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Homegarden agroforestry systems: an intermediary for biodiversity conservation in Bangladesh

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Abstract Biodiversity conservation is one of the important ecosystem services that has been negatively impacted by anthropogenic activities. Natural forests (NF) harbor some of the highest species diversity around the world. However, deforestation and degradation have resulted in reduced forest land cover and loss of diversity. Homegarden agroforestry (AF) systems have been proven to be an intermediary for biodiversity conservation. In this study, we evaluate the effectiveness of home garden AF practices to conserve tree species diversity in Bangladesh and compare them with tree species diversity in NF. A total of nine locations were selected for this synthesis from published literature which comprised of five AF sites and four NFs. Shannon–Weiner Diversity Index (H) was similar for home-garden AF (3.50) and NF (2.99), with no statistical difference between them. Based on non-metric multi-dimensional scaling (NMDS) ordination analysis, the AF and NF plots showed distinct separation. However, Bray–Curtis dissimilarity index ranged from 0.95 to 0.70 indicating nearly no overlap in species composition to significant overlap between AF and NF. Based on our results, we conclude that AF can serve as an important ecological tool in conserving tree species diversity, particularly on landscapes where NF fragments represent only a small fraction of the total land area. Creating and maintaining AF habitats in such human dominated landscapes should be part of the biodiversity conservation strategy.

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Introduction

It is well established that biodiversity conservation and the maintenance of associated ecosystem services are vital for human well-being (Beaumont et al. 2011). However, over 75 % of Earth's terrestrial biomes have shown alteration as a result of anthropogenic activities. Species diversity is one of the most intuitive and widely adopted measures of biodiversity at both ecological and biogeographic scales. Species diversity is often defined as a combination of richness and evenness (Chiarucci et al. 2011). Tropical forests play an indispensable role in biophysical equilibrium at regional and global levels, in particular, by regulating water, carbon and nitrogen cycles while maintaining species diversity.

Habitat degradation, fragmentation, and overexploitation have contributed to the loss of biodiversity around the world. The impact of these changes on biological systems are manifested as shifts in phenology, interactions, species distributions, morphology and net primary productivity (Gardner et al. 2009; Beaumont et al. 2011). Several biodiversity hotspots in south-east Asia are endangered as a result of deforestation, habitat destruction, overexploitation, pollution, and climate change. The impact has been drastic particularly in the species rich moist tropical forest vegetation of Bangladesh (Appanah and Ratnam 1992). There has been a lack of concern about ecosystem restoration compounded with primitive and ineffective forest practices and on-going deforestation (Muzaffar et al. 2011). The ability of many tree-covered, but intensively used landscapes to support native species suggests that maintaining and creating habitats in human dominated landscapes can help to conserve a large proportion of biodiversity (Acharya 2006; Bhagwat et al. 2008).

Agroforestry has received widespread attention in tropical and temperate regions of the world for providing ecosystem services such as carbon sequestration, biodiversity conservation, soil quality, and preserving air and water quality (Thevathasan and Gordon 2004; Jose 2009). Especially in tropical landscapes, more than 90 % of biodiversity resources are found in human dominated landscapes (Garrity 2004). Agroforestry practices can be a potentially valuable conservation tool that can be useful for reducing land-use pressure while enhancing rural livelihoods (Garrity 2004; Maroyi 2009).

Agroforestry has been shown to preserve rich species diversity around the world (Mendez et al. 2001; Hemp 2006; Borkhataria 2012). The role of agroforestry (AF) systems in maintaining species diversity can play an important role in biodiversity conservation in human-dominated landscapes (Anand et al. 2010). Considering the fact that ecosystems and species are disappearing at an alarming rate, the role of AF as a conservation tool needs to be exploited further (Bengtsson et al. 2000; Alavalapati et al. 2004; Jose 2009; 2011). The multifunctional role of AF has been highlighted by the Millennium Ecosystem Assessment (MEA 2005) and the International Assessment of Agricultural Science and Technology and Development (IAASTD 2008). In a country like Bangladesh where less than 6 % forest land cover exists, it is critical to examine the role of AF for conserving species diversity. In this study, we compared two different habitats, homegarden AF and natural forests (NF), to test the hypothesis that AF can conserve tree species diversity and serve as biodiversity havens on a landscape where NF have declined and the remaining fragments are degraded.

Materials and methods

We selected nine published studies from Bangladesh that provided original species data from AF and NF. The selected study sites were located in north-eastern and south-eastern Bangladesh (Table 1), with two sites in Sylhet, five sites in Chittagong, and one each in Thakurgaon and Gazipur. One site each for AF and NF was located in Sylhet. Three NF and two AF sites were located in Chittagong while the last two AF sites were located in Gazipur and Thakurgaon. The soils across the study area ranged from clay loam to sandy loam, depending on the topography and other geographical location. A tropical to sub-tropical climate dominates the study area with long dry season and moderately cool winter and mean annual precipitation varying from 1,800 to up to 3,800 mm. In most studies, AF sites

Table 1 List of study sites included in the meta-analysis of tree species diversity in homegarden AF and NF from Bangladesh

Land use	Location	References
AF1	Chitagong	Alam and Masum (2005)
AF2	Chittagong	Momen et al. (2006)
AF3	Gazipur	Ahmed and Rahman (2004)
AF4	Sylhet	Motiur et al. (2005)
AF5	Thakurgaon	Zaman et al. (2010)
NF1	Chittagong	Ullah and Al-Amin (2008)
NF2	Chittagong	Alamgir and Al-Amin (2008)
NF3	Sylhet	Saha and Azam (2004)
NF4	Chittagong	Madecor (1997) (Unpublished data)

were divided into three size classes (small, medium, and large) with total area ranging from less than 500 to more than 2,500 m^2. In all the studies, data was collected either through direct recording or through interviews with rural household members. Forest inventory data was collected following standard procedures. Trees with less than 20 cm diameter at breast height (DBH) were not included as part of the dataset.

We calculated species richness or number of unique species (S), Shanon–Weiner diversity index (H) (Krebs 1985), and Bray–Curtis dissimilarity index (Bray and Curtis 1957) using PC-ORD 6.0 (McCune and Mefford 2011). The equations for the different indices are as follows:

1. The Shanon–Weiner diversity index,

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

where H = Index of species diversity, Pi = Proportion of the ith species, S = Total number of species.

2. Bray–Curtis dissimilarity index.

$$BC_{ij} = \frac{2C_{ij}}{S_i + S_j}$$

where C_{ij} = the sum of the lesser value of only those species in common between both sites, S_i and S_j = the total number of specimens counted at both sites.

After evaluating the dataset, we decided to use only the tree species data for this study because of comprehensiveness. Shrubs and herbs were not included in our analysis as detailed information was not available for all sites. PC-ORD 6 software (McCune B, Mefford MJ: PC-ORD for Windows: multivariate analysis of ecological data, 6 ed, MjM Software, Gleneden Beach, Oregon, 2011) was used for all multivariate statistical analyses of the species diversity. The non-metric multidimensional scaling (NMDS) ordination method calculated on the basis of Sørensen's distance. NMS was run with two ordination axes, 250 iterations, stability criterion of 0.0001, and 50 runs with the real data.

Results and discussion

A total of 126 tree species were recorded across the nine sites that included all AF and NF plots. A total of 91 individual species were observed in all the AF plots while 61 tree species were observed in the NF plots. Mango (*Mangifera indica*), Guava (*Psidium guajava*), Jackfruit (*Artocarpus heterophyllus*), Coconut (*Cocos nucifera*), and betel nut (*Areca catechu*) were the most common tree species in the AF sites and were observed at each location. Other common tree species observed were litchi (*Litchi chinensis*), tamarind (*Tamarindus indica*), date palm (*Phoenix sylvestris*), teak (*Tectona grandis*) and mahogany (*Swietenia mahagoni*). In the NF, the commonly observed tree species were kadam (*Anthocephalus chinensis*), black berry (*Syzygium cumini*), jackfruit (*Artocarpus heterophyllus*), and koroi (*Albizia procera*). It can be predicted that homestead owner preference had a large impact on species richness in AF systems. Preferential selection of fruit, nuts, and ornamental trees among the AF sites most likely had a major influence for the observed richness in these sites. This was empirically observed by Harvey and Gonza'lez Villalobos (2007) who found that AF systems maintained avian species richness but modified assemblage.

The Shannon–Weiner Diversity Index did not exhibit any significant difference between AF (3.5) and NF (2.989) ($p < 0.0725$) (Table 2). Natural forests have been reported to have higher species diversity as a result of complex interaction among the biota and minimal anthropogenic disturbances (Hackl et al. 2004). Intentional inclusion of fruit, nut, and ornamental trees in AF and the degradation of NF due to anthropogenic pressure might explain the similar levels of diversity observed in our analysis (Gibson et al. 2011). NMS plots provide a best-fit technique to arrange samples which is interpreted by measuring the distance between each pair of samples in ordination space.

The NMDS distribution plot for the nine plots (Fig. 1) shows that the AF and NF sites clustered separately along the two principal axes. The two axes together explained approximately 81 % of the variability in tree species diversity among the habitats. Using Bray–Curtis ordination, it was observed that

Table 2 Species richness (number per hectare) and Shannon–Weiner diversity index for the two habitat types for the meta-analysis of tree species diversity in Bangladesh

	Richness (S)	Shannon–Weiner Index (H)
AF	91	3.50
NF	61	2.99

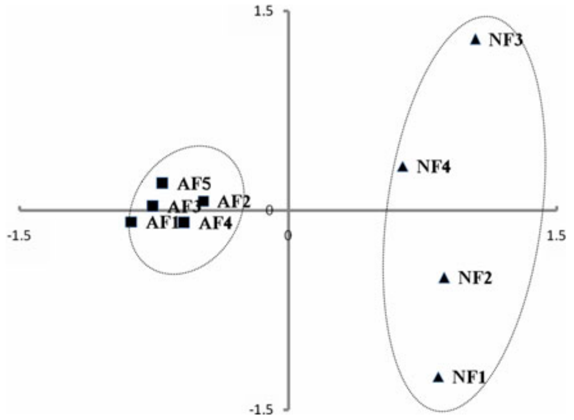

Fig. 1 Non-metric multidimensional scaling plot for the different locations (final stress 10.53, instability 0.00001). X and Y axes explained 52 and 29 % of the total variation respectively. AF refers to agroforestry systems while NF refers to natural forests. Numbers associated with AF and NF refers to individual site locations

there was moderate to high variation between AF and NF in terms of species diversity (Table 3). While this dissimilarity was lower between the different AF sites, it was higher between AF and NF. Within each land use type however, there was a greater variation among the AF, most likely due to the variations in location, climate and topography. Using the different diversity indices and Bray–Curtis dissimilarity index, it can be argued that AF systems are equally efficient as NF in conserving tree species diversity, and such systems can be used as stepping stones for biodiversity conservation at the landscape level. It is evident from these results that AF systems can form an intermediary biodiversity haven between NF and agriculture.

Although 6 % forest land cover exists in Bangladesh, a vast majority belongs to plantation forests and not to primary forests. Only the mangrove forests in the Sundarban delta region and moist tropical forests in the Chittagong Hill Tracts are the remnants of natural vegetation in the country. Small scale AF systems like the AF form a diverse and important tropical land use and provide an array of biophysical and socioeconomic values while influencing variability in biodiversity retention rates across agroforests (Acharya 2006). It is an appropriate form of land use system in tropical and subtropical areas where cropping patterns are dependent on the owner's choice, farm size, availability of planting material and financial capacity. AF systems in Bangladesh comprise approximately 270,000 ha and about 80–82 % of forest products annually is harvested from these farming systems. It is critical to create and maintain species rich homegarden AF systems on such human-dominated landscape to conserve both floral and faunal diversity.

The most important attribute of AF is the rich diversity of herbs, shrubs, vines, trees, and other perennials (Kumar 2011). While there is debate on the species-area relationship in AF (Abdoellah et al. 2006; Mendez et al. 2001; Albuquerque et al. 2005), this study found a slightly positive correlation between the size of AF and species diversity (Fig. 2). Previous studies have pointed out that area did not positively influence biodiversity in AF practices (Abdoellah et al. 2006). Kabir and Webb (2009), however, documented that a positive relationship was observed between size of AF systems

Table 3 Bray–Curtis dissimilarity index across the AF and NF plots in Bangladesh

	AF1	AF2	AF3	AF4	AF5	NF1	NF2	NF3	NF4
AF1	0.00	0.61	0.52	0.69	0.67	0.95	0.80	0.89	0.85
AF2		0.00	0.44	0.65	0.58	0.83	0.75	0.83	0.77
AF3			0.00	0.45	0.54	0.86	0.84	0.90	0.70
AF4				0.00	0.66	0.83	0.81	0.86	0.75
AF5					0.00	0.81	0.87	0.86	0.69
NF1						0.00	0.77	0.88	0.75
NF2							0.00	0.83	0.80
NF3								0.00	0.75
NF4									0.00

AF refers to agroforestry systems while NF refers to natural forests. Numbers associated with AF and NF refers to individual site locations

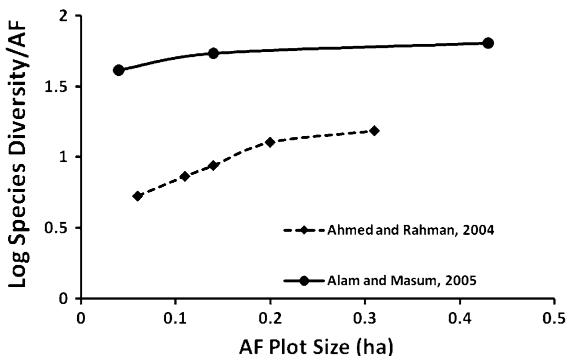

Fig. 2 Species–area relationship observed in studies from the AF sites in this study. A log scale was used for species diversity data

and plant species diversity. Thus, negative influences of biodiversity loss could be balanced to a certain extent through homegarden AF.

Conclusion

Many tropical plant species are threatened due to reduction in forest area, fragmentation, and degradation. In order to conserve biodiversity, it is important to understand the local, regional, socioeconomic patterns that influence biodiversity at a landscape level. In Bangladesh, most studies of AF, whether descriptive or quantitative and experimental, demonstrate that these systems conserve species diversity. These AF systems have been producing commodities for centuries in a resource efficient way and are considered economically viable and ecologically sustainable. Homegarden AF practices with less intensive management and high canopy cover have high species richness and are more similar to NF than intensively managed agroecosystems with open canopies. Our analysis showed that homegarden AF systems in Bangladesh could be critical in conserving tree species diversity. Creating and maintaining species rich homegarden AF in such human-dominated landscapes should be part of the biodiversity conservation strategy.

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References

Abdoellah OS, Hadikusumah HY, Takeuchi K, Okubo S, Parikesit (2006) Commercialization of homegardens in an Indonesian village: vegetation composition and functional changes. Agrofor Syst 68:1–13

Acharya KP (2006) Linking trees on farms with biodiversity conservation in subsistence farming systems in Nepal. Biodivers Conserv 15:631–646

Ahmed MFU, Rahman SML (2004) Profile and use of multi-species tree crops in the homesteads of Gazipur District, Central Bangladesh. J Sustain Agric 24(1):81–93

Alam MS, Masum KM (2005) Status of homestead biodiversity in the offshore island of Bangladesh. Res J Agric Biol Sci 1(3):246–253

Alamgir M, Al-Amin M (2008) Allometric models to estimate biomass organic carbon stock in forest vegetation. J For Res 19(2):101–106

Alavalapati JRR, Shrestha RK, Stainback GA, Matta JR (2004) Agroforestry development: an environmental economic perspective. Agrofor Syst 61:299–310

Albuquerque UP, Andrade LHC, Caballero J (2005) Structure and floristics of homegardens in Northeastern Brazil. J Arid Environ 62:491–506

Anand MO, Krishnaswamy J, Kumar A, Bali A (2010) Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: remnant forests matter. Biol Conserv 143(2010):2363–2374

Appanah S, Ratnam L (1992) The importance of forest biodiversity to developing countries and Asia. J Trop For Sci 5(2):201–215

Beaumont LJ, Pitman A, Perkins S, Zimmermann NE, Yoccoz NG, Thuiller W (2011) Impacts of climate change on the world's most exceptional ecoregions. PNAS 108: 2306–2311

Bengtsson J, Nilsson SG, Franc A, Menozzi P (2000) Biodiversity, disturbances, ecosystem function and management of European forests. For Ecol Manag 132:39–50

Bhagwat SA, Willis KJ, Birks HJB, Whittaker RJ (2008) Agroforestry: a refuge for tropical biodiversity. Trends Ecol Evol 23:261–267

Borkhataria RR (2012) Species abundance and potential biological control services in shade vs. sun coffee in Puerto Rico. Agric Ecosyst Environ 151:1–5

Bray JR, Curtis JT (1957) An ordination of the upland forest communities of southern Wisconson. Ecol Monogr 27(4):325–349

Chiarucci A, Bacaro G, Scheiner SM (2011) Old and new challenges in using species diversity for assessing biodiversity. Phil Trans R Soc B 366:98–109

Gardner TA, Barlow J, Chazdon RL, Ewers R, Harvey CA, Sodhi N (2009) Prospects for tropical forest biodiversity in a human-modified world. Ecol Lett 12:561–582

Garrity DP (2004) Agroforestry and the achievement of the millennium development goals. Agrofor Syst 61:5–17

Gibson L, Tien L, Ming K, Lian P, Brook BW et al (2011) Primary forests are irreplaceable for sustaining tropical biodiversity. Nature 478:378–381

Hackl E, Zechmeister-Boltenstern S, Bodrossy L, Sessitsch A (2004) Comparison of diversities and compositions of bacterial populations inhabiting natural forest soils. Appl Environ Microbiol 70:5057–5065

Harvey CA, Gonza′lez Villalobos JA (2007) Agroforestry systems conserve species-rich but modified assemblages of tropical birds and bats. Biodivers Conserv 16:2257–2292

Hemp A (2006) The banana forests of Kilimanjaro: biodiversity and conservation of the Chagga homegardens. Biodivers Conserv 15:1193–1217

IAASTD (2008) International Assessment of Agricultural Knowledge, Science and Technology for Development: executive summary of the synthesis report, http://www.agassessment.org/index.cfm?Page=About_IAASTD&ItemID=2. Accessed 2 March 2012

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76:1–10

Jose S (2011) Managing native and non-native plants in agroforestry systems. Agrofor Syst 83:101–105

Kabir ME, Webb EL (2009) Household and homegarden characteristics in southwestern Bangladesh. Agrofor Syst 75:129–145

Krebs CJ (1985) Ecology: the experimental analysis of distribution and abundance. Harper and Row, New York

Kumar BM (2011) Species richness and aboveground carbon stocks in the homegardens of central Kerala, India. Agric Ecosyst Environ 140:430–440

Maroyi A (2009) Traditional homegardens and rural livelihoods in Nhema, Zimbabwe: a sustainable agroforestry system. Int J Sustain Dev World Ecol 16:1–8

McCune B, Mefford MJ (2011) PC-ORD for windows: multivariate analysis of ecological data, 6th edn. MjM Software, Gleneden Beach

Mendez VE, Lok R, Somarriba E (2001) Interdisciplinary analysis of homegardens in Nicaragua: micro-zonation, plant use and socioeconomic importance. Agrofor Syst 51:85–96

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, DC. http://www.millenniumassessment.org/documents/document.354.aspx.pdf. Accessed 2 March 2012

Momen RU, Huda SMS, Hossain MK, Khan BM (2006) Economics of the plant species used in homestead agroforestry on an offshore sandwip Island of Chittagong District. Bangladesh J For Res 17(4):285–288

Motiur RM, Tsukamoto J, Furukawa Y, Shibayama Z, Kawata I (2005) Quantitative stand structure of woody components of homestead forests and its implications on silvicultural management: a case study in Sylhet Sadar, Bangladesh. J For Res 10:285–294

Muzaffar SB et al (2011) The endangered forests of Bangladesh: why the process of implementation of the convention on biological diversity is not working. Biodivers Conserv 20:1587–1601

Saha N, Azam MA (2004) The indigenous hill-farming system of Khasia Tribes in Moulvibazar District of Bangladesh: status and impacts. Small scale For Econ Manag Policy 3(2):273–281

Thevathasan NV, Gordon AM (2004) Ecology of tree intercropping systems in the North temperate region: experience from southern Ontario, Canada. Agrofor Syst 61:257–268

Ullah MR, Al-Amin M (2008) Natural Forest of Bangladesh with changing climate. Institute of Forestry and Environmental Sciences, Chittagong University, Bangladesh. http://www.forestrynepal.org/article/946/3677. Accessed 2 March 2012

Zaman S, Siddiquee SU, Katoh M (2010) Structure and diversity of homegarden agroforestry in Thakurgaon District, Bangladesh. Open For Sci J 3:38–44