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Composition, diversity and regenerating potential of plant species in shifting agricultural landscape in North East India; A case study in and around Dihang-Dibang Biosphere Reserve, Arunachal Pradesh, India

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Abstact

Anthropogenic disturbances in the form of deforestation for diverse purposes such as collection of timber and firewood, expansion of agriculture land and human settlement, have been a serious issue for sustainable development. This kind of disturbance may regulate the regeneration dynamics, structure and floristic composition of forest. On the other hand the effect of anthropogenic disturbance on forests may be either positive or negative, depending on the insensity of the disturbances. Most changes in terrestrial biodiversity brought about by human activities are driven by (a) land cover conversion (b) land degradation (c) land use intensification. Assessment of changes in biodiversity and its functions requires a thorough understanding of forces driving the land cover change process, ecological modelling of land cover change rates and land cover-biodiversity relationships. There exists a vast pool of traditional ecological knowledge which is to be appreciated and incorporated in conservation programmes.

Keyword: North east India, plant species, shifting agriculture, land use/cover

Introduction

The forest farmer in the tropics has managed the traditional shifting agriculture (known as ‘Jhum’ in north east India), which is essentially an agro-forestry system organized both in space and time for centuries. The small-scale perturbations caused during jhum done in the past, ensured enhanced biological diversity in the forest, with enriched crop and associated biodiversity, with the added bonus of being able to capitalize upon the nutrients released during the slash and burn phase for ecosystem. With increasing pressure on forest resources from outside, and population pressure from within, and the consequent declining soil fertility through land degradation agricultural cycle (jhum cycle) has got shortened. The north eastern hill region of India is no exception (Ramakrishnan, 1992) to this well-known and widespread situation prevailing in all parts of the world. It is suggested (FAO/UNEP, 1982) that, in late 1980s, about 500 million people were dependent upon shifting agriculture in 90 countries, covering an area of 400 million ha approximately of tropical forest land area. A subsequent forest resource assessment (FAO, 1995) found that more than 7% of the 1980 forest area underwent change during the period 1980-1990, more than half of this change being due to shifting agriculture, resulting in moderate to severe degradation.

North east Indian region forms the entire eastern range of Himalayas which is characterized with high biodiversity, presence of various endemic fauna and flora species, economically and ecologically important plants and animal species and prevalence of medicinal plants. Although many works have been carried out on Himalayas, they are mostly from western and central Himalayas. The north east India is an abode of many rare, endemic, relic, primitive and endangered species. However, very little information exists on the extent and distribution of the state's biodiversity. In the absence of spatial data on the distribution and abundance of species, it is difficult to assess the prospect of conservation of biodiversity, both in the immediate future and over time. Unfortunately, this region is no longer immune to anthropogenic demand and technological development (Bhuyan et al., 2003). There is major transformation of this once pristine landscape region over the last few decades (Menon et al., 2001).

Differences in species composition and structure may point to variation in biotic and abiotic conditions such as soil moisture, light availability, temperature, exposure to prevailing wind, and soil macro and micro organisms. When tracked over time, species and individual dynamics can reveal patterns of response to disturbance and how the community changes over time.

Thus the present study aims to analyze the status and regenerating potential of plant species in shifting agricultural landscape in north east India taking two remote village landscapes as representative sites.

Study site

The study was conducted in two representative traditional shifting agricultural villages in Arunachal Pradesh; one of the eight states of north east India, located at 28º10´N to 28º30´N latitude and 94º40´E to 95º00´E longitude at the altitudinal range of 600-1600 m asl. This area falls under the south western region of the Dihang-Dibang Biosphere Reserve. Both the study sites are located 20 km apart and inhabited by 'Adi' community of Tibeto-Mongoloid race; one of the major tribes of Arunachal Pradesh.

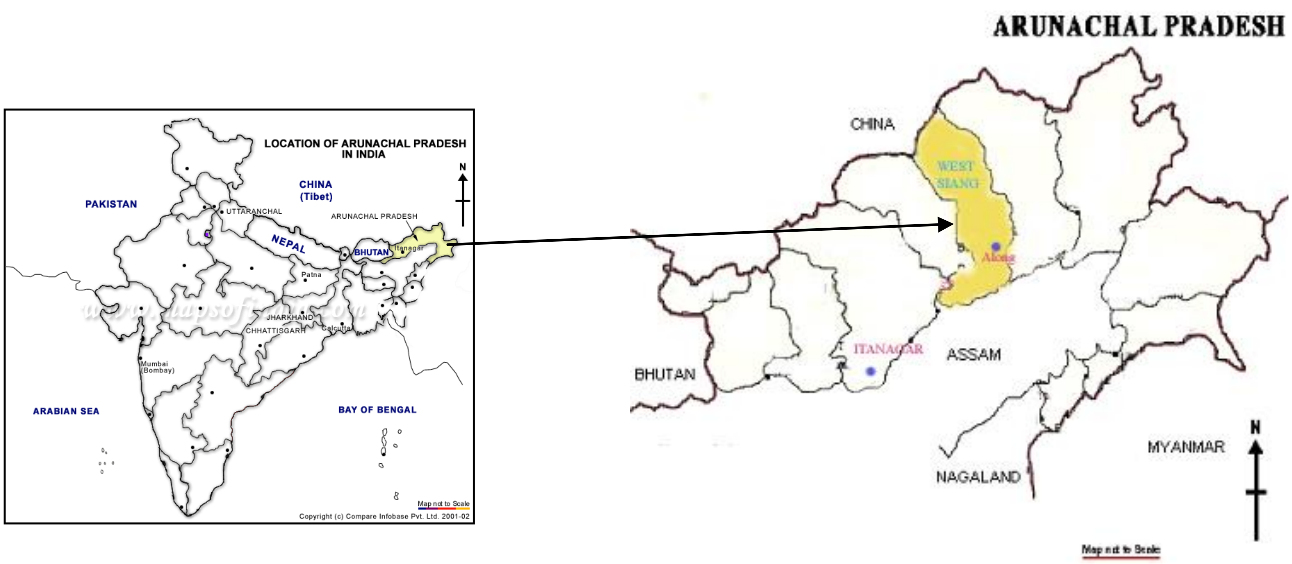
These sites are located in a tropical humid environment with 4 distinct seasons in a year, namely, spring (March-April), summer (May-August), autumn (October-November) and winter (December-February). The mean annual minimum and maximum temperature varies between 12^0C and 37^0C respectively. More than 80% of the rainfall occurs during monsoon (May-September) registering about 60-80% relative humidity. The area experiences occasional winter rainfall too.

The main features of two selected representative village landscapes can be summarized as in Table 1:

Table 1 Landscape characteristics of study villages

Features	Domong	Yogong
Accessibility	easily accessible	highly inaccessible
Location	$28^{0}10'$ - $28^{0}15'$ N and $94^{0}46'$ – $94^{0}48'$E	$28^{0}22'$- $28^{0}25'$N and $94^{0}51'$- $94^{0}58'$E
Elevation	920 m amsl	1600 m amsl
Area (km$^{2)}$	64	150
Settlements	5 hamlets	1 hamlet
Population density (persons/km^{2})	28.05	1.44
Degree of anthropogenic pressure	High	low
Distance from Along, nearest urban hub	8 km	44 km
Households and population (2005)	260 and 1795	36 and 216

The landscape in these two sites was characterized by a heterogeneous mosaic of land cover types of which woodland, cropland and fallow are prominent.



Methods

A total of 234 plots (Quadrats), each of 20 m x 20 m size, were laid; all mature tree individuals (cbh > 30 cm) were counted and their cbh and height measured. Nested quadrats of 2 m x 2 m, four in corners and one in the centre of 20 m x 20 m plot were laid to estimate the density of tree saplings/seedlings (cbh < 30 cm). All the names; both botanical as well as vernacular names of plant species falling under the quadrats, were recorded. Local people were interviewed to know the local names of tree species and their values/uses as perceived/practiced by the people. Herbarium sheets were made and botanical names identified by consulting taxonomists.

Results

Species richness – village landscape scale

A total of 86 tree species represented by 41 families were encountered in the two village landscapes considered together. Domong village landscape showed a higher tree species richness (71 species) compared to 44 species in Yogong village reflecting a positive effect of improvement in accessibility, increase in population pressure and other associated changes on tree species richness. Twenty-four species belonging to 14 families were confined to village Domong and four families and five species to village Yogong, while 58 species belonging to 23 families were common to the two villages. Lauraceae, Moraceae, Euphorbiaceae and Fagaceae were the richest family represented by 8, 7, 6 and 5 species, respectively.

Direct uses of 34 species were identified by people during participatory discussions. While deadwood of all tree species was valued as fuelwood with no rating of the fuelwood quality, 22 species were valued as timber species classified as (i) the best quality timber species including *Morus laevigata*, *Terminalia myriocarpa*, *Altingia excelsa* and *Duabanga grandiflora*, (ii) medium quality timber species including *Castanopsis* spp., *Chaerospondias axillaris*, *Cinnamomum* spp. and *Artocarpus heterophyllus*, and iii) average quality timber species including remaining 16 species. Some species such as *Cinnamomum glaucescens*, *Sarchochlamys pulcherima* and *Syzygium assamicum* were valued more for their indirect values in terms of providing preferred food of wild animals, a source of meat to local people, than their direct values.

Nine tree species including *Bombax ceiba*, *Cinnamomum glaucescens, Duabanga grandiflora, Dysoxylum gobara, Dysoxylum procerum, Engelhardia spicata, Pterospermum acerifolium, Saurauia cana* and *Turpinia pomifera* were the top canopy species confined to Domong and seven species including *Chisocheton* spp., *Eurya arunachalensis, Ficus hispida, Ficus religiosa, Leportia* spp., *Litsea cubeba* and *Trevisia palmata* to Yogong landscape, *Altingia excelsa, Canarium resiniferum, Castanopsis indica, Dysoxylum gobara, Elaeocarpus floribundus, Morus laevigata* and *Terminalia myriocarpa* were top canopy species common to the two village landscapes. Fifteen species including *Albizzia chinensis, Bauhinia purpurea, Colona floribunda, Dysoxylum gobara, Elaeocarpus varunua, Engelhardia spicata, Ficus gasparriniana, Gynocardia* *odorata, Lithocarpus listeri, Magnolia campbellii, Meliosma pinnata, Michelia champaca, Pterospermum lanceaefolium, Quercus lancifolia* and *Trevisia palmata* were occurred as middle canopy species only in Domong village landscape, five species including *Alangium* spp., *Antidesma* spp., *Ficus hirta, Ficus religiosa* and *Podocarpus neriifolia* occurred only in Yogong village landscape while 10 species including *Artocarpus heterophyllus, Castanopsis purpurella, Dysoxylum bracteata, Dysoxylum alliarium, Lithocarpus* spp., *Leportia* spp., *Pandanus nepalensis, Sapium baccatum, Saurauia cana* and *Turpinia pomifera* were common middle canopy species in both village landscapes. Twentytwo species viz., *Actinodaphne obovata, Callicarpa arborea, Caseria vareca, Cinnamomum tamala, Colona floribunda, Ficus roxburghii, Glochidion* spp, *Lindera assamica, Litsea khasyana, Maesa chisia, Maesa ramentacea, Mallotus tetracoccus, Mangifera indica, Pandaca* sp., *Polyalthia* sp., *Rhus javanica, Saurauia cana, Sterespermum chelonoides, Styrax serrulatus, Syzygium cumini, Trema orientalis* and *Zanthoxylum rhetsa* were the lower canopy species confined Domong village, four species including *Ficus hirta, Leportia* spp., *Pandanus nepalensis* and *Sarcochlamys pulcherrima* to only Yogong village, while 11 species including *Clerodendum viscosum, Cyathea spinosa, Diospyros cerasifolia, Elatostema platyphylla, Garcinia lanceaefolia, Litsea salicifolia, Livistona jenkinsiana, Macaranga denticulata, Musa acuminata, Ostodes paniculata* and *Persea* species were lower canopy species common to the two landscapes. Some species like *Castanopsis indica, Dysoxylum alliarium* and *Dysoxylum gobara* occurred both as top canopy and middle canopy species and species like *Livistona jenkinsiana* as middle and lower canopy species.

Quantitative analysis of species dominance and diversity: mature tree component

Abundance of different tree species was compared for the mature tree component and regenerating individuals separately. Species wise density, relative density, basal area and relative basal area values of mature tree component of the community (mature tree means an individual with cbh > 30 cm) in sample plots aggregated by finer classes which represent different nature and magnitudes of land use – land cover modification, management and land use intensification are given in Table. One-three Young fallow fields in Domong village had three species viz. *Artocarpus heterophyllus*, *Dalhousiea bracteata* and *Sterospermum chulonoides* which were equally dominant whereas *Lithocarpus listeri*, *Litsea salicifolia* and *Trema orientales* were the most dominant species in three-seven year old fields. *Livistona jenkinsiana* was planted in all plantations but its proportion varied. *Artocarpus heterophyllus* and *Duabanga grandiflora* were the most dominant species in riverside forests and *Castanopsis indica* in streamside and hillside forests of Domong village. Further, hillside forests had higher proportion of *Artocarpus heterophyllus*, *Livistona jenkinsiana* and *Chaeospondias axillaris* but lower of *Dysoxylum gobara* and *Colona floribunda* compared to streamside forests. Fallows in Yogong differed from the fallows in Domong in that *Livistona jenkinsiana* was more dominant in the former compared to the latter. Streamside and hillside forests of Yogong differed more in terms of degree of dominance of rare infrequent species, both the forests being dominated by *Altingia excelsa*, *Castanopsis indica* and *Terminalia myriocarpa*. Forests of Yogong showed a higher dominance of *Altingia excelsa* and *Terminalia myriocarpa* but a lower of *Duabanga grandiflora* and *Lithocarpus listeri* compared to the forests of Domong. No species contributed more than 15% of total mature trees per unit area.

The sequence of dominance of species based on numerical density and basal area matched in most but not in all cases. In other words, species dominance in terms of numerical abundance was not always correlated with that in terms of basal area. *Livistona jenkinsiana* showed a relative density of 9 compared to relative area value of 35 in 3-7 year fallow fields in Domong village. Thus this species, in this land use category, was the fourth most dominant species in terms of numerical abundance but the most dominant one in terms of basal area. *Diospyros cerasifolia* contributed 23% of total basal area but only < 1% of total number of trees in streamside forests of Domong village. In all land use land cover types in Yogong village and plantations, hillside and riverside forests in Domong village, the most dominant species based on density were the same as those based on basal area.

Quantitative analysis of species dominance and diversity: regenerating tree component

Litsea salisifolia showed the highest level of regeneration in younger fallow fields in both villages and in older fallow fields of only Domong village. This species also showed the highest level of regeneration in toko plantations indicating light-loving nature or early successional status of these species. *Citrus sinensis* contributed 25% individuals of < 30 cm cbh in timber plantations indicating farmers' attitude of diversification of crop. This attitude seems to be partly related to farmer's concern about environmental unsustainability of intensity timber harvesting regimes and partly to increasing policy restrictions on timber trade. It appeared that in timber plantations, farmers weeded out the regeneration of the present dominant timber species and species not valued economically with an objective of diversification of timber species over time. The reasons behind dominance of *Styrax serrulatus* in plantations need to be found out. Regenerating community of Domong riverside forests was dominated by *Castanopsis indica*, of Domong streamside forests by *Lithocarpus listeri*, Domong hillside forests by *Styrax serrulatus*, Yogong streamside forests by *Altingia excelsa* and Yogong hillside forests by *Morus laevigata* and *Castanopsis indica* (Tables 1-3).

The order of species dominance in regenerating component in overstorey differed from that in understorey, more so in natural forests and plantations. In toko plantation, *Litsea salicifolia*, *Lithocarpus listeri* and *Casearia vareca* were the most dominant species of regenerating community while *Livistona jenkinsiana* dominated the overstorrey. *Livistona jenkinsiana* was interspersed with orange trees in overstorey but was altogether absent in understorey in orange plantations. *Morus laevigata* and *Livistona jenkinsiana* accounted for > 10% of mature trees but did not show similar degree of dominance understorey of regenerating component in timber plantations. Similarly the most dominant species of seedlings+saplings component were different from most dominant species component of mature trees in all forests in Domong. On the other hand, in Yogong the species that dominated the seedling + sapling component also dominated the mature tree component. These differences indicate that forests in Domong are exposed to a higher degree of disturbance compared to the forests of Yogong.

Table 1. Relative density of mature trees (number of individuals with circumference >30 cm per ha) in different land use land cover types.

	Domong village landscape									Yogong village landscape			
Tree species	1-3 year fallow	3-7 year fallow	Toko pure	Toko mixed	Orange mixed	Timber mixed	Forest-riverside	Forest-streamside	Forest-hillside	1-4 year fallow	4-8 year fallow	Forest streams	Forest-hillside
Altingia excelsa	0	0	0	0	0	0	2	2	1	0	2	13	10
Artocarpus heterophyllus	33	0	2	0	6	0	11	0	10		2	0	1
Bauhinia purpurea	0	8	0	0	0	0	8	0	1	0	0	0	1
Castanopsis indica	0	5	2	0	0	0	8	13	14	0	2	13	9
Chaerospondias axillaris	0	0	0	0	0	0	6	0	6	0	2	0	1
Cinnamomum spp	0	0	0	4	0	0	6	0	0	0	0	5	2
Citrus spp	0	1	0	0	70	4	0	0	0	0	2	0	0
Colona floribunda	0	3	0	0	0	4	0	4	0	0	6	0	0
Duabanga grandiflora	0	1	0	0	0	0	10	7	6	0	0	2	1
Dysoxylum gobara	0	4	0	7	0	0	0	7	0	0	3	2	1
Engelhardia spicata	0	0	0	0	0	0	0	2	0	0	5	1	4
Lithocarpus listeri	0	14	0	7	0	0	5	7	5	0	3	1	0
Litsea spp	0	13	0	0	0	4	2	2	1	0	3	0	0
Livistona jenkinsiana	0	9	95	67	18	16	0	4	9	50	18	1	5
Morus laevigata	0	1	0	15	6	44	5	7	9	0	5	6	9
Sterospermum chelonoides	33	0	0	0	0	4	3	0	3	0	0	0	0
Terminalia myriocarpa	0	2	0	0	0	0	2	6	9	0	3	13	11
Others	33	42	0	0	0	24	32	39	23	50	48	41	45
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 2. Relative density of regenerating individuals (circumference >30 cm) in different land use land cover types

Tree species	Domong village landscape								Yogong village landscape			
	1-3 year fallow	3-7 year fallow	Toko mixed	Orange mixed	Timber mixed	Forest-riverside	Forests-streamside	Forests-hillside	1-4 year fallows	4-8 year fallows	Forests-streamside	Forests-hillside
Altangia exelsa	0	0	0	0	0	0	0	0	8	6	15	3
Caseraia verica	0	13	13	0	0	0	0	4	0	6	0	3
Castanopsis indica	9	3	3	0	0	27	0	9	0	6	20	13
Cinnamomum spp	0	0	0	0	25	0	16	4	0	0	10	3
Citrus aurantium	0	0	0	96	25	0	0	0	0	0	0	0
Dysoxylum gobara	0	2	2	0	0	0	0	4	0	6	15	0
Ficus religiosa	0	1	1	0	0	0	0	0	17	0	0	6
Lithocarpus listeri	17	13	13	0	0	3	21	9	0	0	5	9
Litsaea spp	30	21	21	0	25	0	0	0	33	0	0	0
Morus laevigata	0	2	2	4	0	0	5	9	0	3	0	9
Quercus lancifolia	0	1	1	0	0	3	5	0	17	3	0	0
Sapium baccatum	9	1	1	0	0	0	5	4	0	0	0	0
Styrax serrulatus	0	0	0	0	25	0	11	9	0	0	0	0
Terminalia myriocarpa	0	2	2	0	0	6	5	0	0	0	0	9
Tremma orientalis	13	7	7	0	0	6	0	0	0	0	0	0
Trevesia palmate	4	0	0	0	0	0	11	0	8	0	0	0
Zythoxylum rhetsa	0	1	1	0	0	0	11	0	0	6	0	0
Others	18	31	31	0	0	48	11	48	16	61	35	44
Total	100	100	100	100	100	100	100	100	100	100	100	100

Table 3. Floristic (seedlings/saplings) and structural characteristics of two village landscapes in different land uses

	Land uses	Sub-land uses	No. of families	No. of Species	Density (stem/ha)	Relative abundance	Basal area (m2 h-1
Domong	Fallow	1-3 yr fallow	3	3	383	8.5	1.31
		3-7 yr fallow	14	16	395	12.4	1.91
	Plantation	Toko	4	6	100	4.3	0.67
		Timber	9	10	200	9.0	1.39
		Orange	3	4	675	23.4	3.61
	Forest	Streamside	12	14	271	5.6	0.87
		Hillside	12	14	230	6.6	1.02
		Riverside	11	16	330	7.1	1.1
Yogong	Fallow	1-3 yr fallow	1	1	400	5.8	0.89
		3-7 yr fallow	16	19	356	8.0	1.23
	Forest	Streamside	10	11	200	4.3	0.66
		Hillside	14	16	168	4.9	0.75

Within broad land use land cover classes, rare species were more numerous than the common ones. Only two species viz., *Lithocarpus listeri* and *Litsea salicifolia* in fallows in Domong, three species viz., *Citrus sinensis, Morus laevigata* and *Livistona jenkinsiana* in plantations in Domong, only one species *Castanopsis indica* in forests in Domong, only one species in *Livistona jenkinsiana* in fallows in Yogong and four species viz., *Altingia excelsa*, *Castanopsis indica*, *Morus laevigata* and *Terminalia myriocarpa* in forests in Yogong showed frequency of occurrence of more than 30%. A high degree of variability within broad land use land cover class is also evident from a high coefficients of variation of density and basal area if all samples of a given broad land use land cover type are merged (Tables 4-5). *Altingia excelsa*, *Castanopsis indica*, *Diospyros cerasifoliaa*, *Morus laevigata* and *Terminalia myriocarpa* could be considered as the climax species as they are able to regenerate under their own canopy/highly shaded conditions and are represented by giant-size trees.

Species richness – area modeling

Analysis of the data collected so far indicate a logarithmic relationship between species richness and area (Figure 1). More than 85% of variation in species richness was explained by the size of the area sampled. However, the degree of increase in species richness with increase in area varied depending upon the land use land cover type under consideration. In case of 1-3 year old shifting cultivation fallows, species richness reached almost an asymptote at sample area of about 700 m^2. In contrast, species richness was not saturated even when the sample area reached a value of 1500 m^2 in case of older fallows and forests where shifting cultivation was not practiced over the time scale which people could recall. The results are comparable to those of Rivera and Aide (1998) who determined species area curve for trees by taking the average curve of 500 randomly ordered selections of the total number of species and observed a total of 53 species in a sample area of 3200 m^2.

Table 4. Tree density (minimum, maximum, mean, standard deviation, coefficient of variation and sample size of number of individuals with circumference > 30 cm per ha in different land use land cover types

	Minimum	Maximum	Mean	SD	CV	n
Domong village landscape						
1-3 year fallow fields	0	300	150	215	143	3
3-7 year fallow fields	0	1100	396	248	62.6	26
Toko pure plantations	700	1500	1025	340	33.2	4
Toko mixed planatations	300	900	675	263	39.0	4
Orange mixed plantations	200	1100	660	336	50.9	5
Timber mixed plantations	500	1100	833	305	36.6	3
Forests - riverside	200	700	477	159	33.3	13
Forests -streamside	300	700	491	104	21.2	11
Forests - hillside	400	700	513	99	19.3	15
Yogong village landscape						
1-4 year fallow fields	100	700	400	120	30.1	5
4-8 year fallow fields	300	900	650	201	30.9	10
Forests - streamside	400	700	553	92	16.6	15
Forests - hillside	200	800	559	132	23.6	29

Discussion

Shastri et al. (2002) in Western Ghats region observed that the species found in the agro-ecosystems were similar to those found in adjacent forests, indicating the willingness of the farmers to mimic the natural forests in their agroecosystems. This study showed a low degree of similarity in species composition of forests and fallows. The average area of the homegarden in Western Ghats region (Shastri et al., 2002) was 376 sq m and the number of tree species varies between 20 and 40 in a given homegarden, indicating that these gardens are highly diverse compared to those in

Mexico and Brazil (Gomez-Pompa, 1996; Herrera et al., 1993). An average Mayan household has an area of 0.65 ha as homegarden and the number of species maintained here may be as high as 164. Some of the species are maintained in homegardens after a realization of their decline natural environments (Levasseur and Olivier, 2000). Homegardens were altogether lacking in the present landscapes. Closed tropical forests are usually resistant to invasion by alien exotic species (Whitmore, 1991). However, *Maesopsis eminii* is an exception. This tree species introduced to restock logged forests and as a nurse species for timber *Cephalosphaera usambarensis* has invaded submontane rainforests in Tanzania (Cronk and Fuller, 1995). Such cases are lacking in the study area.

Table 5. Tree density (minimum, maximum, mean, standard deviation, coefficient of variation and sample size of number of individuals with circumference < 30 cm per ha) in different land use land cover types

Density of tree individuals < 30 cm cbh

	Minimum	Maximum	Mean	SD	CV	n
Domong village landscape						
1-3 year fallow fields	200	600	383	147	38	6
3-7 year fallow fields	100	900	394	201	51	34
Toko pure plantations	9	215	100	118	118	4
Toko mixed planatations	15	200	100	125	125	4
Orange mixed plantations	200	1100	675	403	60	4
Timber mixed plantations	100	300	200	135	68	
Forests - riverside	100	800	330	200	61	10
Forests - streamside	100	600	271	198	73	7
Forests - hillside	100	400	230	82	36	10
Yogong village landscape						
1-4 year fallow fields	200	700	400	265	66	3
4-8 year fallow fields	100	800	356	235	66	9
Forests - streamside	100	400	200	105	53	10
Forests - hillside	100	300	168	75	45	19

Until 1983, timber extracted from RFs and other forests was supplied to local sawmills which converted round timber to finished or semi-finished products like sawn timber that was supplied to the market centres in Assam. The harvesting of silviculturally available trees from unclassed forests was done by contractors, invariably the local people, under the control of Forest Department, while timber from RFs was allotted to wood based industries. The removal of round timber outside Arunachal Pradesh was banned by the government in 1983. This resulted in a sharp growth of wood based industries within the State. Since recent years, extraction of even deadwood from forests has been banned. Bamboos are present in huge quantities but have not been intensively extracted because of absence of paper and pulp industries. Canes have been utilized locally and exported to a significantly greater extent. A large number of medicinal plants are found in these forests but this resource base has been, by and large, used for local health care. Harvesting of various forest produces was being done through the agency of local tribal contractors under Departmental control. Silviculturally available trees were marked annually from the unclassed forests and disposed of on permit system in which the local contractor deposits royalty and monopoly fee to the department; all expenditures (felling to transporting) being borne by the contractor. Quota timber was operated from Reserve Forests as per prescription of the working plan and allotted to wood based industries. The most important NTFPs are bamboo, cane, roofing grasses, riverbed material and medicinal plants. Extraction of NTFPs was done by the local people on permit system for their use. Large scale commercial exploitation of these resources has not been done. Traditional forest product requirements have been estimated as: (a) 35 kg of firewood per day per family (b) 20 cum timber, 1000 bamboo culms and 100-120 bundles of Toko palm (*Livistona jenkinsiana*) leaves, each bundle having 40-45 leaves, for construction of a house and durability of a house in foot hills was considered to be of 20 years duration and in hills of 10 years duration.

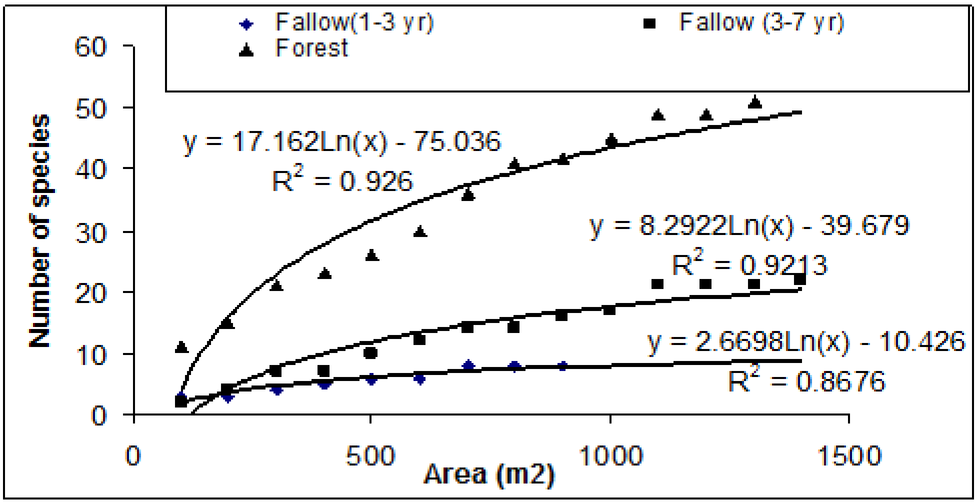


Figure 1. Species-area models for major vegetation classes

Contrary to the common notion that logging is the causal factor of deforestation (Geist and Lambin, 2002), Bray et al. (2004) observed forests are protected when selective logging was allowed in Mayan zone. An organized programme promoting logging together with establishment of community forest enterprises (CFE – an institution that negotiates with buyers, administers the logging process and establishes mechanisms of benefit sharing) could bring up peoples' initiatives to restrict land use land cover under shifting agriculture but only when adequate timber removals were allowed in Mexico. Timber extraction may not be considered unsustainable in that the forest area is being reduced (Ekins, 2003). Loss of primary forest is often not because of scarcity of land but because of cultural reasons often moderated by socio-economic forces. While 30 years ago primary forest was abundant within San Jose's boundaries, there is virtually no unclaimed land within community boundaries and less than 1% of the land area is under primary forest. Shifting cultivation in this region is practiced in the upland areas around settlements since centuries and in more distant terrace lands since last few decades. Land holdings range from 0.5 to 45 ha (mean holding of 10 ha), with 20% of households possessing 58% of land (Connes et al., 2000). Given the differences in land holding size and management within communities, aims of forest conservation and poverty alleviation may not be concordant. The farming systems of indigenous peoples, practiced at low population densities and with specialized ecological knowledge accumulated through the ages, are thought to be relatively sustainable as compared to the practices of the migrants (Moran, 1990). Large scale deforestation is not witnessed in the study area as only selective logging has been allowed and expansion of cultivation or conversion of natural forests to plantations discouraged by the government, local people have never depended on marketing of wood and wood products to secure livelihood or for economic development and availability of medicinal herbs, canes, bamboos, toko palm and wild animals (valued for delicious meat) needing forest habitats for their growth and reproduction is critical for survival in highly inaccessible environments.

Often dependence on non-timber forest products is considered to be a more sustainable livelihood option than that on timber. However, the land area required for securing livelihood exclusively through this option may be too large to sustain the present population density. For example, an area of 420 ha per person may be required for continuous extraction of resin from *Manilkara zapota* (source of chewing gum) in Brazil. Compared to this, an area of 20 ha of forests is required if a family has to meet its requirements through shifting cultivation (Bray et al., 2004).

In a sustainable slash and burn landscape conversion of forest/secondary vegetation in agricultural areas may be compensated by forest regeneration, and so that primary and secondary forest reserves may be maintained over time (Metzer, 2002). Zinke et al. (1978) described a ratio of 1:9 (1 year of cropping to 9 years of fallow) as sufficient to maintain soil fertility on moist tropical forest soils in northern Thailand for a traditional slash-and-burn agroecosystem. Sabhasri (1978), also investigating the same agroecosystem in northern Thailand, estimated that a minimal time ratio of 1:6 is required to maintain original soil fertility levels. Greenland and Nye (1959) suggested a ratio of 1:3 to maintain organic matter levels in Alfisols for a traditional slash-and-burn agroecosystem in West Africa. Van Wambeke (1992) listed ratios from 5:12 to 6:15 as most common for long-term organic matter maintenance in Oxisols of high basic cation status. Laudelout (1962) suggested a minimum range of ratios from 3:10 to 4:15 for organic matter maintenance on forested soils of central Africa. Lal (1985) referred to a study conducted by Watters in Venezuela in which a ratio of 3:15 was required to maintain soil fertility. Ramakrishnan (1992) described a positive correlation between crop yields and fallow period length because of the role of fallow in controlling soil erosion.

Turner II et al. (2001) reported negligible difference in biomass and species composition of mature forests and 25 year old secondary forests, a conclusion also supported from a comparison of basal area of more disturbed forests in Domong village with that in less disturbed forests in Yogong village. While none of the farmers reported any decline in hill rice yield over the last few decades, feature that reflects sustainability of shifting agricultural system, farmers' sustainability of the entire farming system or village landscape rather than that of its selected element(s). Angelsen (1995), based on the studies in Indonesia concluded that: (a) technical progress (e.g., intensification programmes) in frontier areas may increase forest clearing, (b) development of off-farm jobs is crucial in limiting future forest clearing, (c) improved infrastructure and roads reduce transport costs, thereby increasing land rent and forest clearing, (d) the transition from a rice based shifting cultivation system to a smallholder rubber system has several positive features, (e) a large potential for sustainable intensification exists, but the incentives for sustainable intensification are limited, (f) government-sponsored land claims have a multiplier effect on forest clearing. In the present study area, policy and market induced intensification is a very recent process. Because of low road density and a highly and difficult fragile terrain, such an intensification is observed only around road side villages close to semi-urban centres.

Conclusions

Agricultural intensification is important in that it can result in higher rates of carbon sequestration (Woomer et al., 1997; IPCC, 2000) and it reduces agricultural expansion which is a key driver for removal of forested land, which is the major carbon stock in many regions. Intensification may be of two types: capital led intensification involving increase in non-labour inputs such as fertilizers and capital deficient intensification which utilizes the inputs of family or hired labour but without channeling the surplus labour towards capital inputs. Without these capital inputs use of surplus labour leads to extensification or unsustainable intensification, e.g., reduced fallow periods, expansion to marginal lands and excessive planting density (Reardon et al., 1999). Because of the precarious nature of rainfed agriculture, farmers are often forced to take an approach that maximizes aversion to risk, making intensification a poor alternative (Darkoh, 2003).

Farmers are often forced to make choices or trade-offs between (a) short-term profitability and natural resource conservation (b) on-farm and off-farm employment (c) household, educational and farming expenses (d) low-input, low-risk farming practices and high-input, high- risk farming practices. The results presented in this study show that instead of completely abandoning a given land use, a gradient of land use intensification is maintained at village landscape scale. Labour-intensive intensification that has progressed so far seem to have enhanced species richness at village landscape scale without any loss of species on a regional scale or at the cost of deterioration of ecosystem functions and risks to human health.

The use of NTFPs has been identified as means of promoting sustainable rural development together with achieving the goal of environmental conservation. However, efforts on documentation/research on ecological implications of harvesting on multiple ecological levels are limited (Tickin, 2004). One of the aspects in need of further analysis is the impact of land use change, mainly for agriculture, on the availability of NTFPs (Shanley et al., 2002; Alexiades and Shanley, 2004). Both positive and negative effects on the availability of NTFPs in relation to land use change have been documented. *Endopleura uchi* becomes scarcer (Shanley et al.,

2002) and production of palms like *Orbygnia phalerata* (Pinheiro, 2004) and *Astrocarym tucuma* (Schroth et al., 2004) increases following conversion from forest to other land uses. Studies by Pulido and Caballero (2006) show that availability and quality of Sabal yapa decreases due to shifting cultivation and that the harvest of this species in natural systems is sustainable for nine more decades and will be compatible with shifting cultivation as long as land tenure remains communal, long fallow periods and other factors remain unchanged. As at present, timber species and toko palm plantations are the major source of economic benefits to local people. There are several other species like canes and bamboos whose cultivation can be promoted.

The data presented here clearly show that the study area, despite of its extreme marginality, is self-sufficient in food and other essential requirements for survival on one hand and rich in biodiversity and ecosystem functions on the other. A basal area value of exceeding 140 m^2/ha and individual trees as large as 5.57 m circumference indicate huge carbon stocks in these forests. This richness derives from the appreciation of conservation and richness of indigenous knowledge. This aspect should be appropriately recognized in policy documents as a boost to indigenous efforts.

Authors' contributions K.S. Rao was the PHD supervisor of the main author (Shimrah). K.G.Saxena was the Project PI under whom Shimrah worked. T. Shimrah was responsible for experimental and project design.

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