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Disappearing Forest Tree Species Diversity in Tropical Moist Deciduous Forest and Its Implications: A Case Study in the Madhupur Tract of Central Bangladesh

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ABSTRACT : A study was conducted for indentifying the floral biodiversity of woody species by calculating four diversity indices using data collected from 4 stands of different age groups and disturbance regimes in two areas of Madhupur tract. Results showed that highest species diversity in the old growth secondary coppice forest (>60 years) under moderate anthropogenic disturbances of Madhupur National Park area (delete (D=0.74, H'=3.36) followed by old growth secondary forest stands (>40 years) under moderate disturbances at Bhawal National Park area (D=0.65, H'=2.81). Plant species diversity of the young enrichment plantations (<20 years and <15 years) under high anthropogenic disturbances in both the areas are much low (D=0.54 and H'=2.16 and D=0.52 and H'=1.92 respectively), which indicate high anthropogenic disturbances coupled with introduction of invasive exotics that are rival for endemic species are detrimental for conservation of biological diversity of tropical moist deciduous forests of Madhupur tract in Bangladesh.

Keywords : Floral biodiversity, Anthropogenic disturbances, Diversity indices, Madhupur Tract, Bangladesh.

INTRODUCTION

Bangladesh is a South Asian country with very low percentage of forests. The total area of forest of Bangladesh is 1.3 million hectares that amounts 10.2 % of the country's land area (FAO, 2003). One of the peculiarities of forest resources distribution of Bangladesh is that the resources are very eccentrically distributed. More than 90 percent of the government forests are concentrated within 12 districts in the east and southeastern region of the country. Vast central and northwestern parts have only patches of forests covering 0.12 million ha, that represents only 4.65% of country's forested area (GOB, 1992; Rahman et. al., 2010). These forests are classified as tropical moist deciduous forests (Champion et. al., 1965). Sal (*Shorea robusta*) is the dominant species. Other than the sal, the other common trees are palash (*Butea monosperma*), haldu (*Adina cordifolia*), shidah jarul *(Lagerstroemia parviflora*), bazna (*Zanthoxylum rhetsa*), hargoja (*Dillenia pentagyna*), koroi (Albizia spp.), menda (*Litsea monopetala*), kushum(*Schleichera olosa*), udhal (*Sterculia villosa*), bahera (*Terminalia belerica*) , kurchi (*Holarrhena antidysenterica*), haritaki (*Terminalia chebula*), pitraj (*Aphanamixis polystachya*), sheora (*Streblus asper*), dephajam (*Cleistocalyx operculatus*) sonalu (*Cassia fistula*), assar (*Grewia microcos*), amlaki (*Phyllanthus emblica*), adagash (*Croton oblongifolius*), etc. (Banglapedia, 2010). Until the beginning of the 20th century, tropical moist deciduous forests existed as a continuous belt from Comilla to Darjeeling of India. At present, most of the forest area is under occupation and the present remaining stands of sal are of poor stocking and quality, consisting of degraded coppice and plantations. The mass destruction of sal forests occurred in early 70s during and immediately after the liberation war of Bangladesh in 1971, as freedom fighters widely used these forests as shelter and absence of law and order immediately after the liberation war.

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The main cause of depletion of this forest was due to the land clearance for agriculture and forestland encroachment. Encroachment and illicit removal of timber and firewood from the forests are the major forest conservation problems in the area. The sal forests are under constant human pressure from all sides as there was no boundary of the forest. The areas under encroachments estimated about 0.036 million ha and the number of encroachers are about 100,000 (Rahman et. al., 2010). The chief reasons of encroachments are: legal lacunae due to past tenurial history of the lands, and intricate nature of the boundary of the forest land and cultivable lands, and failure to complete the forest settlement operations initiated in the 1950's. The main reason of illicit removal of timber are: wide gap between the demand and supply of wood and its consequent high; limited year round employment in rural areas resulting in compelling dependence on collection of wood from the forests for subsistence (Chowdhury, 1994). The present notified area of sal forests is largely honeycombed with rice fields. These forests are now distributed in Dhaka, Tangail, Mymensingh, Dinajpur and Comilla (Rahman et. al., 2010). Owing to huge population pressure, wrong management approach and hostile activities of both the indigenous and greed encroachers' diversity of Madhupur tract is decreasing continuously. Due to degradation of the natural forest, most of the wildlife in the sal forest has also rapidly vanished. Two centuries ago elephants, rhinoceros have been reported in these forests but became extinct in the late nineteenth century. Tigers and leopards were numerous, but tigers dwindled in the early twentieth century and extinct fifty years ago. Leopards, bears, deer, and many other animals, which were abundant in the sal forest areas, have now totally disappeared. Bands of monkeys are rarely seen these days. Although common in the past, pheasants, peacocks, pythons, and a variety of birds have no place now in the afforested rubber and fuel-wood plantations. The Leopard-Cat, Fishing-Cat, Jungle Cat and small Indian Civet are still to be found (UNEP, 2001; Banglapedia, 2010). In Bangladesh Capped Langur (*Trachypithecus pileatus*) was found most frequently in the Madhupur forest tract (Khan, 1981). But due to habitat loss and degradation induced by human, IUCN enlisted Capped langur (*Trachypithecus pileatus*) as endangered species in its red list of 2008 (IUCN, 2008). Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES) listed capped langur under appendix I, which means the species is threatened with extinction for Bangladesh (UNEP-WCMC, 2004). Tree species like *Vatica lanceaefolia*, and *Hopea odorata* are also listed as critically endangered and vulnerable species respectively in 2008 IUCN Red List of Threaded Species (IUCN, 2008). Hence it is desirable that measures should be taken to preserve the biodiversity of Madhupur tract. The two areas where part of the original tropical moist deciduous forest remains are the Madhupur National Park in the north and the Bhawal National Park in the south. These parks were expected to protect the natural ecosystems of the area (Banglapedia, 2010). The real importance for conservation of deciduous forest lies in the fact that they are the most used and threatened ecosystem (Janzen, 1986; Rahman et. al., 2010). The conservation of plant diversity for present and future use is very essential (Pimm et. al., 1995; Murali et. al., 1996). There have been many studies that deal with diversity and different aspects vegetation analysis of tropical deciduous forests from various regions of India and Nepal (Gupta and Shukla, 1991; Singh et. al., 1995; Murali et. al., 1996; Sukumar et. al., 1998; Pandey, 1999; Uma, 2001; Pandey and Shukla, 2003; Saha, 2003; Webb and Sah, 2003). Though there is concern in all quarters regarding the loss of biodiversity of deciduous sal forests of central Bangladesh but there is no evidence of systematic studies of biodiversity in sal forests of the area. As biological diversity is a key issue of nature conservation (Wilson, 1999), and species diversity is one of the important components of biological diversity (Ito, 1997). In this study efforts have made to assess species diversity of different forest stands representing the major two age groups under different level of anthropogenic and other biotic disturbances. We compared four diversity indices that are usually used in biodiversity studies based on data collected from four different forest stands of different age

groups and disturbance regimes in the Madhupur tract to elucidate the status of species diversity in the area. Results were compared with findings from other studies from India and other parts of the world to make a comparative assessment of diversity. Finally, based our findings, we recommended possible ways to enhance conservation measures to improve the diversity of sal forests of the area.

METHODOLOGY

Study area

This study was conducted in the tropical moist deciduous forest of Madhupur Tract of central Bangladesh (23° 30' N, 24° 50' N to 90° 0' E 90° 50' E) (Fig. 1). Geologically it is a terrace from one to ten meters above the adjacent floodplains. Study sites include stands from two best remaining patches forests, namely Bhawal National Park (24° 01'N, 90° 20'E) in the southern part and Madhupur National Park (24° 45'N, 90° 05'E) in the northern part. Bhawal National Park covers an area of 5,022 ha and Madhupur National Park covers an area of 8,436 ha. The soils of the tract have developed largely on Madhupur clays; which are nutrient poor and somewhat acidic. They are red or brown in color. The climate of the Tract varies slightly from north to south; the northern part reaches much cooler in winter. Average temperatures vary from 28°C to 32°C in summer, falling to 20°C in winter, with extreme lows of 10°C. Rainfall ranges between 1,000 mm and 1,500 mm annually. Two tribal clans, the Koch and the Mande (Garo), who are dependent on these forests, live in the Madhupur tract. The Koch is among the earliest people of Bangladesh, while the Mande have their main center of dispersal in the Garo hills in India. The Bengali-speaking people, who used to live along the fringes of the extensive forests, have entered in large numbers and cleared most of the forests. The Bengali-speaking people, who used to live along the fringes of the extensive forests, have entered in large numbers and cleared most of the forests. Bengalis has developed stable agro-horticultural systems in the west. Due to anthropogenic disturbances, the landscape and ecosystems of most of the Tract has changed drastically in last thirty years that triggered the loss of invaluable biodiversity in area.

Fig. 1. Map showing the tropical moist deciduous forest of Madhupur tract of central Bangladesh (Source: Banglapedia, 2010).

Four stands with varying sizes (ranging from 3 to 5 ha) were selected in two protected areas of tropical moist deciduous forests of Madhupur tract. Two stand, stand-1 old growth secondary coppice forest of >40 years age of 4 ha area and stand-2 young forest stand of enrichment plantation of <20 years age of 3 ha area were located in Bhawal National Park (BNP). Other two stands were located in Madhupur National Park (MNP). Stand 3 of 5 ha area is of old growth secondary coppice forests of >40 years old and stand 4 is a young forest stand under enrichment plantation with an area of 4 ha. Age of the stands were approximated by checking forest department records, consulting long time senior residents of the area, judging the girth size of the trees, growth features like branching pattern based on branch scars (Shukla and Ramakrishnan, 1986) as well as considering the physiognomy of the stands such as existence of large woody liana for old growth stands. A simple disturbance index (DI) was developed as the ratio of the number of cut as well as severed individuals expressed as percent of total number of individuals of all perennial plants occurring within a sample area of 100 m^2 (Pandey and Shukla, 1999). The level of anthropogenetic and other biotic disturbances were intermediate in both the old growth secondary forests stands (DI 32 for MNP and 36 for BNP stands) and high in both the young enrichment forest stands (DI 65 for MNP, 60 for BNP stands). As rectangular plots tend to sample more species than square plots of the same area (Condit et. al., 1996), each stand was divided into rectangular plots of 20 m × 10 m size and 10 plots were randomly selected from each stand. All freestanding woody species in the plots were identified and dbh of all plants ≥ 5 cm were measured. Species identification was done with the help of teachers and students of Department of Botany of Dhaka Imperial College, Dhaka.

Four non-parametric diversity indices that are often used in studies on species diversity (Krebs, 1989) were computed and compared with results from other similar studies. The four indices are:

1. Inverse of Simpson's Index (Simpson, 1949)=$1/\lambda$ (1)

2. D=1-λ Simpson diversity index (Lande, 1996) (2)

3. Shannon-Wiener index (MacArthur, 1955; Odum, 1971)
$H'=-\Sigma[ni/N*\log_2 (ni/N)]$ (3)

4. Equitability index recommended by Pielou (1969) $J'=H'/H'_{max}$ (4)

Where: $\lambda=\Sigma\ p_i^2$, p_i is the proportion of the number of i^{th} species (n_i) to total number of individuals (N), i.e., $p_i=n_i/N$, and $H'_{max}=\log_2 S$, S=total number of species found in all the samples.

Although Simpson's original equation for λ is expressed by equation $\lambda=\Sigma\ p_i^2$, we followed example of Ito (1997) to calculate an unbiased estimator (Morisita 1967; Pielou, 1969) of λ, which is expressed by the equation

$$\lambda=[n_i*(n_i-1)/N*(N-1)] \quad (5)$$

Based on statistical re-examination of the indices, Lande (1996) concluded that D is the best index for comparative studies. His simulation showed that values of D were not affected by the sample size (N) and the confidence intervals became reasonably small with 50 to 100 individuals in a sample. However, we also calculated H' and J' for making comparison of our results with results from other similar studies from India and other parts of the world. Though J' expresses only one aspect of species diversity, the equitability of numbers of each species comprising the community, it is convenient for comparing communities having different number of species (Ito, 1997).

RESULTS AND DISCUSSIONS

Table 1 shows that altogether 46 species under 24 families were found in the different forest stands of Madhupur tract. Old growth secondary forest stand in Madhupur National Park has the greatest species richness (34) under 20 families and maximum number of individuals (211) followed by old growth secondary forest stand of Bhawal National Park with 29 species under 20 families with 190 individuals.

Table 1. Species, family, life form, and number individuals per species, number species and families found in the different forests stands of the Madhupur tract.

Family	Species	Life form	Total number of individuals			
			MNP[1] >60yrs	BNP[2] >40yrs	BNP <20 yrs	MNP <15 yrs
Anacardiaceae	*Spondias pinnata*	Small tree	0	2	0	0
Anacardiaceae	*Swintonia floribunda*	Tall tree	2	1	0	0
Anacardiaceae	*Lannea coromandelica*	Medium tree	2	0	0	0
Anacardiaceae	*Semicarpus anacardium*	Medium tree	0	2	0	0
Annonaceae	*Meliusa velutina*	Medium tree	2	0	2	2
Apocynaceae	*Holarrhena antidysentrica*	Medium tree	2	1	1	0
Apocynaceae	*Wrightia tomentosa*	Small tree	3	0	0	0
Apocynaceae	*Alstonia scholaris*	Medium tree	2	0	0	0
Bombacaceae	*Bombax ceiba*	Tall tree	3	3	0	0
Burseraceae	*Garuga pinnata*	Small tree	2	2	2	0
Combretaceae	*Terminalia belerica*	Medium tree	3	3	2	1
Dilleniaceae	*Dellenia pentagyna*	Medium tree	6	5	2	2
Dipterocarpaceae	*Shorea robusta*	Tall tree	106	101	81	71
Dipterocarpaceae	*Hopea odorata*	Tall tree	1	1	0	0
Dipterocarpaceae	*Vatica lanceofolia*	Medium tree	1	0	0	0
Euphorbiaceae	*Phyllanthus emblica*	Medium tree	4	3	1	0
Euphorbiaceae	*Croton oblongifolius*	Small tree	0	1	1	0
Euphorbiaceae	*Mallotus philippinensis*	Small tree	1	0	0	0
Lauraceae	*Litsea polyantha*	Medium tree	2	0	0	0
Lecythidaceae	*Carea arborea*	Tall tree	5	0	2	0
Leguminosae	*Xylia dolabiformis*	Medium tree	0	0	4	2
Leguminosae	*Entada phaseolodes*	Woody climber	8	7	0	0
Liguminosae	*Albizia procera*	Tall tree	13	11	4	3
Liguminosae	*Albizia chinensis*	Tall tree	5	0	0	0
Liguminosae	*Butea monosperma*	Medium tree	2	2	0	0
Liguminosae	*Albizia lebbeck*	Tall tree	2	0	0	0
Liguminosae	*Cassia fistula*	Medium tree	3	3	1	0
Liguminosae	*Acacia auricoliformis*	Medium tree	0	0	0	8
Liguminosae	*Acacia mangium*	Medium tree	0	0	0	4
Lythraceae	*Lagerstroemia parviflora*	Medium tree	4	4	0	0
Meliaceae	*Aphanamixis polystachya*	Tall tree	0	2	0	0
Meliaceae	*Switeina mahogany*	Tall tree	0	0	7	3
Moraceae	*Artocarpus chaplasha*	Tall tree	5	5	2	1
Moraceae	*Ficus hispida*	Medium tree	2	2	0	0
Myrtaceae	*Syzygium grande*	Medium tree	3	2	2	3
Myrtaceae	*Cleistocalyx operculatus*	Small tree	2	1	2	0
Rhamnaceae	*Zyzyphus jujuba*	Small tree	2	1	2	0
Rubiaceae	*Hymenodictyon excelsum*	Small tree	2	0	0	0
Rubiaceae	*Adina cordifolia*	Medium tree	5	2	0	2
Sapindaceae	*Scleichera oleosa*	Tree	4	5	0	0
Sterculiaceae	*Sterculia colorata*	Medium tree	0	1	0	0
Thymalaceae	*Aqularia agallucha*	Tall tree	0	1	0	0
Tiliaceae	*Microcos paniculata*	Medium tree	0	2	0	0
Urticaceae	*Streblus asper*	Small tree	1	0	0	0
Verbanaceae	*Gmelina arborea*	Tall tree	0	1	2	1
Verbanaceae	*Vitex glabrata*	Small tree	1	0	0	0
Total number of individuals			211	190	120	103
Total number of species			34	29	18	13
Total number of families			20	20	13	10

Source: Analysis of field data 2004. Keys: [1]Madhupur National Park, [2]Bhawal National Park

Both the enrichment plantation of younger age have much lesser number families, species and individuals in comparison to old growth secondary forest stands but the least number of these parameters were found in young enrichment plantation of Madhupur National Park being represented by 13 species under 10 families with 103 individuals. Liguminosae is the species richest family with 9 species followed by Anacardiaceae with 4 species while each of Dipterocarpaceae, Euphorbiaceae, Miliaceae and Apocynaceae represent 3 species Table 2 shows the number of species, number of individuals and four α species diversity indices for different forest stands in Madhupur tract for trees $\geq$ 5 cm dbh. Values of Inverse of Simpson's index (1/λ)and Simpson's diversity index described by Lendle (D), which are measures of dominance, show that moderate dominance for all stands but it decreases with the increase of stand age and decrease of disturbance index. Values for Shannon-Wiener index (H') that takes account of species richness and the abundance of constituent species show that highest species diversity in the old growth stand of MNP with

Table 2. Comparison of diversity indices in different Stands

Stands	Area (m^2)	Species #	Total N	lλ	1/λ	D	H'	J'=H'/H'max
MNP, >60 years	2000	34	211	0.26	3.84	0.74	3.36	0.66
BNP, >40 Years	2000	29	190	0.35	2.86	0.65	2.81	0.58
BNP, <20 Years	2000	18	120	0.46	2.17	0.54	2.16	0.52
MNP, <15 years	2000	13	103	0.48	2.07	0.52	1.92	0.52

Source: Analysis of field data, keys: MNP= Madhupur National Park, BNP=Bhawal National Park.

Table 3. Species, family, life form, total individuals climber in different forest stands for individual $\geq$ 1 cm dbh.

Species	Family	Life form	Number of individuals			
			BNP>40yrs	MNP>60 yrs	BNP<20 yrs	MNP<15 yrs
Calamus latifolius	Araceae	Climber	0	18	0	6
Dioscorea esculenta	Dioscoreaceae	Climber	18	0	24	28
Mucuna prurens	Leguminosae	Climber	22	28	25	27
Glinus lotoides	Molluginaceae	Climber	12	10	21	24
Vitis quadrangularis	Vitaceae	Climber	15	13	15	20
Entada phaseolodes	Leguminosae	Climber	14	18	2	3
Dioscorea pentaphylla	Dioscoreaceae	Climber	2	0	15	18
Thumbergia grandifolia	Acanthaceae	Climber	0	0	15	12
Bauhinia vahlii	Leguminosae	Climber	14	12	5	12
Smilex aspera	Smilaceae	Climber	18	16	12	15
Bauhinia anguina	Leguminosae	Climber	14	15	5	7
Spatholobus roxburghii	Leguminosae	Climber	12	14	18	16
Hemidesmus indicus	Asclepidaceae	Climber	8	9	12	15
Asparagus acerosus	Liliaceae	Climber	0	0	11	9
Vitis repens	Vitaceae	Climber	0	6	16	18
Vitis glabrata	Vitaceae	Climber	14	8	12	16
Scindapus officinalis	Araceae	Climber	2	0	0	0
Total number of individuals			165	167	208	246
Total number of species			13	12	15	15
Total number of families			8	8	8	8

Source: Analysis of field data. [a]We did not discern between liana and climbers, all individuals that have a climbing habit are treated as climber.

least disturbance followed by old growth stand of BNP while least in the youngest stands with highest disturbance in MNP. Species diversity decrease with the increase of disturbance index and decrease of stand age. Relatively low values of Pielou's index (J'), which is a measure of species evenness, indicate that species in all the stands are moderately evenly distributed though old stand at MNP with modest disturbance is most evenly distributed amongst them.

Table 3 shows the species, family, life form, total individuals; Shannon-Weiner index (H') of climber and liana in different forest stands for individual ≥ 1 cm dbh. All together 17 species under 9 families were found to occur in all the stands. Liguminosae is the most species rich family with 4 species followed by Vitaceae with 3 species. Number of individuals is highest in the most disturbed young stand of MNP while more or less same in the moderately disturbed old growth stands of BNP and MNP. It was realized that the number of individuals of climber increase with the increase of disturbances and decrease of stand age.

Table 4 shows that old growth tropical moist deciduous

Table 4. Comparison of different diversity indices from different studies from the indo-subcontinent and other parts of the world.[a]

Forest types	Location, age, DI, etc.	Area (Ha)	dbh (cm)	S	(N)	1//λ*	D	H'	J'	Source
Tropical moist deciduous forests	MNP, >60 DI moderate	0.2	5	33	195	3.85	0.74	3.36	0.67	1
Tropical moist deciduous forests	BNP, >40, DI moderate	0.2	5	29	190	2.86	0.65	2.81	0.58	1
Tropical moist deciduous forests	BNP, <20, DI high	0.2	5	18	120	2.17	0.54	2.16	0.52	1
Tropical Moist Deciduous Forests	MNP, <15 DI high	0.2	5	13	103	2.07	0.52	1.92	0.52	1
Tropical moist deciduous forests	India, >40 DI moderate	0.1	9.5	-	-	-	0.94	3.47	-	2
Tropical moist deciduous forests	India, >40 yrs, high	0.1	9.5	-	-	-	0.81	1.98	-	2
Tropical deciduous secondary forests	Central India	0.1	5	58	44.61	-	-	2.73	0.66	3
Tropical deciduous mature forests	Central India	0.1	5	57	49.23	-	-	3.16	0.79	3
Tropical semi-evergreen sal forests	UP, India	24.0	9.5	93	[b]404	15.24	0.93	3.96	0.63	4
			9.5	115	[b]20413					
Tropical moist deciduous forest	Darjeeling, India	2	3.18	87	[b]484			3.59	0.80	5
Deciduous broadleaved forest	Hokkaido, JP, Mature	0.05	>4	5	97	1.27	0.21	0.72	0.31	6
Deciduous broadleaved forest	Hokkaido, JP, Mature	0.05	>4	5	75		0.38	1.10	0.47	6
Tropical rain Forest	Thailand, Mature	0.16	>4.5	59	188		0.97	5.30	0.90	7

Sources: 1 Present study, 2 Pandey and Shukla, 1999; 3 Saha, 2003; 4 Pandey and Shukla, 2003; 5 Uma, 2001; 6 Tatewaki and Igarashi, 1971; 7 Ogawa et. al., 1965.

[a]As sample sizes, dbh and formula used vary and in some cases values for different indices are derived from the information provided in the original studies, consequently there are limitations of these values for absolute comparison.

[b]values are per hectare basis.

forest stand of >60 years old with intermediate disturbances in the Madhupur tract has the greatest species diversity (H'=3.36), which is fairly comparable with old growth tropical moist deciduous forests of Gorakpur, India, under moderate anthropogenetic disturbances regimes with species diversity H'=3.47 (Pandey and Shukla, 1999) and mature tropical deciduous forests in central India with H'=3.16 (Saha, 2003) but lower than tropical moist deciduous forest of Darjeeling, India H'=3.59 (Uma, 2001). On the other hand, relatively low value of Simpson diversity index D=0.74, shows relatively higher concentration of species dominance in old growth stand in Madhupur tract than in Gorakpur (D=0.94) which is further confirmed with relatively low value Pielou's evenness index (J=0.67') for Madhupur tract while that of Darjeeling, India J= 0.80. In general old growth tropical deciduous sal forests have higher species diversity, low species dominance and more species evenness than deciduous broad leaved forests with H'=0.72 and 1.10, D=0.21 and 0.38 and J=0.31 and 0.47, in Hokkaido, Japan (Tatewaki and Igarashi, 1971) but lower species diversity, higher concentration of dominance and lower species evenness in relation to tropical rain forest as expressed by values of respective indices H' =5.30, D=0.97 and J=0.90, in Thailand (Ogawa et. al., 1965). However, both species diversity and species evenness decrease and species dominance increase with the increase of disturbance regime and decrease of stand age in Madhupur tract and elsewhere in India.

In Madhupur tract species diversity greatly decreased in the young stands under high disturbances both in Madhupur and Bhawal National Park areas, though situation is worst in Madhupur area with the introduction of exotic species like *Acacia auriculiformis* and *Acacia mangium* and so on. The young stand (S4) with high disturbances, where exotic species were introduced apparently due to their fast growing capacity and resistibility against anthropogenetic and other biotic disturbances, has shown that many of the endemic species like *Phyllanthus emblica*, *Ficus hispida*, *Wrightia tomentosa*, which are important for conservation of threatened wildlife of the area have already disappeared and other important species like *Albizia procera*, *Terminalia belerica and Dellenia pentagyna* have reduced in number while exotic species like Acacia auriculiformis, Acacia mangium, that are not at all suitable for conservation of biological diversity, specially faunal diversity are increasing in number. This phenomenon is a matter of concern to conserve the biological diversity of Madhupur tract, as some of the exotics are invasive in nature. For instance, Islam et. al., (2003) reported that *Acacia auriculiformis* and *Acacia mangium* have proven to be rivals to endemic flora that replace indigenous forest species as well as other native wild flora. These trees do not support wildlife because they do not produce edible fruit or nectar for them (Ameen, 1999). From the results of the study another phenomenon is evident that both species richness and number of individuals of climber and liana increase with the increase of disturbances and decrease of stand age. Thus in the young stands where disturbance is high, enough light and spaces are available and tree stems are relatively slender are increasingly invaded by different species of climber and liana, thus reducing the productivity of the stands. This finding is consistent with other studies that report lianas are often associated with disturbed areas and high light intensities (Hegarty and Clifford, 1991; Richards 1996). From introductory chapter, it is evident Madhupur sal forests were very rich in wildlife, many of which have already been extinct due to unwise destruction of habitat and loss species diversity. At present these forests are the only habitat for endangered wildlife like Capped langur (*Trachypithecus pileatus*). Wilson (1999) stressed the importance of species diversity of communities to avoid extinction of endangered species. Feeding behavior of Capped langur showed that they feed on leaves, fruit and other parts of different endemic plant species. The most important sources of leaves came from *Wrightia tomentosa*, *Bauhinia variegata*, and *Adina cordifolia*. Fruit is consumed most during the rainy season (May-September) where it can comprise almost 50% of the diet. Examples of fruit consumed include Ficus sp., *Spondias mangifera*, and *Terminalia balerica*, with *Garruga pinnata* and *Miliusa vetulina* being the two most important fruit species consumed during the rainy season. Flowers were

consumed during the flowering peaks of May and October, just before and after the monsoon season. Capped langurs prefer fruit to leaves when both are available (Stanford, 1991). Results of our study indicate that virtually sal forest is becoming unsuitable as a habitat for Capped langur as only old growth stands in Madhupur area, though in limited extent, has species diversity where they can find food and remaining stands are not suitable as the species diversity is being reduced and species composition has been changing progressively. Furthermore, results of the study have shown tree species like *Vatica lanceaefolia*, *Hopea odorata*, which are enlisted as critically endangered and vulnerable species respectively in 2002 by IUCN (IUCN, 2002) have already disappeared from young stands and only a few individuals are still found in old growth forests.

CONCLUSION

The results of this study provide evidences that endangered and vulnerable species of the tropical moist deciduous forests of Madhupur tract are on the verge of extinction are confined in the old growth stands that are under moderate anthropogenetic disturbance regimes and pose threat of complete extinction unless wise conservation measures are put in place immediately. The very relevant questions that would arise are: what measures should be taken, where to be taken and how those measures could be implemented. The current study addresses the first two questions. The tropical moist deciduous forests of Madhupur tract have the species diversity that is fairly comparable with other such forests in India and elsewhere in the world. Results of this study suggest that the old growth stands should be preserved from any further damage to thwart the risk of extinction of many valuable species. Enrichment plantations or any other such silvicultural operations should exclude exotic invasive species. Protection of the sal coppice supplemented with endemic species that are natural to the sal forests of the area should be encouraged and reintroduced to reclaim the natural ecosystem in the degraded sites. Studies on similar sites justify the argument for forest protection. For example, studies from West Bengal showed that forest protection costs are only 5% of the cost of plantation establishment. Finally, anthropogenetic disturbances should be kept to a tolerable moderate level in all forest stands.

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LITERATURE CITED

Ameen, M. 1999. Development of guiding principles for the prevention of impact of alien species. Paper presented at a preparatory workshop for the 4th meeting of SBSTTA to CBD, organized by IUCN Bangladesh, Dhaka 25 May, 1999.

Banglapedia. 2010. National encyclopedia of Bangladesh, sal forest, Banglapedia. Available online at http://banglapedia.search.com.bd/HT/S_0035.htm, last accessed Apr. 10, 2010.

Champion, H. G., Seth, S. K. and Khattak, G. M. 1965. Forest Types of Pakistan, Pakistan Forestry Institute, Peshawar, Pakistan.

Chowdhury, R. A. 1994. History and importance of sal forests and current management status. *In*: Agroforestry for the degraded sal forest, Proceedings of national workshop held at Bangladesh Agricultural Research Council, BARC and Forest Department with the financial assistance of APAN, Dhaka.

GOB. 1992. Forestry Master Plan (Participatory Forestry), p-45, Ministry of Environment and Forests, Peoples Republic of Bangladesh, Dhaka.

Gupta, O. P. and Shukla, R. P. 1991. The composition and dynamics of associated plant communities of sal plantations. Trop. Ecol. 32:296-309.

FAO. 2003. State of World's Forests 2003. FAO, Rome, Italy.

Hegarty, E. E. and Clifford, H. T. 1991. Climbing angiosperms in the Australian flora. In Werren, G., Kershaw, P. (eds.) The rainforest legacy. Australian Government Publishing Service, Canberra, Australia, pp. 105-120.

Islam, M. M., Ruhul A. S. M. A. and Sarker, S. K. 2003. Alien Plants Species in Bangladesh. In: Pallewatta, N., Reaser, J. K., andGutierrz, A. T. (eds.). Invasive Alien Species in Southeast Asia: National Reports and Directory of Resources. Global Invasive Species Proramme, Cape Town, South Africa.

Ito, Y. 1997. Diversity of Forest Tree Species in Yanbaru, the northern part of Okinawa Island. Plant Ecol. 133:125-133.

IUCN. 2008. Red List of Endangered Species. Available online at http://www.redlist.org, last accessed Apr. 29, 2010.

IUCN. 2002. Red List of Endangered Species. Available online at http://www.redlist.org, last accessed May, 20, 2010.

Janzen, D. H. 1986. In: Biodiversity, Wilson, E. O. (eds.). National Academy Press, Washington, pp. 130-137.

Khan, M. A. R. 1981. The non-human primates of Bangladesh. Tiger Paper. 8:12-15.

Krebs, C. J. 1989. Ecological Methodology, Harper and Row, New York, USA.

Lande, R. 1996. Statistics and portioning of species diversity, and similarity among multiple communities. Oikos. 76:5-13.

MacArthur, R. H. 1955. Fluctuations of animal populations and a measure of community stability. Ecology. 36:533-536.

Murali, K. S., Uma, S., Ganeshaiah, K. N. and Bawa, K. S. 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India.2. Impact of NTFP extraction on regeneration, population structure, and species composition. Econ. Bot. 50: 252-269.

Morisita, M. 1967. Seasonal distribution of butterflies near Kyoto city. In Morisita, M. and Kira, T. (eds.). Nature: Ecological studies. Chuokoronsha, Tokyo (in Japanese), pp. 95-132.

Odum, E. P. 1971. Fundamentals of Ecology, Toppan Printing Company Ltd. Tokyo, Japan.

Ogawa, H., Yoda, K., Kira, T., Ogino, K., Ratanawonse, D. and Apasutaya, C. 1965. Comparative ecological study on three main types of forest vegetaion in Thailand. Nat Life Southeast Asia. 4:13-48.

Pandey, P. K. 1999. Comparative vegetation analysis and sal (*Shorea robusta*) regeneration in relation to their disturbance magnitude in some sal forests. Trop. Ecol. 40:51-61.

Pandey, S. K. and Shukla, R. P. 1999. Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (*Shorea robusta Gaertn*.). Curr. Sci. 77:814-818.

Pandey, S. K. and Shukla, R. P. 2003. Plant diversity in managed sal (*Shorea robusta Gaertn*.) forests of Gorakhpur, India. Bio. Conser. 12:2295-2319.

Pielou, E. C. 1969. An Introduction to Mathematical Ecology. Wiley Interscience, New York, USA.

Pimm, S. L., Russell, G. J., Gittleman, J. L. and Brooks, T. M. 1995. The future of biodiversity. Science. 269:347-35.

Rahman, M. M., Motiur, M. R., Guogang, Z. and Islam, K. S. 2010. A review of the present threats to tropical moist deciduous sal (*Shorea robusta*) forest ecosystem of central Bangladesh. Trop. Conser. Sci. 3(1):59-69.

Richards, P. W. 1996. The tropical rain forest: an ecological study (2nd edition). Cambridge University Press, Cambridge.UK.

Saha, S. 2003. Patterns in woody species diversity, richness and partitioning of diversity in forest communities of tropical deciduous forest biomes. Ecogoraphy. 26:80-86.

Singh. A., Reddy, V. S. and Singh, J. S. 1995. Analysis of woody vegetation of Corbett National Park, India. Vegetatio. 120:69-79.

Simpson, E. M. 1949. Measurement of diversity. Nature. 163:688.

Shukla, R. P. and Ramakrishnan, P. S. 1986. Architecture and growth strategies of tropical trees in relation to successional status. J. Ecol. 74:33-46.

Stanford, C. B. 1991. The diet of the capped langur (*Presbytis pileata*) in a moist deciduous forest in Bangladesh. International J. Primatol. 12:199-216.

Sukumar, R., Suresh, H.S., Dattaraja, H. S. and Joshi, N.V. 1998. Dynamics of tropical deciduous forest: Population changes (1988 through 1993) in a 50-ha plot at Mudumalai, Southern India. In: Dallmeier, F. and Comiskey, J. A. (eds.). Forest Biodiversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies. The Parthenon Publishing Group, Camforth, UK, pp. 529-540.

Tatewaki, M. and Igarashi, T. 1971. Forest vegetations in Teshio-Nakagawa area of Hokkaido University Forests. Research Reports of University Forests, Hokkaido University, 28:1-192.

Uma, S. 2001. A case of high tree diversity in a sal (*Shorea robusta*) dominated lowland forest of Eastern Himalaya: floristic composition, regeneration and conservation. Curr. Sci. 81:776-786.

UNEP. 2001. State of the Environment Report - Bangladesh.

UNEP-WCMC. 2004. UNEP-WCMC Species Database: CITES-Listed Species.

Webb, E. L. and Sah, R. N. 2003. Structure and diversity in the natural and managed sal (*Shorea robusta* Gaertn.f.) forest in the Terai of Nepal. For. Ecol. Manage. 176:337-353.

Wilson, E. O. 1999. The diversity of life, Harvard University Press, USA.

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