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CLIMATE RESILIENCE THROUGH NATURAL REGENERATION IN DEGRADED NATURAL FORESTS OF SOUTH-EASTERN HILLY REGION OF BANGLADESH

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Abstract

A study was conducted by using 5m × 5m sized 179 quadrates following multistage random sampling method for comparative regenerating tree species, quantitative structure, diversity, similarity and climate resilience in the degraded natural forests and plantations of Cox's Bazar North and South Forest Divisions. A total of 70 regenerating tree species were recorded representing maximum (47 species) from degraded natural forests followed by 43 species from 0.5 year 39 species from 1.5 year and 29 species from 2.5 year old plantations. Quantitative structure relating to ecological dominance indicated dominance of *Acacia auriculiformis*, *Grewia nervosa* and *Lithocarpus elegans* seedlings in the plantations whereas seedlings of *Aporosa wallichii*, *Suregada multiflora* and *Grewia nervosa* in degraded natural forests. The degraded natural forests possess higher natural regeneration potential as showed by different diversity indices. The dominance-based cluster analysis showed 2 major cluster of species under one of which multiple sub-clusters of species exists. Poor plant diversity and presence of regenerating exotic species in the plantations indicated poor climate resilience of forest ecosystem in terms of natural regeneration.

Introduction

Global climate change scenarios strongly alarmed that the low-lying areas of Bangladesh are likely to go under water (McCarthy *et al.* 2001). Moreover, climate changes impart severe impacts on the forest ecosystem, species distribution, diversity, re-vegetation potentiality of forest ecosystems and plantations etc. (Wang *et al.* 2015). Bangladesh, being a transition part of the Indo-Myanmar biodiversity hot spot, harbored rich biological diversity (Hossain 2001, Nishat *et al.* 2002). The South-Eastern region of Bangladesh covers the significant part of hill forests representing features of tropical evergreen and semi-evergreen forests. The natural forests of the region are one of the species-rich and productive government managed reserve forests, but these are becoming degraded through illegal logging, forest fire, shifting cultivation, human settlement, agriculture and horticulture expansion in the valleys, clear felling followed by commercial plantation with short rotation exotic species etc. (Ahmed 2008).

Information on natural regeneration is required for sustainable forest management in terms of both economic and environmental considerations (Verma *et al.* 1999). The plantation preparation and maintenance activities, i.e. clear felling accelerates loss of seedlings and saplings as well as disturbs the natural condition of the forests and hence the ecosystem (Haque and Alam 1988). Patterns of natural regeneration and recruitment also answer the basic question about forest management (Hossain *et al.* 1999). Uncontrolled browsing, regular weeding has limiting effects on recruitment of natural regeneration (Chapman *et al.* 2002). Some sporadic research on regeneration composition and potential was conducted in different forests of Bangladesh by

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different researchers, i.e. Hossain *et al.* (2004) reported 64 species in natural forests and 40 species in plantations of Chittagong South Forest Division, Alamgir and Al-Amin (2007) reported 39 species in Banskhali Eco-Park. Similarly, Hossain *et al.* (2013) reported 120 regenerating species from Dudhpukuria-Dhopachari Wildlife Sanctuary; Hossain and Hossain (2014) reported 105 regenerating species from Chunati Wildlife Sanctuary. Previously researchers showed that deforestation, degradation, plantation management systems deeply influence regeneration (Kadavul and Parthasarathy 1999, Islam *et al.* 2001). But there is great dearth of information about the regeneration composition in both degraded forests and plantations of Cox's Bazar forest region of Bangladesh as well as the regenerating species diversity, distribution and influences of repeated weeding on regeneration in the plantations and climate resilience by the regenerating species. To fill up these information gap, the present study was undertaken to record both native and exotic regenerating tree species under different management condition, assess influence of plantations and maintenance activities at different ages on quantitative structure and diversity of regenerating tree species. The study is expected to contribute to both scientific community and policy makers regarding to understand the role of natural regeneration in building climate resilience.

Materials and Methods

The study area comprises degraded hill forests of Cox's Bazar, the south-eastern district of Bangladesh. Administratively the area falls under Cox's Bazar South and Cox's Bazar North Forest Division. Small to medium hills of up to 400 m altitude constituted the land form of Cox's Bazar. The average rainfall is 4,285 mm which varies seasonally with maximum (93% of the mean annual rainfall 3670 mm) from May to October (Khatun *et al.* 2016). The annual average temperature is 32.8°C with a minimum of 16.1°C. Soil of the study areas were mostly brown sandy loams to clay loams, slightly to strongly acid, sometimes shallow over sandstone bedrocks on very steep high hills (BBS 2012). Bangladesh Forest Department (BFD) conducted plantations of both exotic and indigenous tree species in three subsequent years starting from 2013under Climate Resilient Participatory Afforestation and Reforestation Project (CRPARP). A total of 4,671 ha block plantations were established by BFD in deforested or degraded natural forest areas of Cox's Bazar North Forest Division and Cox's Bazar South Forest Division (Eusuf and Associates 2016). Plantations composed of 68% indigenous and 32% exotic species and were maintained through regular weeding activities including 3 weeding in 1st year, 2 weeding in 2nd year and 1 weeding in 3rd year.

Multistage sampling method was followed for selecting the plantations to conduct the study. Two forest Ranges with CRPARP plantations were selected from each of the two Forest Divisions of Cox's Bazar district. From each Forest Ranges two beats were selected for the survey. The regeneration study was conducted in 4 categories of sites having, (i) degraded natural forest or bushes that were used for reforestation, (ii) 0.5 years old plantation sites, (iii) 1.5 years old plantations, and (iv) 2.5 years old plantation.

Data was collected from the month of April - December 2016. A total of 179 quadrates of 5 m × 5 m size (determined by species-area curve following Mueller-Dombois and Ellenberg, (1974)) including 52 from 0.5 year, 37 from 1.5 year and 23 from 2.5 year old plantations, and 67 from degraded natural forests following stratified random sampling method. Seedlings less than 1.5 m height were considered as regeneration and recorded. Regeneration data were analyzed in MS Excel to get diversity indices, similarity index and importance value index following Simpson (1949), Shannon and Wienner (1963), Margalef (1958), Pielou (1966), Magurran (2004) and Shukla and Chandal (2000). Hierarchical cluster analysis was done using R programming software to identify the groups of species having similar abundance and dominance characteristics.

Results and Discussion

The findings revealed a total of 70 regenerating tree species belonging to 55 genera and 29 families in plantations and natural degraded sites (Table 1). The degraded natural forest was represented by maximum 47 regenerating tree species followed by 0.5 (43 species), 1.5 (39 species) and 2.5 (29 species) years old plantations. Natural regeneration is an important indicator of forest ecosystem (Rahman *et al.* 2011). Profuse coppicing ability, as seen during the data collection, of the regenerating tree species resulted in the similar species richness in degraded natural forest and 0.5 yr plantation. However, the regenerating species in the degraded forests and plantations were higher than Rahman *et al.* (2011) who reported 55 regenerating tree species from two sites of the northeastern region of Bangladesh which include forest, road side and fallow lands. Rahman *et al.* (2011) also recorded 43 regenerating species from Khadimnagar National Park which is almost comparable to the regenerating species richness of the degraded natural forest and 0.5-year-old plantations of present study site. On the other hand, 31 species reported from Tila-gor Eco-Park (Rahman *et al.* 2011) is comparable to that of 2.5 years old plantations. The regenerating species composition of present study is quite lower than that of the Dudhpukuria wildlife sanctuary (120 species) and Chunati Wildlife Sanctuary (105 species) (Hossain *et al.* 2013, Hossain and Hossain 2014). Natural regeneration potentiality of the plantations at early stage (0.5 year to 1.5 years) and degraded natural forest sites is seemed higher than that of the Tankawati Reserve Forest (29 species) as reported by Motaleb and Hossain (2007). It may be noted that, if protection was extended instead of repeated complete weeding activities there might not be any reduction of tree diversity in the subsequent stages of plantation establishment.

Relative density in 0.5 year, 1.5 year and 2.5-year-old plantations were dominated by *G. nervosa* (12.5%), *S. firmum* (10.6%) and *L. elegans* (22.8%), respectively whereas in the degraded natural forests *A. wallichii* (14.1%) occupied maximum relative density. *L. elegans* occupied maximum relative frequency in both 0.5 (11.7%) and 2.5 (17.6%) year old plantations while *S. firmum* (11%) was dominant in 1.5 years old plantation. However, relative frequency of *A. wallichii* (12.4%) topped in degraded sites. Relative abundance of *Bridelia tomentosa* was found maximum (5.3%) in 0.5-year-old plantations whereas *A. mangium* (7.4%) and *C. macrophylla* (10.3%) occupied maximum relative abundance in 1.5- and 2.5-years old plantations, respectively. In the degraded natural forests, *S. multiflora* was mostly abundant species (10.7%) followed by *M. roxburghianus* (8%) (Table 1). Importance value index of the recorded species from plantations indicate that *G. nervosa* (26%), *S. firmum* (23.9%) and *L. elegans* (45.7%) were dominant in 0.5, 1.5 and 2.5-year-old plantations, respectively (Table 1).

The 4 important diversity indices i.e. Shannon-Wiener diversity index, Simpson's dominance index, Margalef's Richness and Pielou's Evenness index indicate poor regenerating plant diversity in all the study sites though ANOVA and DMRT indicated significantly higher Shannon-Wiener diversity index in degraded natural forests in comparison to plantations. But Species Evenness Index was significantly higher in 2.5 years old plantations than that of other study sites (Table 2).

The diversity indices indicate that species diversity is significantly higher in degraded natural forest than in the plantations. Though, species richness is higher in degraded natural forests, as indicated by Margalef's richness index, it is not significantly different than other. Rahman *et al.* (2011) reported much higher diversity indices for regeneration in two protected areas of Northeastern Bangladesh (Shannon-Wiener index 3.62, richness index 4.92, evenness index 2.26, dominance index 0.03).

Table 1. Ecological dominance of regenerating tree species recorded from plantations of 3 different age and degraded natural forest patch [Here, P1 = Plantation of 0.5-year age, P2 = Plantation of 1.5-year age, P3 = Plantation of 2.5-year age and DF = Degraded Natural Forest].

Sl.	Species		Family	Relative density				Relative frequency				Relative abundance				IVI			
No.	Local name	Scientific name		P1	P2	P3	DF	P1	P2	P3	DF	P1	P2	P3	DF	P1	P2	P3	DF
1	Akashmoni	*Acacia auriculiformis*	Mimosaceae	8	10.1	3.5	0.4	5.6	4.5	2.3	0.8	3.8	5.6	6.2	0.8	17.4	20.2	12	2.0
2	Amloki	*Phyllanthus emblica*	Euphorbiaceae	2.6	3.1	0	0.2	3.6	4.5	0	1.2	2	1.7	0	0.6	8.2	9.3	0	2
3	Arjun	*Terminalia arjuna*	Combretaceae	0.3	0	0	0	0.5	0	0	0	1.5	0	0	0	2.3	0	0	0
4	Arsol	*Vitex glabrata*	Verbenaceae	0	0	0.3	1.5	0	0	1.1	3.9	0	0	1.1	1.0	0	0	2.5	6.4
5	Assorgola	*Grewia nervosa*	Tiliaceae	12.5	10.1	7.4	9.4	10.4	7.4	4.6	9	3.3	3.6	6.4	3.2	26	21.1	18.4	21.6
6	Attaillya	*Chaetocarpus castanocarpus*	Euphorbiaceae	0	0	0	0.4	0	0	0	0.8	0	0	0	1.4	0	0	0	2.6
7	Baittyagarjan	*Dipterocarpus costatus*	Dipterocarpaceae	0.7	1.1	0.3	0	0.5	1.3	1.1	0	3.8	2.1	1.1	0	5	4.5	2.5	0
8	Ban naranga	*Suregada multiflora*	Euphorbiaceae	0.6	0	0	12	0.5	0	0	3.5	3	0	0	10.7	4.1	0	0	26.2
9	Bara batna	*Lithocarpus elegans*	Fagaceae	11.4	9.9	22.8	6.3	11.7	9	17.6	8.2	2.6	2.7	5.3	2.3	25.7	21.6	45.7	16.8
10	Baramala	*Callicarpa macrophylla*	Verbenaceae	1.6	0.7	2.9	0.4	1	0.6	1.1	1.2	4.2	2.6	10.3	0.6	6.8	3.9	14.3	2.2
11	Bohera	*Terminalia bellirica*	Combretaceae	3.6	0	0.3	0.1	3.1	0	1.1	0.4	3.2	0	1.1	0.6	9.9	0	2.5	1.1
12	Bon boroi	*Ziziphus rugosa*	Rhamnaceae	0	0	0	0.4	0	0	0	0.8	0	0	0	1.7	0	0	0	2.9
13	Borta	*Artocarpus lacucha*	Moraceae	0	0	1	0.1	0	0	1.1	0.4	0	0	3.4	0.6	0	0	5.5	1.1
14	Bura	*Macaranga denticulate*	Euphorbiaceae	1.2	1.3	3.2	0	1	1.9	2.3	0	3	2.6	5.6	0	5.2	5.8	11.1	0
15	Chagollodi	*Actinodephne angustifolia*	Lauraceae	0	0	0	0.3	0	0	0	0.4	0	0	0	2.2	0	0	0	2.9
16	Chakuakoroi	*Albizia chinensis*	Mimosaceae	0.3	0.4	0	0	1	1.3	0	0	0.8	0.9	0	0	2.1	2.6	0	0
17	Champa	*Michelia champaca*	Magnoliaceae	0.1	0	0	0	0.5	0	0	0	0.8	0	0	0	1.4	0	0	0
18	Chapalish	*Artocarpus chama*	Moraceae	0	0.7	0	0	0	0.6	0	0	0	2.6	0	0	0	3.9	0	0
19	Chatian	*Alstonia scholaris*	Apocynaceae	1.6	2.6	3.2	0	2	3.2	4.6	0	2.1	2	2.8	0	5.7	7.8	10.6	0
20	Civit	*Swintonia floribunda*	Anacardiaceae	0	0.7	0	0	0	0.6	0	0	0	2.6	0	0	0	3.9	0	0
21	Dakrum	*Mitragyna rotundifolia*	Rubiaceae	0	0	0	1.8	0	0	0	1.2	0	0	0	4.7	0	0	0	7.7
22	Dhaki jam	*Syzygium firmum*	Myrtaceae	6	10.5	17.3	1.5	6.6	11	16.6	2.3	2.4	2.4	4.3	2	15	23.9	38.2	5.8
23	Dharamara	*Stereospermum colais*	Bignoniaceae	0.1	0.7	0	0	0.5	1.3	0	0	0.8	1.3	0	0	1.4	3.3	0	0
24	Dholibatna	*Lithocarpus acuminata*	Fagaceae	0	0	0	0.1	0	0	0	0.4	0	0	0	0.6	0	0	0	1.1

(Contd.)

Sl. No.	Species		Family	Relative density				Relative frequency				Relative abundance				IVI			
	Local name	Scientific name		P1	P2	P3	DF	P1	P2	P3	DF	P1	P2	P3	DF	P1	P2	P3	DF
25	Dhullyagarjan	*Dipterocarpus alatus*	Dipterocarpaceae	0	0.7	5.8	4.3	0	1.9	6.9	3.1	0	0.9	3.4	4.6	0	3.5	16.1	12
26	Dumur	*Ficus hispida*	Moraceae	2	0	0	0.2	1.5	0	0	0.4	3.6	0	0	0.6	7.1	0	0	1.2
27	Eucalyptus	*Eucalyptus camaldulensis*	Myrtaceae	0	0	0.3	0.2	0	0	1.1	0.4	0	0	1.1	0.2	0	0	2.5	0.8
28	Gamar	*Gmelina arborea*	Verbenaceae	2.8	1.8	1	0	2.6	3.2	1.1	0	2.9	1.4	3.4	0	8.2	6.4	5.5	0
29	Goda	*Vitex peduncularis*	Verbenaceae	2.5	3.1	3.5	0.6	2	3.2	3.4	0.8	3.2	2.4	4.1	0.2	7.8	8.7	11	1.6
30	Gutgutya	*Protium serratum*	Burseraceae	0	0.7	0	8.6	0	0.6	0	4.7	0	2.6	0	5.1	0	3.9	0	18.4
31	Haldu	*Haldina cordifolia*	Rubiaceae	0.3	0.4	0	3.1	0.5	0.6	0	1.6	1.5	1.7	0	6	2.3	2.7	0	10.7
32	Hargaza	*Dillenia pentagyna*	Dilleniaceae	0	1.1	0	0	0	0.6	0	0	0	4.3	0	0	0	6	0	0
33	Harinagoda	*Vitex pinnata*	Verbenaceae	0	0	0	0.4	0	0	0	0.8	0	0	0	1.4	0	0	0	2.6
34	Haritoki	*Terminalia chebula*	Combretaceae	0.7	1.3	1.3	0	1.5	1.3	1.1	0	1.3	2.6	4.5	0	3.5	5.2	6.9	0
35	Jalpai	*Elaeocarpus tectorius*	Elaeocarpaceae	0.3	1.5	0.6	1.1	0.5	1.9	2.3	2	1.5	2	1.1	1.7	2.3	5.4	4	4.8
36	Jarul	*Lagerstroemia speciosa*	Lythraceae	1.3	0	0	0.5	1	0	0	1.2	3.4	0	0	1	5.8	0	0	2.7
37	Jialbhadi	*Lannea coromandelica*	Anacardiaceae	0	0	0	0.4	0	0	0	0.8	0	0	0	1.7	0	0	0	2.9
38	Kala jam	*Syzygium cumini*	Myrtaceae	0	0	0	0.3	0	0	0	1.6	0	0	0	0.6	0	0	0	2.5
39	Kannyari	*Gardenia coronaria*	Rubiaceae	2.8	2.4	7.1	3.4	1.5	2.6	3.4	2.7	4.8	4.3	8.2	3.8	9.1	9.3	18.7	9.9
40	Kau	*Garcinia cowa*	Clusiaceae	0	0	0.3	0.5	0	0	1.1	0.4	0	0	1.1	3.9	0	0	2.5	4.8
41	Kechua	*Aporosa wallichii*	Euphorbiaceae	11.2	2.9	4.2	14.2	9.2	3.2	3.4	12.5	3.2	2.2	4.9	3.4	23.5	8.3	12.5	30.1
42	Khooisabatna	*Quercus gomeziana*	Fagaceae	0	0	0.3	0.2	0	0	1.1	1.2	0	0	1.1	0.6	0	0	2.5	2
43	Kiabang	*Carallia brachiata*	Rhizophoraceae	0.1	1.1	0	0	0.5	0.6	0	0	0.8	4.3	0	0	1.4	6	0	0
44	Kom	*Neonauclea sessilifolia*	Rubiaceae	0.3	0	0	0.4	0.5	0	0	1.6	1.5	0	0	0.8	2.3	0	0	2.8
45	Kuramara	*Archidendronjiringa*	Mimosaceae	0.3	0	0	0.1	0.5	0	0	0.4	1.5	0	0	0.6	2.3	0	0	1.1
46	Kurchi	*Holarrhena antidysenterica*	Apocynaceae	0	0.2	0	0.6	0	0.6	0	1.2	0	0.9	0	0.7	0	1.7	0	2.5
47	Lana assar	*Pterospermum semisagittatum*	Sterculiaceae	1.5	0	0	0.4	1.5	0	0	1.2	2.5	0	0	1.1	5.5	0	0	2.7
48	Mangium	*Acacia mangium*	Mimosaceae	2.8	5.7	0	0.2	1.5	1.9	0	0.4	4.8	7.4	0	0.8	9.1	15	0	1.4

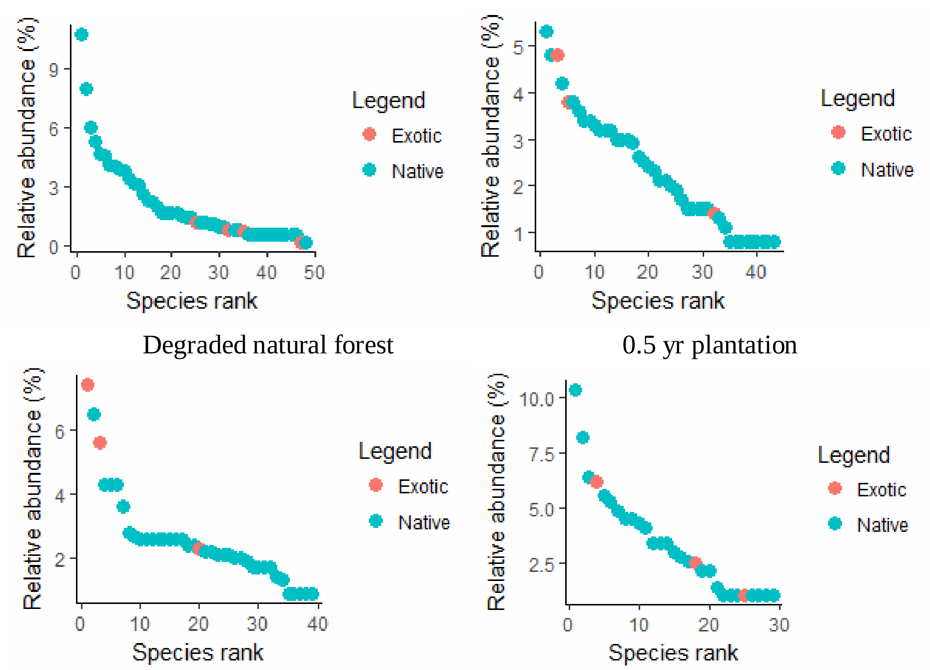
(Contd.)

Sl.	Species		Family	Relative density				Relative frequency				Relative abundance				IVI			
No.	Local name	Scientific name		P1	P2	P3	DF	P1	P2	P3	DF	P1	P2	P3	DF	P1	P2	P3	DF
49	Menda	*Litsea monopetala*	Lauraceae	0	0.2	0	0.7	0	0.6	0	1.2	0	0.9	0	1.7	0	1.7	0	3.6
50	Minjiri	*Senna siamea*	Caesalpiniaceae	0	0	0	0.5	0	0	0	1.6	0	0	0	1	0	0	0	3.1
51	Moricha	*Maesa indica*	Rubiaceae	0.2	0.9	0	0.1	0.5	1.9	0	0.4	0.8	2.1	0	0.6	1.4	4.9	0	1.1
52	Muchighandha	*Pterospermum acerifolium*	Sterculiaceae	2	4	2.2	0.8	2.6	5.2	3.4	2	2.1	1.9	2.6	1.2	6.7	11.1	8.2	4
53	Nali jam	*Syzygium claviflorum*	Myrtaceae	0.1	0.7	0	0	0.5	0.6	0	0	0.8	2.6	0	0	1.4	3.9	0	0
54	Naricha	*Trema orientalis*	Ulmaceae	0	0	0	0.1	0	0	0	0.4	0	0	0	1.1	0	0	0	1.6
55	Nuniakachi	*Macaranga roxburghianus*	Euphorbiaceae	0	2.6	0	4.1	0	2	0	1.6	0	6.5	0	8	0	11.1	0	13.7
56	Painagola	*Flacourtia jangomas*	Flacourtiaceae	0	0	0.3	0	0	0	1.1	0	0	0	1.1	0	0	0	2.5	0
57	Painnyaturi	*Glochidion multiloculare*	Euphorbiaceae	0.2	0	0	0.7	0.5	0	0	2.2	0.8	0	0	0.8	1.4	0	0	3.7
58	Patkhoi	*Bridelia tomentosa*	Euphorbiaceae	1	0	0	0	0.5	0	0	0	5.3	0	0	0	6.9	0	0	0
59	Putijam	*Syzygium fruticosum*	Myrtaceae	6.3	7	2.6	6.3	7.1	7.5	3.4	7.4	2.3	2.2	3	2.6	15.8	16.7	9	16.3
60	Putki	*Bauhinia malabarica*	Caesalpiniaceae	0	0	0	2.1	0	0	0	1.3	0	0	0	4.1	0	0	0	7.5
61	Ramjani	*Eurya acuminate*	Theaceae	0	0.7	0	0	0	0.6	0	0	0	2.6	0	0	0	3.9	0	0
62	Sadakoroi	*Albizia procera*	Mimosaceae	0.2	1.3	0	0	0.5	1.9	0	0	0.8	1.7	0	0	1.4	4.9	0	0
63	Sal	*Shorea robusta*	Diperocarpaceae	0	0	0.6	0	0	0	1.1	0	0	0	2.2	0	0	0	3.9	0
64	Segun	*Tectona grandis*	Verbenaceae	1.3	2.3	2.9	0.4	2.6	2.6	4.6	0.2	1.4	2.3	2.5	1.2	5.2	7.2	10	1.8
65	Sil parul	*Fernandoa adenophylla*	Bignoniaceae	0.1	0	0	0	0.5	0	0	0	0.8	0	0	0	1.4	0	0	0
66	Teliagarjan	*Dipterocarpus turbinatus*	Diperocarpaceae	2.3	2.2	1.6	6.1	3.7	3.2	4.6	4.5	1.7	2.8	1.4	4	7.6	8.2	7.6	14.6
67	Telsur	*Hopea odorata*	Diperocarpaceae	1	2.2	0.6	0	2.6	2.6	1.1	0	1.1	2.1	2.2	0	4.6	6.9	3.9	0
68	Tezbohal	*Cinnamomum glaucescens*	Lauraceae	0.7	0.2	0	0	1	0.6	0	0	1.9	0.9	0	0	3.7	1.7	0	0
69	Toon	*Toona ciliata*	Meliaceae	0.6	0	0	0	0.5	0	0	0	3	0	0	0	4.1	0	0	0
70	Wisherchoa	*Antidesma bunius*	Euphorbiaceae	4.5	0.9	2.6	3.5	3.6	1.3	2.3	3.7	3.4	1.7	4.5	1.9	11.5	3.9	9.4	9.1
Total				100	100	100	100	100	100	100	100	100	100	100	100	300	300	300	300

Table 2. Important ecological indices indicating regenerating tree species diversity in four sites.

Study site	Shannon-Wiener diversity index	Simpson's dominance index	Margalef's richness index	Species evenness index
0.5-year-old plantation	1.1904 ± 0.059[b]	0.3639± 0.025[b]	1.1721 ± 0.136[a]	0.8425 ± 0.033[a]
1.5-year-old plantations	1.1794 ± 0.072[b]	0.3299 ± 0.023[b]	1.2772 ± 0.098 [a]	0.8716 ± 0.033[ab]
2.5-year-old plantation	1.1541 ± 0.113[b]	0.3796 ± 0.049[b]	1.1529 ± 0.135[a]	0.9531 ± 0.008[b]
Degraded natural forest	1.2739 ± 0.087[a]	0.2165 ± 0.043[a]	1.3430 ± 0.112[a]	0.8764 ± 0.021[ab]

*Values with same letter column indicate no significant difference at $p \leq 0.05$.



Degraded natural forest 0.5 yr plantation

1.5 yr plantation 2.5 yr plantation

Fig.1. Abundance of the exotic and native tree species in different studied sites.

Climate resilience of the forest ecosystems is likely to be enhanced through increasing plant diversity and abundance of native species in comparison to exotic plant species. Regenerating species diversity was higher in the degraded natural forests but gradually reduced later on in the plantations as found in the study. The study revealed that, *A. auriculiformis*, *A. mangium*, *E. camaldulensis* and *T. grandis* are the four-exotic species recorded in the study sites (Fig. 1). Key informant interview of local stakeholders indicated seed broadcasting by BFD to cover the vacant spaces as well as dispersal by different agents from adjacent exotic species plantations resulted in exotics in natural forest sites. However, the relative abundance of the species varied from 0.2 to 7.4 being higher in the plantations. Therefore, it can be said that for better climate resilience through regeneration process, more control should be put over exotics under the present forest management systems.

In Cox's Bazar region, Islam *et al*. (2001) investigated the deforestation effects on vegetative propagation, regeneration and soil quality, where it was indicated more plant species in the protected forest areas than that of the degraded forests. The species composition in plantations as indicated by the present study is in conformity with the findings of Chauhan *et al.* (2008) who compared species diversity of natural and planted tropical deciduous forests in western Uttar Pradesh. The present research showed that the plantation maintenance activity particularly the repeated weeding at the initial stage of plantation establishment caused reduction of species diversity. It can be inferred from the results that protection of the degraded natural forests from anthropogenic disturbance instead of plantations might be a more effective tool for biodiversity conservation and enhancing climate resilience of forest ecosystems.

Deforestation and subsequent degradation of natural forest is a major threat for sustainable management and increasing climate resilience of forest ecosystems in Bangladesh. Plantations with sound maintenance activities are prime means for rapid restoration of the degraded forests. On the other hand, natural regeneration and recruitment in disturbed or degraded forests under regular protection that governed by residual seed sources and dispersal characters are primarily soil driven process for maintaining ecological stability and achieving climate resilience. Though deforested and degraded, the natural forests of Cox's Bazar North and South Forest Divisions possessed substantial residual regeneration and soil seed sources that have potential for forest ecosystem restoration. The plantations studied in this research made immediate coverage of the barren or degraded sites but regular weeding activities reduced the diversity of natural regeneration and recruitment. The plants with coppicing ability were able to revegetate naturally under plantations. The diversity of naturally regenerating plants within plantations undergoes more gradual reduction with age of plantations. Certain plants either with profuse coppicing ability or aggressive in nature or capable to grow under all sorts of difficulties, i.e. *Acacia auriculiformis*, *G. nervosa*, *Lithocarpus* sp., *Aporosa wallichii* etc. become dominant in the comparatively older plantations. Native plants that are supposed to be more climate resilient species over exotics dominate the natural regeneration in both degraded natural forests and plantations though several exotic plants were also found regenerating in all the sties. Protection of the degraded natural forests to help recruitment of the regenerations might be effective for achieving more native plant diversity and thus climate resilience. From the present study it can also be recommended that change of existing plantation maintenance strategy from complete weeding to patch weeding would protect the regenerations to turn that into a dense and diverse forest. Based on the results, it is also proposed to keep the natural forests as it is under protection from anthropogenic disturbance instead of plantations.

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