agroforest in the biodiversity rich area in the north-eastern region. Vegetation, soil and detrital parameters were studied following standard procedures in 3 replicated traditional agroforestry stands in Harmutty (North Lakhimpur district, Assam) and in 3 permanent quadrats (25m x 25m) in a tropical forest in Banderdewa, Arunachal Pradesh (Figure 2).

Tree density in the tropical forest (Table 1) of Eastern Himalayan region ($658 \text{ plants ha}^{-1}$) was well within the limits range ($245\text{-}859 \text{ stems ha}^{-1}$) that was reported for tropical forests (Richard, 1952; Campbell, 1992). The traditional agroforestry system had greater tree density ($1006 \text{ stem ha}^{-1}$) 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., *Averrhoa carambola* Linn., *Psidium guajava* Linn., etc) in the study sites. However, species diversity of trees, shrubs and herbs in tropical forests was higher than the agroforests. While comparing older agroforests to natural forest stands Marjokopri and Ruokolainen, (2003), observed similar proportions of species at different successional stage 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 m² ha⁻¹ for > 10 cm diameter. The basal area of agroforestry tree species (37.01 m² ha⁻¹) is well within the above range, whereas the tropical forest stand registered a greater value (85.55 m² ha⁻¹) than the reported values elsewhere. However, these values were lower than those reported by Singh *et al.* (1981) (102.7 m² ha⁻¹) and Parthasarathy *et al.* (1992) (94.6 m² ha⁻¹). Overall, the differences in densities and basal area may be attributed to the composition, age structure, successional stage of the forest and the degree of disturbances (Sundarapandian, 1997).

The minimum litterfall studied in tropical forests were in the range of 3400-15300 kg ha⁻¹ year⁻¹. The litterfall studied in agroforestry systems (1406 kg ha⁻¹) were lower than the above range, whereas the values obtained in tropical forest of this region (11504 kg ha⁻¹ yr⁻¹) was within the range of tropical forests. Litterfall production in lowland evergreen tropical rainforests around the world ranged from 5700 kg ha⁻¹ yr⁻¹ in a heath forest in Venezuela to 12400 kg ha⁻¹ yr⁻¹ in Zaire (Proctor, 1984). The fine root biomass in tropical forests stand was 5293.69 kg ha⁻¹ which is higher than the reported range (1790-3500 kg ha⁻¹ in the Western Ghats (Parthasarathy, 1988). The agroforestry system recorded a lower value (533.87 kg ha⁻¹), whereas a teak forest, formed after successional stage showed nearly same value (960 kg ha⁻¹ year⁻¹, Srivastava *et al.*, 1986) of agroforestry systems. The central Amazonian rainforest, however, had 12 times more root biomass (8430 kg ha⁻¹) than the present traditional agroforestry system. Ranges of 1 to 6.2 Mg ha⁻¹ for fine roots were reported for a number of agroforestry tree species (Tufekcioglu *et al.*, 1999). Most other data (1.8 to 17.7 Mg ha⁻¹) are from old natural fallow or forests (Sundarapandian *et al.*, 1996).

Agroforestry systems provide ways for simultaneously tackling soil constraints such as loss of soil organic matter, limited nutrient availability and water holding capacity (Sanchez and Sanchez, 1995; Young, 1997). Agroforests utilize more N than the 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 an efficient C/N ratio (2.29) due to the presence of more N_2 -fixing plants and have both forest and crop N storage activities (Sharrow and Ismail, 2004). The quantity, quality, timing and mode of addition of organic matter and good quality residue in different fallow systems would strongly influence the decomposition process and their contribution to soil organic matter pools and nutrient availability. In this context, the role of soil microbes has been advocated in various tropical ecosystems (Singh *et al.*, 1989).

Microbial biomass C, N and P were more in tropical forests than the man-made traditional agroforestry systems (Table 1) and this might be due to the more nutrient restoration by the microbes in the forest sites; in other words, nutrients are not actively utilized by the systems as the agroforestry systems are more 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 systems. The soil microbial biomass C and N in the agroforest and tropical forest were 378-809 $\mu\text{g g}^{-1}$ and 17-74 $\mu\text{g g}^{-1}$ respectively in our study sites. These values are comparable to microbial biomass C (60-2000 $\mu\text{g g}^{-1}$) (Singh *et al.*, 1989; Henrot and Robertson, 1994) and N (9-239 $\mu\text{g g}^{-1}$) (Vitusek and Matson, 1988) content 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.

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	51.33
	N	0.26	1.12	76.79
	P	0.22	4.09	94.62
Litter biomass	C	2.97	14.10	78.94
	N	0.23	2.92	92.12
	P	0.08	0.30	73.33
Root biomass	C	2.81	3.04	7.57
	N	0.24	0.90	73.33
	P	0.15	0.11	36.37

The contribution of microbial biomass C, N and P to soil nutrient pool (Table 2) were greater in tropical forest than in the traditional agroforestry system. The contribution of microbial biomass C to soil organic C (2.54-4.84%) was however lower, but well 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 as compared to other arable lands (1.4-3.5). Litter biomass contributed 14.1% C to the tropical forest soil and 2.97% in the traditional agroforestry system. The contribution of C, N and P from litter and root biomass was 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 been established that soil microbial biomass C is positively correlated to soil organic matter (Henrot and Robertson, 1994). This further substantiates the abundance of microbial population, microbial biomass C, N and P in the tropical forest stand.

Overall, this study revealed 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. The traditional agroforestry systems studied in north east India are seemingly not well-managed, but upon scientific management might prove to be a sustainable land use system in the hills and flood plains and promote conservation and sustainability of the tropical forests (Arunachalam *et al.*, 2002).

Summary

A tropical forest and an agroforest are complex ecosystems and their relationships depend on the composition of system itself and the way it is managed. Arecanut-based agroforestry systems in the northeast India are multilayered and have greater tree density like a natural forest stand in the humid tropics. However, the differentiation between traditional agroforest and the tropical

forest is significant in terms of soil and microbial characteristics. Nonetheless, most of the parameters are within the range reported for tropical forest soil. Thus, the traditional agroforests can play a vital role in maintaining the sustainability of the tropical forest.

Bibliography

- Alavapati, J. R. R. and Nair, P. K., 2001. *World Forests, Society and Environment Markets and Policies* (eds. Polo, M. and Uusivuori, J.) Kluwer, Dordrecht, The Netherland, pp. 71-81.
- Anonymous, 1999. Ministry of Environment and Forestry, *National Forestry Action Programme in India*.
- Arunachalam, A., Khan, M. L. and Arunachalam, K., 2002. *Curr. Sci.*, 83, 117-118.
- Campbell, D. G., Stone, J. L. and Rosas, A., 1992. *Bot. Jour. of Linn. Soc.*, 108: 213-237.
- Caulfield, C., 1985. *A report at large: The Rain Forests.*, New York, pp. 49-79.
- Henrot, J. and Robertson, 1994. G. P., *Soil Bio. and Bioc.*, 1994, pp. 111-116.
- Holling, C. S., 1978. *Adaptive Environmental Assessment and Management* (ed. Wiley, J.), New York, p. 576.
- Luizao, R. C. C., Bonde, T. A. and Rosswall, T., 1992. *Soil Bio. and Bioc.*, 24, 805-813.
- Marjokopri, A. and Ruokolainen, K., 2003. *Biodiversity Conservation*, 12, 799-822.
- Mc Neely, J. A., 2004 *Agro. Syst.*, 61, 155-165.
- Mollison, B., 1993. *The Permaculture Book of Ferment and Human Nutrition*. Tagari Publication, Australia, p. 288.
- Myers, N., 1980. *Conversion of Tropical Moist Forest*, National academy of Sciences, Washington, D.C.
- Parthasarathy, N., 1988. *Jour. of Ind. Bot. Soc.*, 66: 338-345.
- Parthasarathy, N., Kinhal, V. and Praveen, K. L., 1992. *Natural Functioning and Anthropogenic Impact*, Indo-French workshop on tropical forest ecosystems, Pondichery, French institute
- Proctor, J. 1984. *Tropical Rain Forest: Ecology and Management* (ed. Chadwick, A. C. and Sutton, S. L.), 1984, pp. 83-113.
- Rai, S. N. and Proctor, J., 1986. *Jour. of Ecol.* 74, 455-463.
- Rastogi, A., *Managing Agrobiodiversity* (ed. Pratap, T. and Sthapit, B.), 1998, pp. 357-366.
- Richard, B. P., *Essential of Biodiversity Conservation* (3rd ed.), 2002, pp.

213-263.

Richard, P. W., 1952. *The Tropical Rainforest*, Cambridge University Press, Cambridge.

Sanchez, R. G. and Alvarez-Sanchez, J., 1995. *Trop. Eco.*, **36**: 191-201.

Sharrow, S. H. and Ismail, S. *Agro. Syst.*, 2004, **60**:123-130.

Singh, J. S., Raghuvanshi, A. S., Singh, R. S. and Srivastava, S. C., 1989. *Nature* (London), **399**: 499-500.

Singh, J. S., Singh, S. P., Saxena, A. K. and Rawat, Y. S., 1981. *The silent valley forest ecosystem and possible impact of proposed hydroelectric project: report on silent valley study*; Ecology Research Circle, Kumaun University, Nainital, p. 69.

Srivastava, S. K., Singh, K. P. and Upadhyay, S. R., 1986. *Canadian Journal of Forest Research*, **16**, 1360-1364.

Sundarapandian, S. M. 1997. *Ecological Studies on Forest Ecosystems at Kodayar in Western Ghats of Tamil Nadu*, Ph.D. Thesis, Madurai Kamraj University, Madurai, p. 113.

Sundarapandian, S. M., Chandrasekharan, S. and Swamy, P. S. 1996. *Curr Science*. **70**, 242-246.

Tufekcioglu, A. Raich, J. W. Isenhardt, T. M., Schultz, R. C., 1999. *Agro. Syst.*, **44**, 163-174.

Vitousek, P. M. and Matson, P. A., 1988. *Soil Bio. and Bioc.*, **20**, 361-367.

Young, A., 1997. *Agroforestry for Soil Management (ed.)*, CAB International, Wallingford, UK, 1997, p. 320.