Chapter 8
Biodiversity Conservation and Ecosystem Functions of Traditional Agroforestry Systems: Case Study from Three Tribal Communities in and Around Lawachara National Park

Sharif Ahmed Mukul

Abstract Agroforestry—now-a-days considered as a future land-use strategy due to its' structural complexity and perceived environmental benefits. The present study was performed on four contrasting traditional agroforestry systems (i.e. betel vine based *Khasia* agroforestry, lemon and pineapple based *Tripura* agroforestry, and short-term shifting cultivation practised by the *Garo* tribes) in Bangladesh, to realize their conservation prospects (in terms of plants, birds and mammalian diversity) and ecosystem benefits. The study identified betel vine (*Piper betel*) based agroforestry system in the area as critical in conserving biodiversity and maintenance of few ecosystem services. In Bangladesh, where poverty and high population density is widespread with higher dependence on forests for livelihoods and high deforestation rate, indigenous agroforestry systems could potentially be used to bridge the gap between conservation and livelihoods. Incorporating such systems in REDD + mechanism could also be used for sustainable financing of conservation projects in protected areas in human dominated landscapes.

8.1 Introduction

Agricultural expansions has widely recognized as the major driver of forests and biodiversity loss in developing countries (Sala et al. 2000). It is also one of the main challenges today, particularly in the developing tropics in order to meet the

S. A. Mukul (✉)
Tropical Forestry Group, School of Agriculture and Food Sciences,
The University of Queensland, Brisbane, QLD 4072, Australia
e-mail: s.mukul@uq.edu.au; sharif_a_mukul@yahoo.com

S. A. Mukul
Centre for Research on Land-Use Sustainability, Maijdi, Noakhali 3800, Bangladesh

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ever growing demand for agricultural products while conserving biodiversity, providing and regulating critical ecosystem services, and maintaining rural livelihoods (Harvey and Gonzalez 2007). As rates of deforestation continue to rise in many parts of the tropics, the international conservation community is faced with the challenge of finding approaches which can reduce deforestation and provide rural livelihoods in addition to conserving biodiversity (Bhagwat et al. 2008). Agroforestry is an integration of agricultural and forestry production system, and has believed to hold a great potentials for conserving biodiversity (Schroth et al. 2004). There has been lot of evidences where agroforestry has been found suitable for biodiversity conservation over agricultural practices. The tropical region is the home of world's most diverse and traditional agroforestry systems practiced by indigenous communities that have proven their conservation potentials while providing or maintaining other necessary services and benefits (Schroth et al. 2004). The coffee, cacao or the jungle rubber production systems are some example. However these systems are also in verge of extinction due to rapid intensification to increase crop yields or productivity. Understanding biodiversity pattern is essential in establishing science based conservation strategies (Trimble and van Aarde 2012). Conservationists from across the globe in the last years hence tries to explore 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 (Khan et al. 2006), which further accelerated by market forces, rapid development and need for more foods and other products necessary for sustaining livelihoods (Mukul et al. 2012,2014. Although numerous research works have so far been conducted on various aspects of agroforestry in the country (Khan et al. 2006; 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 traditional agroforestry systems, viz., betel-vine (*Piper betel*) based *Khasia* agroforestry system, lemon (*Citrus limon*) and pineapple (*Ananas comosus*) based *Tripura* agroforestry systems and short-term shifting cultivation system followed by the *Garo* tribe (Figs. 8.1, 8.2, 8.3 and 8.4). 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 ecosystem functions taking carbon storage as an example. The study is useful for understanding conservation values of such systems in protected areas, and to reevaluate their potentials for conservation and management of protected areas in human dominated landscapes.

Fig. 8.1 Betel leaf harvesting from the betel vine (*Piper betel*)-based *Khasia* agroforestry system in Lawachara NP

Fig. 8.2 Lemon (*Citrus limon*)-based *Tripura* agroforestry system in and around LNP

Fig. 8.3 Pineapple (*Ananas comosus*)-based *Tripura* agroforestry system in and around LNP

Fig. 8.4 Short-term shifting cultivation system by the *Garo* tribe in the forests of LNP

8.2 Findings of the Study

8.2.1 Site Characteristics

Table 8.1 shows the physical and historical attributes of the survey plots. Averaged elevation was highest (34.1 m) in case of betel-vine agroforestry plots where pineapple agroforestry plots were located in steeper slope (39.5°). Also canopy coverage in the studied agroforestry plots were highest (40.5 %) in case of betel-vine based agroforestry system followed by in forest (34.3 %). Amongst the survey plots, betel-vine based agroforestry plots were under such kind of land-uses for about 39 years, whereas the plots under shifting cultivation system was only 1 year old because the system is different than the conventional shifting cultivation system as followed in south-east Asia and only permitted by the forest department for only 1 season after clear felling a site and/or before establishment of new plantation.

Table 8.1 Physical and historical attributes of the sites

Variable	Land cover/agroforestry land use				
	Forest	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Elevation (m)	29.1 (±10.39)	34.1 (±17.97)	26.8 (±11.93)	24.6 (±7.30)	27.9 (±9.50)
Slope (in degree)	17.0 (±14.76)	28.5 (±16.51)	17.0 (±8.56)	39.5 (±13.01)	28.0 (±15.31)
Canopy cover (%)	34.3 (±13.27)	40.5 (±12.35)	17.2 (±6.49)	4.2 (±2.53)	7.1 (±4.48)
Year under land cover/use	65.8 (±15.94)	39.0 (±15.6)	20 (±8.22)	17.5 (±6.84)	1.0 (0.0)

Values in the parenthesis indicate the (±SD) under corresponding group/sub-group

8.2.2 Plant Diversity

A total of 188 plant species were recorded from the study plots. Among the species 66 were tree followed by 49 herbs, 48 shrubs, 20 climbers and 5 species of orchids. Shannon-Weiner biodiversity index (*H*) 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). Astonishingly, the number of trees and saplings in unit area also highest in case of betel-vine based agroforestry system (1,670 individuals/ha) as compared to forest (1,490). However the number of tree seedlings (per ha) was highest (19,375) in forest followed by in betel-vine based agroforestry system (19,000). Table 8.2 shows the plant diversity and other information in the studied agroforestry plots and in plots in the forest. The number of cultivated species was higher in shifting cultivation areas. Also both forest and agroforestry areas supported eight plant species those are endangered and 'Red listed' locally.

8.2.3 Wildlife Diversity

During the survey 27 mammalian species and 53 bird species were recorded from the studied land-uses/cover. Interestingly, betel-vine based agroforestry system holds the highest diversity of birds (31 species), followed by 23 species recorded from the forest. Also highest diversity of mammals was found in forest (15 species) followed by in betel-vine based agroforestry areas (11 species), lemon agroforestry (11 species), shifting cultivation (8 species) and pineapple agroforestry (7 species) system (Fig. 8.5). The survey however does not represent the actual diversity since the survey was carried out during the day and was constrained by time.

Table 8.2 Plant diversity in forest and in the agroforestry land uses

Variable	Land cover/agroforestry land use				
	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[a]	8	8	3	1	–
H^{b}	2.71	3.29	2.85	2.24	1.94
No of tree and sapling/ha	1,490	1,670	740	330	680
No. of tree seedlings/ha	19,375	19,000	8,125	3,812	5,875

[a] As per Khan et al. (2001)
[b] *H*—Shannon-Weiner biodiversity index

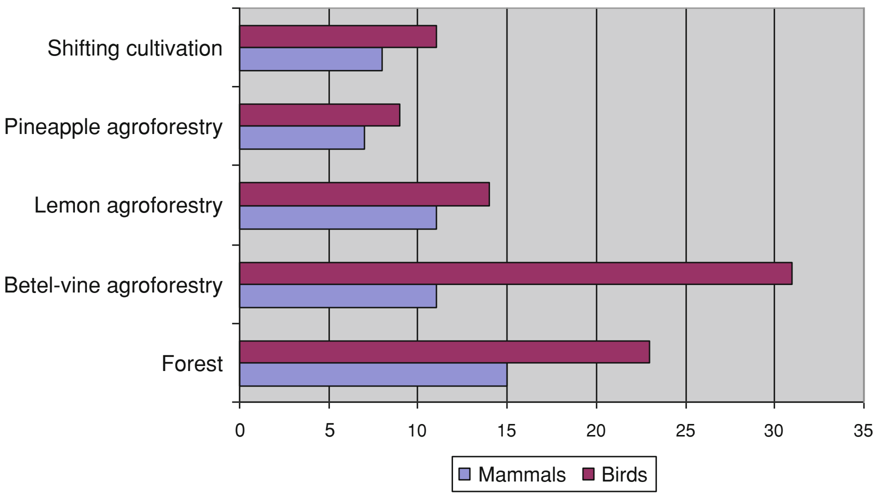

Fig. 8.5 Mammals and bird diversity in contrasting agroforestry land-uses and in forest

8.2.4 Ecosystem Carbon Storage

Soil organic carbon (up to 20 cm depth) and allocation of biomass carbon in different agroforestry land uses and in forest is given in Table 8.3. Biomass carbon was greater in betel-vine based agroforestry system (134.44 Mg ha^{-1}) followed by in forest (103.37 Mg ha^{-1}), lemon agroforestry (47.90 Mg ha^{-1}), shifting cultivation

Table 8.3 Biomass and soil carbon in different land-uses/cover

Variable	Land cover/agroforestry land use				
	Forest	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Biomass carbon (Kg) in trees (in 10×10 m^2 plot, $d < 6$ cm)	898.90 (±834.1)	1169.04 (±645.13)	416.49 (±358.27)	86.50 (±120.23)	92.48 (±96.84)
Below ground biomass carbon (Kg) (in 10×10 m^2 plot, $d < 6$ cm)	134.84 (±125.12)	175.36 (±96.77)	62.47 (±53.74)	7.79 (±15.02)	12.48 (±14.38)
Total woody biomass carbon Mg ha^{-1}	103.37	134.44	47.89	5.97	9.57
Soil organic carbon in Mg ha^{-1} (up to 20 cm depth)	33.98 (±10.50)	30.36 (±8.92)	23.08 (±8.67)	19.94 (±3.58)	29.05 (±4.58)

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

(9.57 Mg ha^{-1}) and pineapple agroforestry (5.97 Mg ha^{-1}) system. Soil organic carbon was however higher in forest (33.98 Mg ha^{-1}), followed by in betel-vine based agroforestry (30.36 Mg ha^{-1}) system, shifting cultivation (29.05 Mg ha^{-1}) and in others.

Tables 8.4, 8.5 and 8.6 shows the similarities of plant diversity, mammals and birds across different agroforestry land-uses as well as in the forest. Betel-vine based agroforestry system and forest shows the highest similarity (0.640, 0.529, 0.286), where the lowest similarity was observed between pineapple based agroforestry and between forest. The reason behind is, production of pineapple requires regular sunlight. Betel-vine agroforestry system supported comparatively higher number of mammals and birds than other agroforestry systems do supports, which even sometimes found superior than the forest. In case of ecosystem functions (i.e. carbon storage) betel-vine based agroforestry systems also shows the highest similarity with forest.

8.3 Conclusion and Policy Implications

It has repeatedly been argued by the conservation biologists that, the application of wildlife-friendly farming methods could potentially reduce the impact of agriculture on biodiversity (Green et al. 2005). In regions, where deforestation has

Table 8.4 Similarity matrix of plant species across studied land-cover/uses in Lawachara

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 8.5 Similarity index of mammals across studied land-cover/uses in Lawachara

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 8.6 Similarity index of birds across studied land-cover/uses in Lawachara

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

drastically affected original forests, and where poverty, unemployment and high population density is pervasive, traditional agroforestry systems can act as refuges for many species (Moguel and Toledo 1999; Bhagwat et al. 2008). From this study it was clear that in Lawachara area betel-vine based agroforestry system contributed to the conservation of biodiversity in greater extent than that of other studied agroforestry systems in that area, and could provide as much environmental benefits as by forests.

Park-people conflicts and limited access to economic incentives are common in tropical developing countries, which is not different in Bangladesh (Mukul et al. 2012, 2014; Rashid et al. 2013). The study demonstrates that, some of the indigenous agroforestry systems (here betel-vine agroforestry) could potentially be used in such context where conservation of biodiversity is critical. In tropical developing region clean development mechanism (CDM) and reducing emissions from deforestation and forest degradation (currently REDD + in short) is gaining wider recognition for rewarding small-holder farmers for any carbon offsets made by their land-use (Shin et al. 2007). The Government of Bangladesh through proper planning could use that opportunity which could provide twofold benefits, i.e. sustainable financing of conservation projects and cash support to small-holder farmer for their environmentally sustainable land-use practice.

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