Contribution of indigenous agroforestry systems in biodiversity conservation and ecosystem functioning: experiences from four contrasting systems of Bangladesh

Sharif Ahmed Mukul[1,2,3] and **Narayan Saha**[4]

[1]Technical University of Dresden, Tharandt 010735, Germany
[2]Center for Research on Land-use Sustainability, Maizdee 3800, Bangladesh
[3]Faculty of Life Science, Centre for Forest Landscape and Planning, University of Copenhagen, Denmark
[4]Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh

Summary

In recent years the multipurpose role of agroforestry in conservation of biodiversity and ecosystem functioning has widely been recognized, particularly in most developing countries. We conducted an exploratory study on four contrasting indigenous agroforestry systems in the north-eastern Bangladesh; viz. betel-vine (*Piper betel*) based *Khasia* agroforestry, lemon (*Citrus limon*)/horticulture based and pineapple (*Ananas comosus*) based *Tripura* agroforestry and short-rotation shifting cultivation by *Garo* indigenous community, to realize their biodiversity conservation and ecosystem functioning potentials. The functional diversity of plants, planted-wild crop ratio, cultural management, conservation values and ecosystem benefits of each agroforestry systems were evaluated through a series of systematic survey and standard procedures. Study revealed that betel-vine based agroforestry is the most environmentally and ecologically feasible land-use system in the area supporting higher plant and wildlife diversity and providing greater ecosystem benefits which sometimes even seems better than the indigenous forest cover. Intensification of management practices and extensive use of agro-chemical for higher yield in few of these agroforestry systems however possesses threat to local ecosystem. Study concluded for scientific improvement, greater recognition and wider application of few of these indigenous agroforestry systems that will certainly bring positive outcome in the sustainability of land-use in the country.

Key-words: agroforestry; land-use; livelihoods; conservation; Lawachara National Park; Bangladesh.

Background

One of the main challenges today, particularly in the tropics, is to meet the ever growing demand for agricultural products while conserving biodiversity, providing and regulating critical ecosystem services, and maintaining rural livelihoods (Bhagwat et al. 2008). In that region, agricultural expansions have widely been recognized as the major drivers of forests and biodiversity loss (Sala et al. 2000). Since rates of deforestation continue to rise in many parts of the tropics, a great challenge today is to find suitable approaches which could reduce deforestation and provide rural livelihoods simultaneously in addition with conservation of biodiversity (Bhagwat et al. 2008). Agroforestry is the integration of agricultural and forestry system. There are a lot of evidences where agroforestry has found suitable for biodiversity conservation where the agricultural practices were blamed for the losses of biodiversity. Tropical region is home of world's most diverse and indigenous based agroforestry systems with proven potentials for conservation and ecosystem regulations. The coffee, cacao or the jungle rubber production systems are few examples. However these systems are also in verge of extinction due to rapid intensification to increase the yield . Understanding biodiversity pattern is essential in establishing science based conservation strategies and conservationists from across the globe in last years emphasized on exploring the role of these age-old agro-ecosystems in conserving biodiversity (Schroth et al. 2004).

Bangladesh, being situated in the tropical climate also exceptionally rich in biodiversity (Appanah and Ratnam 1992). In the country there are many agroforestry systems that have been managed by local or indigenous communities for decades. However, atypical to other tropical countries the country also now facing the challenge of intensified management over its traditional agroforestry management systems, which further accelerated by market forces, rapid development and need for more foods and other products necessary for sustaining livelihoods. Although numerous research works have so far been conducted on various aspects of agroforestry in the country (e.g. Khan et al. 2001; Alam et al. 2007) but their conservation role or complementarities as forest have rarely been evaluated. The present study was performed in a north-eastern protected area of the country characterized by four indigenous agroforestry systems. The aim of the study was to explore the plant and wildlife diversity in these agroforestry systems and to assess the role play by these agroforestry systems to sustain certain ecosystem functions.

Figures (from the left)

i. Betel-vine based agroforestry;
ii. Lemon/horticulture agroforestry;
iii. Pineapple agroforestry;
iv. Short-term shifting cultivation;
v. Natural forest patch of the area.

Methods

Field surveys were undertaken in country's most diverse forest patch, i.e. Lawachara National Park ($24^0 30^/$-$24^0 32^/$ N and $91^0 37^/$-$91^0 39^/$ E) during February 2008 to April 2009 (peak vegetation period) through a series of field visits. Survey data were analyzed using standard procedures and methods. The survey procedures are briefly described hereafter;

i. Plants: 50 (10 m X 10 m / 0.01 ha) plots were established in the agroforestry land-uses (10 X 4 land-use) as well as in the forests (or old growth plantations), representing 5 different land-use/land-cover. Plots were chosen randomly using GPS data. All plant individuals ≥ 6 cm at d.b.h were considered as tree, all other individuals ≥ 1.3 m tall and d.b.h less than 6 cm were considered as sapling. Trees and saplings within 10 m X 10 m plot were enumerated for the study. Four rectangular subplots of 2 m X 2 m size were established within each plot to sample the understory vegetation (i.e. herb, shrub and tree seedlings less than < 1.3 m height).

ii. Wildlife:

a) Mammals: Since the primary aim of the study was to compare the mammalian communities at different sites only abundance (presence/absence) data were collected. Abundance data was recorded through arranging visits in some pre-established transects within the agroforestry land-uses/cover. Walk was done at a slow pace (approximately 2 km/hour) along the trails looking for mammalian tracks. Abundance index for each species was estimated by dividing the number of sightings (tracks or primate groups) by the length of a given trail.

b) Birds: 15 points (3x5 land-uses) with 25 m radius were surveyed for a period of 1 hour to assess the bird diversity. Plots were visited in a random and nocturnal birds were excluded from these survey. Most observations were made from the census area centre, with periodic movements within the area to detect and identify cryptic and non-vocal species.

iii. Soil: 25 soil samples (5 X 5 replicates) were collected from four agroforestry land-uses and from forests. Plots for soil sampling were chosen alternately with intention to cover all slope and elevation gradient. For each plot 4 soil samples from 0 - 20 (Of-C horizon) cm depth were collected. A composite sample was prepared by mixing soils from four sites. Soil sampling for bulk density measurement was done once for each of 25 plots using a 178 cm^3 cylinder.

Results

Plant diversity:

A total of 188 plant species were recorded from the survey plots. Among the species 66 were tree followed by 49 herbs, 48 shrubs, 20 climbers and 5 orchids. Shannon-Weiner biodiversity index was highest (3.29) in case of betel-vine based agroforestry system, followed by in lemon agroforestry system (2.85) and in forest (2.71). Betel-vine based agroforestry system also supported the highest number of tree (46), herbs (38) and climber species (14). **Table 1** shows the plant diversity and other features in the study plots.

Table 1. Plant diversity in forest and in the agroforestry land uses

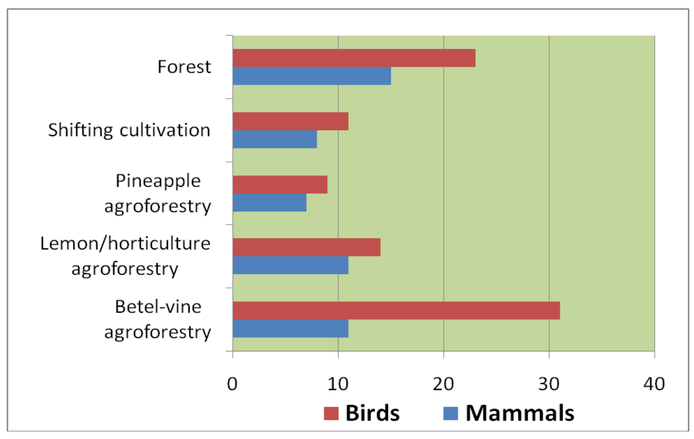
Variables	Land cover / agroforestry land use type				
	Forest	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
No. of tree spp.	37	46	27	14	14
No. of shrub spp.	34	30	21	37	18
No. of herb spp.	28	38	26	23	24
No. of climbers	11	14	5	7	13
Orchids	5	5	2	0	1
Cultivated	-	4	3	5	9
Red listed*	8	8	3	1	-
H	2.71	3.29	2.85	2.24	1.94
No. of tree+sapling /ha	1490	1670	740	330	680
No. of tree seedlings/ha	19375	19000	8125	3812	5875

* as per suggested by Khan et al. 2001; for tree species; *H*- Shannon-Weiner biodiversity index

Wildlife:

27 mammals and 53 bird species were recorded from the study plots. Interestingly, betel-vine based agroforestry system holds the highest diversity of birds, followed by 23 species recorded from the forest. Highest diversity of mammals was found in forest followed by in betel-vine based agroforestry and other agroforestry systems (**Figure 1**). These figure however doesn't show the actual diversity since the survey was carried out during day and was also constrained by time.

Figure 1. Mammals and bird diversity in agroforestry landscapes and in forest



Ecosystem functions:

Ecosystem functions in terms of soil organic carbon and woody biomass allocation in different agroforestry land uses and in forest is given in **Table 2**. Woody biomass was greater in betel-vine based agroforestry system (134.4 ton ha^{-1}) followed by in forest (103.3 ton ha^{-1}), lemon agroforestry (478.9 ton ha^{-1}), shifting cultivation (9.5 ton ha^{-1}) and pineapple agroforestry (5.9 ton ha^{-1}) system and other agroforestry systems. Soil organic carbon was however highest in forest (33.9 ton ha^{-1}), followed by in betel-vine based agroforestry (30.3 ton ha^{-1}) system, shifting cultivation (29.0 ton ha^{-1}) and in others.

Table 2. Biomass and soil carbon in different land cover/land uses

Variables	Land cover / agroforestry land use type				
	Forest	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Woody biomass in trees	898.90 (± 834.1)	1169.04 (± 645.13)	416.491 (± 358.27)	86.503 (± 120.23)	92.48 (± 96.84)
Below ground biomass	134.835 (±125.12)	175.356 (± 96.77)	62.474 (±53.740)	7.785 (±15.0198)	12.484 (±14.380)
Total woody biomass (tones $ha^{-1)}$	103.37	134.44	47.89	5.97	9.57
Soil organic carbon (tones ha^{-1})	33.98 (±10.503)	30.362 (±8.9247)	23.0751 (±8.6675)	19.940 (±3.5836)	29.054 (±4.5830)

* values in the parenthesis indicate the (±SD) under each sub-group

Discussion

Table 3, **4** and **5** shows the similarities of plant, mammals and birds diversity across different agroforestry land uses as well as in the forest. Betel-vine based agroforestry system and forest shows the highest similarity, i.e. 0.640, 0.529 and 0.286 respectively in case of plants, mammals and bird diversity. Pineapple agroforestry on the opposite in most cases shows the highest dissimilarities with forest. Ecosystem benefits (i.e. biomass and soil organic carbon) from betel-vine based agroforestry systems and from forest was also comparable.

Table 3. Similarity matrix (flora)

Land-cover/uses	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Forest	0.640	0.461	0.331	0.416
Betel-vine agroforestry		0.555	0.443	0.426
Lemon agroforestry			0.526	0.472
Pineapple agroforestry				0.440

Table 4. Similarity matrix (mammals)

Land-cover/uses	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Forest	0.529	0.529	0.467	0.261
Betel-vine agroforestry		0.467	0.636	0.462
Lemon agroforestry			0.500	0.462
Pineapple agroforestry				0.364

Table 5. Similarity matrix (birds)

Land-cover/uses	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Forest	0.286	0.154	0.081	0.135
Betel-vine agroforestry		0.194	0.067	0.214
Lemon agroforestry			0.210	0.136
Pineapple agroforestry				0.111

Key References

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